10. CAMPANIAN TO PLEISTOCENE CALCAREOUS NANNOFOSSIL STRATIGRAPHY FROM THE NORTHWEST PACIFIC OCEAN, DEEP SEA DRILLING PROJECT LEG 86[1]

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ABSTRACT

During Leg 86, Sites 576–581 were drilled in the northwest Pacific Ocean. Only Sites 576, 577, and 580 contain calcareous nannofossils. The cored stratigraphic sequences range from lower Campanian to Pleistocene, although some of the stratigraphic sequences are discontinuous because of hiatuses or poor core recovery.

Site 576 was drilled at the eastern flank of the Shatsky Rise, and recovered a common and moderately well preserved calcareous nannofossil assemblage of lower Maestrichtian to lower Campanian age. Site 577 was drilled on the southwest flank of the Shatsky Rise. Three holes were hydraulically piston cored. Holes 577 and 577A both recovered a very good late Cenozoic to Late Cretaceous sediment section with a major hiatus from the middle Miocene to the middle Eocene. An undisturbed and extended Cretaceous/Tertiary boundary sequence was recovered. An additional core containing the Cretaceous/Tertiary boundary was recovered from Hole 577B. Coccoliths are generally abundant and diversified. Preservation is moderate to poor. The Cretaceous/Tertiary boundary is located in all three holes at a sub-bottom depth of about 109.6 m.

A detailed investigation of the calcareous nannofossil assemblage was conducted on samples from Site 577, and particular attention was given to the flora at the Cretaceous/Tertiary boundary. Few selected early Tertiary species have been investigated both by light and scanning electron microscope.

At Site 580 only one sample (Core Catcher 3) contains calcareous nannofossils. They are poorly preserved and indicate a probable Pliocene age.

INTRODUCTION

Leg 86 of the Deep Sea Drilling Project (DSDP) drilled six sites in the Pacific (Fig. 1). Only the sediments recovered at Sites 576, 577, and 580 contain calcareous nannofossils. The stratigraphic sequence at these sites ranges from lower Campanian to Pleistocene with some discontinuities. The light microscope (LM) was used to study the nannofossils.

A few selected samples were studied by scanning electron microscope (SEM) for taxonomic and illustrative purposes; special attention was given to the early Tertiary species. A few Paleocene species were investigated using Moskhovitz's (1974) technique, which allows the study of the same specimen in both LM and SEM. Zonal assignments of the cores from Sites 576, 577, and 580 are summarized in Table 1 for the Cretaceous and Table 2 for the Tertiary. The full generic and specific names of all taxa considered in this report and reference to the authors are given in the Appendix.

Abundance, preservation, and stratigraphic distribution of calcareous nannofossils are presented in Tables 3 to 10. Preservation is described as etching and overgrowth following the scheme developed by Roth and Thierstein (1972).

CALCAREOUS NANNOFOSSIL ZONES

Cretaceous

The zonation used for the Cretaceous sequences recovered on Leg 86 includes zones and ranges given by Bukry and Bramlette (1970), Martini (1976), Thierstein (1976), Verbeek (1977), and Perch-Nielsen (1979). Table 1 shows the zones used and the biostratigraphic distribution of the cores recovered. The definition of the zones is discussed below from the bottom of the recovered sections to the top.

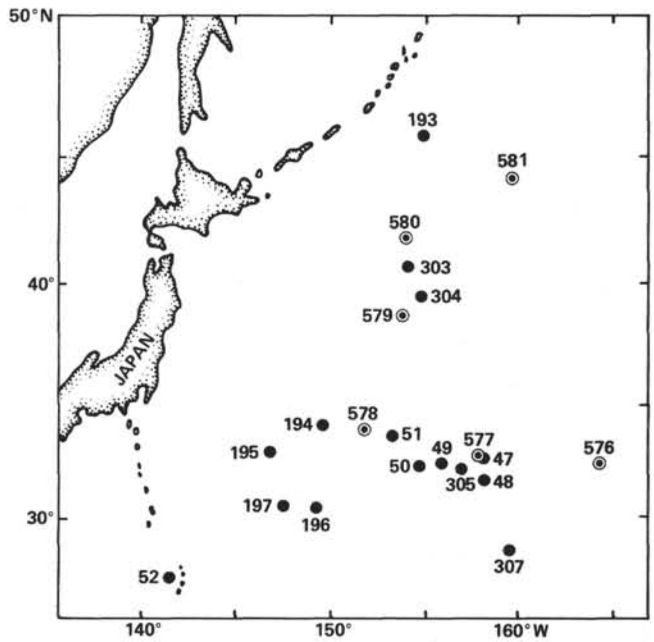

Figure 1. Location of DSDP sites in the Northwest Pacific (◉ = Leg 86, • = other legs).

Aspidolithus parcus Zone, Verbeek, 1977

Definition. Interval from the first occurrence (FO) of *A. parcus* to the FO of *Ceratolithoides aculeus.*

[1] Heath, G. R., Burckle, L. H., et al., *Init. Repts. DSDP*, 86: Washington (U.S. Govt. Printing Office).
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Table 1. Calcareous nannofossil zonation of the Cretaceous from Sites 576 and 577.

Age	Zone	Hole 576		Hole 576B		Hole 577		Hole 577A		Hole 577B	
		Sub-bottom depth (m)	Core-Section (level in cm)	Sub-bottom depth (m)	Core-Section (level in cm)	Sub-bottom depth (m)	Core-Section (level in cm)	Sub-bottom depth (m)	Core-Section (level in cm)	Sub-bottom depth (m)	Core-Section (level in cm)
	Micula prinsii					109.20–110.82	12-5, 130/ 12-6, 142	109.65–111.80	12-4, 75/ 12-5, 146	109.66–111.60	1-4, 76/ 1-5, 120
Maestrichtian	*Micula murus*	—		—		111.10–118.80	12-7, 20/ 13,CC	112.107–120.34	12-6, 26/ 13-5, 44	112.00–113.90	1-6, 10/ 1,CC
	Lithraphidites quadratus							120.96–123.4	13-5, 106/ 13,CC		
	Quadrum trifidum	61.3–69.2	8-1, 136–8,CC	51.70–62.05	6-4, 100–7-5, 35						
	Quadrum gothicum			63.9–67.47	7-6, 73–8-2, 77						
Campanian	*Ceratolithoides aculeus*	—		68.75	8-3, 55						
	Aspidolithus parcus			69.15–74.8	8-3, 90–9,CC						

Note: Where a zone or subzone is represented in samples from two or more core sections the highest/lowest occurrences are given. — means barren of calcareous nannoplankton.

Stratigraphic position. Lower Campanian.

Remarks. The *A. parcus* Zone was found only at Hole 576B and it is the oldest Cretaceous zone recovered. The base of this zone was not reached. Rare species of *Quadrum gothicum* were found in the upper part of this zone; they have been considered here as contaminants.

Ceratolithoides aculeus Zone, Čepek and Hay, 1969a,b; emend. Verbeek, 1977

Definition. Interval from the FO of *C. aculeus* to the FO of *Q. gothicum.*

Stratigraphic position. Lower Campanian.

Remarks. The *C. aculeus* Zone was found only in Hole 576B.

Quadrum gothicum Zone, Martini, 1976

Definition. Interval from the FO of *Q. gothicum* to the FO of *Q. trifidum.*

Stratigraphic position. Middle Campanian.

Remarks. The *Q. gothicum* Zone occurs only in Hole 576B.

Quadrum trifidum Zone, Verbeek, 1977

Definition. Interval from the FO to the last occurrence (LO) of *Q. trifidum.*

Stratigraphic position. Upper Campanian to lower Maestrichtian.

Remarks. This zone was found in both holes at Site 576; in Hole 576 it is the oldest Cretaceous zone recovered.

Lithraphidites quadratus Zone, Bukry and Bramlette, 1970

Definition. Interval from the FO of *L. quadratus* to the FO of *Micula murus.*

Stratigraphic position. Middle Maestrichtian.

Remarks. This zone was found only in Hole 577A and the base was not reached. This zone represents the oldest Cretaceous sediments recovered at Site 577.

Micula murus Zone, Bukry and Bramlette, 1970; emend. Perch-Nielsen, 1981

Definition. Interval from the FO of *M. murus* to the FO of *M. prinsii.*

Stratigraphic position. Upper Maestrichtian.

Remarks. This zone was found in all three holes (577, 577A, 577B) at Site 577. It is known from the literature that *M. murus* is probably restricted to tropical regions, while *Nephrolithus frequens* is common in the boreal regions. In our sediments *N. frequens* was not found, but *M. murus* is present.

Micula prinsii Zone, Perch-Nielsen, 1981

Definition. Interval from the FO of *M. prinsii* to the FO (or increased frequency) of *Thoracosphaera* sp.

Stratigraphic position. Very top of the Maestrichtian.

Remarks. *M. prinsii* was found in all three holes recovered at Site 577. It is usually very rare and not well preserved.

Tertiary and Quaternary

The low latitude coccolith zonation of Bukry (1973, 1975) and Okada and Bukry (1980) was used for the Tertiary and Quaternary deep-sea sediments recovered on Leg 86 (Table 2). This zonation is well suited to the biostratigraphic subdivision of the recovered sequences.

A few remarks are made here only for the early Paleocene Zones CP1, CP2, and CP3.

Zygodiscus sigmoides Zone (CP1)

This zone was defined as the interval from the LO of *Micula murus* and other Cretaceous species to the FO of *Chiasmolithus danicus*. It is not possible in a continuous and expanded Cretaceous/Tertiary boundary to identify precisely the lower limit of the *Zygodiscus sigmoides* Zone, because it is impossible to distinguish Cretaceous coccoliths from those nonreworked. Also Cretaceous coccoliths disappear gradually in many lower Tertiary sequences. The criterium used on Leg 86 to define the Cretaceous/Tertiary boundary was the rapid increase in frequency of *Thoracosphaera*, a calcareous dinoflagellate. This increase occurs sharply in the early Tertiary, together with the first occurrence of small *Biscutum* cf. *B. romeinii*. In some sequences the first occurrence of *B. sparsus* was used, but this datum was rare and discontinuous in the recovered sediments.

The upper boundary of CP1 is defined by the FO of *C. danicus*. The FO of *C. danicus* is not easily recognized since intermediate forms between *C. edwardsii* and *C. danicus* occur. Indeed, *C. danicus* seems to evolve gradually from *C. edwardsii.*

Chiasmolithus danicus Zone (CP2) and *Ellipsolithus macellus* Zone (CP3)

Following the definition of Romein (1979), the lower boundary of the *C. danicus* Zone is defined by the FO of *C. danicus* s.s.

The upper boundary of CP2 is defined by the FO of *E. macellus*. This species is rare and discontinuously present in this zone, it becomes common only in the overlying *Fasciculithus tympaniformis* Zone (CP4).

The first occurrence of *Sphenolithus* occurs in Hole 577A at the top of the *C. danicus* Zone (CP2); the FO of *Fasciculithus* occurs slightly higher in the *E. macellus* Zone.

SITE SUMMARIES

Only Sites 576, 577, and 580, which contain calcareous nannofossils, are discussed here. Tables 1 and 2 show the nannofossil zonations found at these sites. Tables 3 to 10 are range charts showing the distribution of calcareous nannofossil species that are recognized in the samples studied. The first and last occurrence of marker species in the above-mentioned tables are underlined, so that it is easier to recognize the markers and the boundaries of the zones.

The reliability of first and last occurrences of the species recorded varies, since it has only been possible to pick up the exact ranges of the markers and some of the most important species in the limited time available.

Site 576 (Holes 576, 576A, and 576B)

Site 576 is located on the east flank of the Shatsky Rise at a water depth of 6227 m (Fig. 1). Three holes were drilled: 576, 576A, and 576B. One complete hole (Hole 576A) was left unopened for shore-based geotechnical studies (Geotechnical Consortium, this volume).

The lithostratigraphic succession observed in Holes 576 and 576B consists of a pelagic clay unit (barren of nannofossils) overlying an interbedded pelagic clay and a nannofossil and nannofossil–foraminifer ooze; some of the nannofossil ooze layers contain graded bedding characteristic of turbidites (Site 576 chapter, this volume).

Tables 3A and 3B contain the nannofossil distribution of Holes 576 and 576B, respectively.

Calcareous nannofossils are not present in the uppermost seven cores of Hole 576 and in the uppermost five cores of Hole 576B. The recovered calcareous nannofossils are common and moderately to poorly preserved below these levels.

The uppermost samples containing nannofossils from each hole (576-8-1, 135 cm and 576B-6-4, 100 cm) indicate deposition close to the carbonate compensation depth (CCD). This is suggested by the presence of only solution-resistant forms such as *Micula staurophora, Quadrum gothicum, Q. trifidum,* and *Lithastrinus* sp.

All of Core 8 from Hole 576 belongs to the *Q. trifidum* Zone and is assigned to the late Campanian–early Maestrichtian. Few reworked Early Cretaceous nannofossils were noted.

In Hole 576B a lower Campanian to lower Maestrichtian assemblage was recovered. Sections 6-4 to 7-5 belong to the upper Campanian–lower Maestrichtian *Q. trifidum* Zone. The assemblages are characterized by the presence of *Q. trifidum, Q. gothicum, Aspidolithus parcus, Cretarhabdus surrirellus, Cribrosphaera ehrenbergii, Eiffellithus turriseiffeli, Manivitella pemmatoidea,* and *Prediscosphaera cretacea.* Sections 7-6 to 8-2 belong to the late Campanian *Q. gothicum* Zone. Sample 576B-8-3, 55 cm belongs to the *Ceratolithoides aculeus* Zone. The lower part of Cores 8 and 9 belongs to the lower Campanian *A. parcus* Zone.

Few specimens of *Rucinolithus hayii* occurred in this *A. parcus* Zone. A *Braarudosphaera* sp. 1 form was found in the Campanian sediments of Core 8. This species can be related to the species of *Braarudosphaera* (sp. ind.) found by Thierstein and Manivit (1981) in Campanian deep-sea sediments at Site 462.

Various Cretaceous specimens are illustrated in Plate 1. These species are usually overgrown, and this overgrowth appears to occur preferentially along one of the individual calcite crystals of the pentalith. The individual elements are radially asymmetric and the sutures between the elements are inclined relative to the radial symmetry plane of the pentalith. The paleoecological and paleoceanographic implications of these *Braarudosphaera* in Campanian deep-sea sediments are still to be established.

Only one sample (576B-8-3, 55 cm) contains rare specimens of *Kamptnerius magnificus*, a species that is usually found in shallow water sediments. Few specimens of *R. magnus* were found throughout the Campanian (Plate 2, Figs. 1–3). Rare *B. africana, R. irregularis,* and *L. floralis* appear to have been reworked from paleo-outcrops of Aptian–Albian sediments nearby.

Site 577

Site 577 is located very close to Site 47 on the flank of the Shatsky Rise (Fig. 1). The relatively shallow water depth (2680 m) yielded a good preservation of the calcareous microfossils. Three holes were hydraulically piston cored: Holes 577 and 577A both recovered a very good late Cenozoic and Paleogene sequence and an undisturbed Cretaceous/Tertiary boundary sequence. Only one core containing the Cretaceous/Tertiary boundary was recovered from Hole 577B.

Calcareous nannofossils recovered at all three holes are abundant and diversified. Their preservation ranges

Table 2. Calcareous nannofossil zonation of the Tertiary from Leg 86 sites.

Age	Zone Bukry (1973, 1975)			Events	Hole 577 Sub-bottom depth (m)	Hole 577 Core-Section (level in cm)	Hole 577A Sub-bottom depth (m)	Hole 577A Core-Section (level in cm)	Hole 577B Sub-bottom depth (m)	Hole 577B Core-Section (level in cm)	Hole 580	Zone Martini (1971)
	CN15	*Emiliania huxleyi*		*Emiliania huxleyi*	0.50	1-1, 50	1.0	1-1, 100				NN21
	CN14	*Gephyrocapsa oceanica*	CN14b	*Emiliana ovata*	1.75–3.40	1-1, 25/1-3, 40	2.5–4.0	1-2, 100/1-3, 100				NN20
Quaternary			CN14a									
	CN13	*Crenalithus doronicoides*	CN13b		5.75–20.26	1-4, 40/3-3, 96	5.5–22.3	1.4, 100/3-2, 90				NN19
			CN13a									
	CN12	*Discoaster brouweri*	CN12d	*Discoaster brouweri*	21.76–26.13	3-4, 96/4-1, 33	22.50–25.50	3-3, 60/3-5, 50				NN18
			CN12c	*Discoaster pentaradiatus*	26.92–27.60	4-1, 112/4-2, 30	25.90	3,CC			13,CC	NN17
			CN12b	*Discoaster surculus*	28.42–29.05	4-2, 112/4-3, 25	29.2	4-1, 80				NN16
			CN12a	*Discoaster tamalis*	29.92–40.75	4-3, 112/5-4, 95	30.7–44.2	4-2, 80/5-5, 30				
Pliocene	CN11	*Reticulofenestra pseudoumbilica*	CN11b	*Reticulofenestra pseudoumbilica*	42.00–46.90	5-5, 70/6-2, 60	44.9–47.5	5-5, 100/6-1, 15				NN15
			CN11a	*Amaurolithus tricorniculatus*								
	CN10	*Amaurolithus tricorniculatus*	CN10d		47.50–49.90	6-2, 120/6-4, 60	49.05–53.55	6-2, 15/6-5, 15				NN14
			CN10c									NN13
			CN10b	*Ceratolithus rugosus*								
			CN10a		51.50–55.60	6-4, 120/7-1, 130	55.05–56.55	6-6, 15/6-7, 15				NN12
	CN9	*Discoaster quinqueramus*	CN9b	*Discoaster quinqueramus*	56.00–58.60	7-2, 20/7-3, 130	56.9–60.26	6,CC (30)/7-3, 36				NN11
			CN9a	*Amaurolithus primus*								
	CN8	*Discoaster neohamatus*	CN8b									NN10
			CN8a									
	CN7	*Discoaster hamatus*	CN7b									NN9
			CN7a									
Miocene	CN6	*Catinaster coalitus*										NN8
	CN5	*Discoaster exilis*	CN5b									NN7
			CN5a		59.22–60.10	7-4, 42/7-4, 130	62.26	7-4, 86				NN6
	CN4	*Sphenolithus heteromorphus*			60.72	7-5, 42						NN2/NN5
	CN3	*Helicosphaera ampliaperta*										
	CN2	*Sphenolithus belemnos*										
	CN1	*Triquetrorhabdulus carinatus*	CN1c									
			CN1b									NP25/NN1
			CN1a									

	CP19	*Sphenolithus ciperoensis*	CP19b											NP25/NN1
			CP19a											NP24
Oligocene	CP18	*Sphenolithus distentus*												NP23
	CP17	*Sphenolithus predistentus*												
	CP16	*Helicosphaera reticulata*	CP16c											NP22
			CP16b											NP21
			CP16a											
	CP15	*Discoaster barbadiensis*	CP15b		61.60–66.50	7-5, 130/8-2, 120	63.16–63.66	7-5, 36/7-5, 86						NP19/NP20
			CP15a	*Chiasmolithus grandis* ↱										NP18
	CP14	*Reticulofenestra umbilica*	CP14b		67.00	8-3, 20	64.76–65.26	7-6, 36/7-4, 84						NP17
			CP14a											
	CP13	*Nannotetrina quadrata*	CP13c											NP15/NP16
			CP13b											
Eocene			CP13a											
	CP12	*Discoaster sublodoensis*	CP12b		68.00	8-3, 120	65.76	7,CC (2–3)						NP14
			CP12a	*Discoaster sublodoensis* ↳										
	CP11	*Discoaster lodoensis*		*Coccolithus crassus* ↳	69.50–72.50	8-4, 20/8-6, 120	64.85–71.95	8-1, 105/8-4, 105						NP12/NP13
	CP10	*Tribrachiatus orthostylus*		*Discoaster lodoensis* ↳	72.91–74.60	8-7, 11/9-1, 130	72.95–74.43	8-5, 15/8,CC						
	CP9	*Discoaster diastypus*	CP9b	*Tribrachiatus contortus* ↳	74.90–80.47	9-2, 20/9-5, 117	76.20–79.65	9-1, 30/9,CC						NP11
			CP9a											NP10
	CP8	*Discoaster multiradiatus*	CP8b		80.90–86.00	9-6, 10/10-3, 20		Not cored						NP9
			CP8a	*Discoaster multiradiatus* ↳										
	CP7	*Discoaster nobilis*		*Discoaster nobilis* ↳	87.00–88.50	10-3, 120/10-4, 120	85.79–88.10	10-1, 39/10-2, 120						NP7/NP8
	CP6	*Discoaster mohleri*		*Discoaster mohleri* ↳	89.00–95.64	10-5, 20/11-3, 34	88.79–92.78	10-3, 39/10-5, 138						
	CP5	*Heliolithus kleinplellii*		*Heliolithus kleinpellii* ↳			93.00	10-6, 10						NP6
Paleocene	CP4	*Fasciculithus tympaniformis*		*Fasciculithus tympaniformis* ↳	95.70–98.00	11-3, 40/11-4, 120	94.90–97.50	10,CC/11-2, 110						NP5
	CP3	*Ellipsolithus macellus*		*Ellipsolithus macellus* ↳	98.70–100.20	11-5, 40/11-6, 40	98.29–99.80	11-3, 39/11-4, 40						NP4
	CP2	*Chiasmolithus danicus*		*Chiasmolithus danicus* ↳	101.00–104.66	11-6, 120/12-2, 136	100.50–105.35	11-4, 110/12-1, 95	104.4–105.3	1-1, 10/1-1, 90				NP3
	CP1	*Zygodiscus sigmoides*	CP1b	*Cruciplacolithus tenuis* ↳	105.06–107.86	12-3, 60/12-5, 60	105.71–108.06	12-1, 126/12-3, 66	105.3–108.0	1-1, 110/1-3, 60				NP2
			CP1a	*Thoracosphaera* sp. ↳	108.16–109.10	12-5, 36/12-5, 129	108.46–109.60	12-3, 106/12-4, 70	108.10–109.62	1-3, 70/1-4, 72				NP1

Note: Where a zone or subzone is represented in samples from several core sections, the highest/lowest samples are given. ↳ First occurrence, ↱ Last occurrence.

Table 3A. Distribution of Cretaceous calcareous nannofossils in Hole 576.

Age	Nannofossil zone	Core-Section (level in cm)	Sub-bottom depth (m)	Abundance	Preservation	Etching	Overgrowth	Reworking	*Aspidolithus parcus*	*Broinsonia enormis*	*Ceratolithoides aculeus*	*Cretarhabdus conicus*	*C. crenulatus*	*C. surirellus*	*Cribrosphaera ehrenbergii*	*Cyclagelosphaera margereli*	*Cylindralithus serratus*	*Discorhabdus rotatorius*	*Eiffellithus eximius*	*E. turriseiffeli*	*Glaukolithus diplogrammus*	*Kamptnerius magnificus*	*Lithastrinus floralis*	*L. grillii*	*Lithraphidites carniolensis*	*Manivitella pemmatoidea*	*Microrhabdulus decoratus*	*Micula staurophora*	*Parhabdolithus embergeri*	*Prediscosphaera cretacea*	*P. spinosa*	*Quadrum gothicum*	*Q. trifidum*	*Rucinolithus irregularis*	*R.* aff. *magnus*	*Watznaueria barnesae*	*Zygolithus tarboulensis*
late Campanian/early Maastrichtian	*Quadrum trifidum*	8-1,136	61.06	C	P	2	2																					C				F	F				
		8-2,13	61.33	A	M/P	2	1		R					C	C											C		F		C		F	F			A	
		8-2,50	61.70	A	M/P	2	1		R	R				C	C									R		C	R	F		C		F	F		R	A	
		8-2,91	62.11	A	M/P	2	1			F				C	C									R		C	F	F		C		F	F		R	A	
		8-3,30	63.00	A	M/P	2	1		F	F				C	C											C	F	F		C		F	F	R		A	
		8-3,80	63.50	A	M/P	2	1			F				C	C											C	F			C		RR	C			A	
		8-3,104	63.74	A	M/P	2	1			F				C	C									F		C	F			C		F	F		F	A	
		8-3,136	64.06	A	M/P	1	1	R		F					C					C			RR			C	F			C		F	F	R		A	F
		8-3,142	64.12	A	M/P	2	1			F				C	C											C	F			C		F	F			A	
		8-4,4	64.26	A	M/P	2	1			C				C	C				C	C						C	F	F		C			RR			A	
		8-4,12	64.32	B																																	
		8-4,26	64.46	A	M/P	2	2				R			C	C					C				F		C	R	F		A		F	F			C	
		8-4,50	64.70	A	M/P	2	1	F	F	C				C	C					C			F	F	F	C		F	F	A		F	F		R	C	R
		8.4,53	64.73	A	M/P	2	2		F	C				C	C				F	C					F	C	F	F		A		R	R			C	
		8-4,70	64.90	A	M/P	2	1		F	C	R	F		C	C				F	F				F	F	C			F	A		R	R			C	F
		8-4,79	64.99	A	M/P	2	2		R	C				C	C					C						C	F	F	F	A		R				C	
		8-4,116	65.36	A	M/P	2	1			C				C	C				C	C						C	F	F	F	A		RR	RR			A	R
		8-6,14	67.34	A	M	1	1	R	F	F				C	C					C		1	R	F	F	C	F	F	F	C		R	F			A	
		8-6,64	67.84	A	M/P	2	1		R	C				C	C	F				C	F			F	F	C	F		R	C		R	RR			A	
		8-6,72.5	67.92	A	M/P	1	2		R	C			F	C	C	F	F			C				F		C	F		R	C		R	R			A	
		8-6,148	68.68	A	M/P	1	2		F	R			C	C	C	R	F			C				F		C	F		R	C		R	R			A	
		8-7,35	69.05	A	M/P	1	2		F	F			F	C	C	F	F		F	C	R			F		C	F		R	C		R	F			A	
		8-7,bottom	69.15	A	M/P	1	2		F	C			F	C	C		F			C			F			C	F	F		C			R			A	
		8,CC	69.2	A	M/P	2	1	R		F	F		C	C	C			R	C	C			RR	F		C	F	F	R	C	F	F	F			A	

Note: RR = very rare, R = rare, F = few, C = common, A = abundant. Preservation: M = moderate, P = poor. Etching: 1–3 indicates increase in etching, overgrowth: 1–3 indicates increase in overgrowth in calcareous nannofossils (Roth and Thierstein, 1972).

Table 3B. Distribution of Cretaceous calcareous nannofossils in Hole 576B.

Age	Nannofossil zone	Core-Section (level or interval in cm)	Sub-bottom depth (m)	Abundance	Preservation	Etching	Overgrowth	Reworking	*Aspidolithus parcus*	*Braarudosphaera africana*	*B. bigelowii*	*Braarudosphaera* sp. 1	*Broinsonia enormis*	*Ceratolithoides aculeus*	*Chiastozygus litterarius*	*Cretarhabdus surirellus*	*Cribrosphaera ehrenbergii*	*Cyclagelosphaera margereli*	*Cylindralithus* sp.	*Eiffellithus eximius*	*E. turriseiffeli*	*Kamptnerius magnificus*	*Lithastrinus floralis*	*L. grillii*	*Lithastrinus* sp.	*Lithraphidites carniolensis*	*Manivitella pemmatoidea*	*Microrhabdulus decoratus*	*Micula staurophora*	*Parhabdolithus asper*	*P. embergeri*	*Prediscosphaera cretacea*	*Quadrum gothicum*	*Q. trifidum*	*Rucinolithus irregularis*	*R.* aff. *magnus*	*Rucinolithus hayii*	*Watznaueria barnesae*	*Zygolithus? tarboulensis*
Campanian, late	*Quadrum trifidum*	6-4,100	51.70	F	P	2	2							C											C				A				R	R					
		6-4,130	52.00	A	M/P	2	1		F								C				C			F			F		R			C	F	C				A	
		6,CC	55.43	A	M/P	2	1		F								C				C			F			F				R	C		F				A	
		7-1,25	55.95	A	M/P	2	1		R				F			C	C				C					F	F				R	C	F	R		F		A	
		7-3,70	59.40	A	M/P	2	1		R				F			C	C	R	F		C						F		F		R	C	F	R		R		A	
		7-5,35	62.05	A	M/P	2	1		R							C	C		F		C					F	F				R	C	F	R		F		A	
	Quadrum gothicum	7-6,73	63.9	A	M/P	2	1		F				R	F		C	F	R			C						F		F		R	C	F					A	
		7-7,15	64.78	A	M/P	2	1		R				R	R		C	C		F	RR	C			F		F	C		F			C	F			F		A	
		7,CC	65.2	A	M/P	2	1		R				R	C		C	C			F	C						C		F			C	F			F		A	
		8-1,142	66.62	A	M	1	1		F					C			F		F	F	C						F		R			C	F			R		A	
		8-2,77	67.47	A	M/P	1	1		R			R		C			C		F	F	C						F		F			C	F					A	
	Ceratolithoides aculeus	8-3,55	68.75	A	M	1	1		F				F	C			C			R	C	R					F		R			C						A	
		8-3,90–91	69.15	A	M/P	2	1		R		R	R				C	F				C						F		F			C	R				R	A	
Campanian, early	*Aspidolithus parcus*	8-3,126–127	69.46	A	M/P	2	1	R	R				R			F	C	F		F	C		F			F	C	F		C	F	C	R					A	R
		8-4,4–5	69.74	A	M/P	2	1	R	R				F			C	F		F	F	F		F				C	R		F		C						A	
		8-4,68–69	70.38	A	M/P	2	1		R			F	F		F	C	F			F	C						F		F		R	C					R	A	
		8-4,95	70.65	A	M/P	2	1	R			R	F			F		C		F	F	C		F			F	F		C			C			R	R	F	A	
		8-5,7	71.22	A	M/P	2	1					F	F				R		F	F	C			R		F	F		F			C				R	F	A	
		8-5,52	71.72	A	M/P	2	1		R			F					F		F		C			R			F	R	F			C					F	A	
		8-5,120	72.40	A	M/P	2	1		R			F					F				C						F	R	F			C					F	A	
		8-5,140	72.60	A	M/P	2	1		R	R		F					F				C						F		F			C						A	
		8-6,7	72.77	A	M/P	2	1			R			R							R	C			R			F		F			C				R		A	
		8-7,5	74.30	A	M/P	2	1																						F			C						A	
		8,CC	74.73	A	M/P	2	1		R			R					C		F		C						F		F			C				F	R	A	
		9,CC	74.8	C	P	2	2		R			R					C				C						F		F			C				F		A	

Note: See footnote to Table 3A for definition of symbols.

from poor to moderate. Calcareous nannofossils are considerably overgrown near the Cretaceous/Tertiary boundary and in the lower middle Eocene. A significant hiatus is noted from the middle Eocene to the upper Miocene.

The calcareous nannofossil assemblages recovered at Site 577 are discussed below. Tables 4 through 10 show the distribution of the calcareous nannofossils in the samples studied. The detailed correlation between calcareous nannofossil events, magnetostratigraphy, and the numerical time scale is discussed by Monechi, Bleil, and Backman (this volume).

Pleistocene

The upper part of Sections 577-1-1 and 577A-1-1 belongs to the *Emiliania huxleyi* Zone (CN15) (Tables 6 and 9). In both holes the last occurrence of *E. ovata* in Sections 577-1-4 and 577A-1-4 marks the *Ceratolithus cristatus* Subzone (CN14b) (Tables 6 and 9). Few reworked discoasters are found.

In both holes the lower parts of Cores 1 and 2 and the upper part of Section 3-2 contain a rich assemblage of *Gephyrocapsa oceanica, G. caribbeanica, Emiliania annula, E. ovata, G. aperta, Calcidiscus leptoporus*, and *Ceratolithus cristatus*. The assemblages can be assigned to the *E. ovata* Subzone (CN14a) and *Crenalithus doronicoides* (CN13) Zone, which correspond to the *Pseudoemiliania lacunosa* Zone (NN19) of Martini (1971) (Tables 6 and 9). The highest occurrence of *Calcidiscus macintyrei* is observed in both holes in Core 3, Section 1, slightly above the last occurrence of *Discoaster brouweri*. Occasionally rare reworked discoasters are found in the upper part of the sequence.

Pliocene

The top of the *Discoaster brouweri* Zone (CN12) is recognized by the last occurrence of *D. brouweri* in Sections 577-3-4 and 577A-3-3. All the subzones of the *D. brouweri* Zone (CN12) were found in both holes (Tables 6 and 9). Section 577-3-4 through the upper part of Sections 577-4-1 and 577A-3-3 through 577A-3-5 belong to the *Calcidiscus macintyrei* Subzone (CN12d); the lower part of Section 577-4-1 and Sample 577A-3,CC belong to the *D. pentaradiatus* Subzone (CN12c); in Hole 577 the lower parts of Sections 577-4-2 and 577A-4-1 belong to the *D. surculus* Subzone; and the lower parts of Sections 577-4-3 through 577-5-4 and 577A-4-2 through the top of 577A-5-4 belong to the *D. tamalis* Subzone (CN12a). With the exception of the marker species the assemblages are similar to those of the early Pleistocene; discoasters are common to abundant.

The top of the *Reticulofenestra pseudoumbilica* Zone (CN11) is recognized in both holes in Core 5, Section 5 (Tables 6 and 9). Preservation is poor down to the top of Core 7 in both holes.

The top of the *Amaurolithus tricorniculatus* Zone (CN10) is defined by the last occurrence of *A. primus* and *A. tricorniculatus* in Section 577A-6-2 (Table 8). The *A. tricorniculatus* found above that level are considered reworked. In Hole 577 the top of the *A. tricorniculatus* Zone is at the bottom of Section 577-6-2 (Table 6).

The first occurrence of *Ceratolithus rugosus* occurs in Sections 577-6-4 and 577A-6-5. The lower part of the *A. tricorniculatus* Zone could not be divided into subzones because of the scarcity or the absence of *Triquetrorhabdulus rugosus* and *C. acutus*. Rare specimens were found only in one sample in both holes. For this reason the Miocene/Pliocene boundary could not be placed accurately.

Miocene

The Miocene sequence recovered at Site 577 is very short because of a major hiatus that occurs from middle Miocene to middle Eocene time. The Miocene is represented only by the upper part of Core 7 in both holes. Sporadic occurrences of marker species in Core 7 in both holes make zonal assignments of individual samples difficult. Sample 577A-6,CC through Section 577A-7-3 and Sections 577-7-2 through 577-7-3 belong to the *Amaurolithus primus* Subzone (CN9b) (Tables 6 and 9). The first occurrence of *A. primus* occurs in both holes in Section 7-3.

A hiatus from the lower part of the *Discoaster quinqueramus* Zone (CN9) to the middle Miocene is present.

Sections 577A-7-4 and 577-7-4 to 577-7-5 contain a mixed assemblage of Eocene and Miocene species. The presence of *Calcidiscus macintyrei, Coccolithus formosus, Sphenolithus heteromorphus, D. aulakos, D. sanmiguelensis*, and *D. variabilis* s.l. suggests that these samples belong to the upper part of the *S. heteromorphus* Zone (CN14) and the lower part of the *D. exilis* Zone (CN5) (Tables 6 and 9).

Eocene

The Eocene sequence is not complete due to a major unconformity in Sections 577-7-5 and 577A-7-4. All of the upper Eocene is missing. Sections 577-7-5 through 577-8-2 and 577B-7-5 belong to the *Discoaster barbadiensis* Zone (CP15) (Tables 5 and 8). Sections 577-8-3, and 577A-7-6 belong to the *Reticulofenestra umbilica* Zone (CP14). A small hiatus is present in the middle Eocene; the *Nannotetrina quadrata* Zone (CP13) and the upper part of the *D. sublodoensis* Zone (CP12) are missing in both holes. The assignment of Sample 577A-7,CC to the *D. sublodoensis* Zone is suggested by the presence of some upper Eocene species together with *D. sublodoensis*. The *D. sublodoensis* Zone is present in only one sample (Sample 577-8-3, 120 cm).

The *D. lodoensis* Zone (CP11), characterized by the first occurrence of *Coccolithus crassus*, was recognized in both holes from Sections 577-8-4 through 577-8-6 and 577A-8-1 through 577A-8-4.

Sections 577-8-7 through 577-9-1 and Section 577A-8-5 through Sample 577A-8,CC contain an assemblage of the *Tribrachiatus orthostylus* Zone (CP10). *T. orthostylus* is present in both holes and it ranges from the *D. diastypus* Zone (CP9) to the middle part of the *D. lodoensis* Zone (CP11). The few *T. orthostylus* species found in the samples above have been considered reworked.

The very lower part of the Eocene, the *D. diastypus* Zone (CP9), seems not to be complete because of the absence of the *Tribrachiatus contortus* Subzone (CP9a).

Table 4. Distribution of Maestrichtian-early Paleocene calcareous nannofossils in Hole 577.

Age	Zone	Core-Section (interval in cm)	Sub-bottom depth (m)	Abundance	Preservation	Etching	Overgrowth	Reworking	Cretaceous species	*Ahmuerella octoradiata*	*Arkhangelskiella cymbiformis*	*Braarudosphaera bigelowii*	*Ceratolithoides aculeus*	*Cretarhabdus conicus*	*C. crenulatus*	*C. surirellis*	*Cretarhabdus* sp.	*Cribrosphaera ehrenbergii*	*Cylindralithus serratus*	*Cylindralithus* sp.	*Eiffellithus turriseiffeli*	*Glaukolithus diplogrammus*	*Lithraphidites carniolensis*	*L. quadratus*
early Paleocene	CP2	12-1,33–34	102.13	A	M	1	1	R								F								
		12-1,73–74	102.53	A	M	1	1	R								F								
		12-1,113–114	102.93	A	M	1	1	R								F								
		12-2,16–17	103.46	A	M	1	1	R								R								
		12-2,76–77	104.06	A	M	1	1	R								R								
		12-2,136–137	104.66	A	M	1	1	R																
	CP1b	12-3,6–7	104.86	A	M	1	1	R									C	F		F				
		12-3,76–77	105.56	A	M	2	1	R			R						C	R		F				
		12-3,116–117	105.96	A	M/P	2	1	R									F	R		R	F			
		12-3,142	106.22	A	M	1	2	R									F		R	R			R	
		12-4,16–17	106.46	A	M/P	2	1	R									F		R					
		12-4,56–57	106.86	A	M	1	1	R																
		12-4,96–97	107.26	A	M	1	1	R																
		12-4,117	107.47	A	M	1	1	R																
		12-5,6–7	107.86	A	M	1	1	R				R					F	R		R				
	CP1a	12-5,36–37	108.16	A	M	1	1	R																
		12-5,76–77	108.56	A	M/P	1	1	F									R							
		12-5,94–95	108.74	C	M	1	1	F								R					R			
		12-5,100–101	108.80	F	M/P	1	2	F									R							
		12-5,105–106	108.83	F	M/P	1	1	F											R					
		12-5,110–111	108.90	C	M/P	2	1	C			F	R				C	C	F	C	F	F		F	
		12–5,115	108.95	C	M/P	2	1	C			R					C	C	C	F	C	C	R	F	R
		12-5,118	108.98	C	M/P	1	1	C			F					C	C	C	F	C	C		C	
		12-5,120	109.00	A	M/P	1	1	C			C					C	C	C	F	C	C		C	F
		12-5,122	109.02	A	M	1	1	A			C				R	C	C	C	C	C	C		C	R
		12-5,124–125	109.05	A	M	1	1	A			F					F	C	C	C	A	C	F	F	R
		12-5,129	109.10	A	M/G		1	A			C				F	C	C	C	C	A	C	C	C	R
Maestrichtian	*Micula prinsii*	12-5,130	109.11	A	M	1	1				C				F	C	C	C	C	C	C	C	C	R
		12-5,136–137	109.17	A	M	1	1				F			F	C	C	C	C	F	C	C	F	C	F
		12-6,36–37	109.67	A	M	1	1				F						C	C		C	C		C	F
		12-6,96–97	110.27	A	M	1	2										C	C	C	C	C	F	A	R
		12-6,142–143	110.72	A	P	2	1										C			C				R
	Micula murus	12-7,20	111.00	A	M/P	2	2				F					C	C	C	C	C	C	F	A	R
		13-1,50	111.80	A	M/P	2	2			F	C		F			C	C	C	C	C	C	F	A	R
		13-1,111	112.41	A	M	1	1				F		C			C	C	C	C	C	C	F	A	
		13-2,111	113.91	A	M	1	1			R			C			C	C	C	C	C	C	F	A	R
		13-3,111	115.41	A	M	1	1						C	R		C	C	C	C	C	C	R	A	
		13-4,48	116.28	A	M	1	1				F		F			C	C	C	C	C	C	F	A	F
		13-4,111	116.91	A	M	1	1						F		F	C	C	C	C	C	C	F	A	
		13-5,14	117.44	A	M	1	1			R	F		C		F	C	C	C	C	C	C	R	A	R
		13,CC(5)	118.8	A	M	1	1			R			F		F	C	C	C	C	C	C		A	F

Note: See footnote to Table 3A for definition of symbols.

Only rare species of *T. contortus* were found in Sample 577-9-5, 117 cm.

Paleocene

All Paleocene zones (Tables 5 and 8) were recognized in the Paleocene sequence at Site 577. The nannofossils are moderately well preserved.

The *Discoaster multiradiatus* Zone (CP8) was not cored in Hole 577A, but it is well represented in Hole 577 from Sections 577-9-6 to 577-10-3.

Sections 577-10-3 through 577-10-4 and 577A-10-1 to 577A-10-2 belong to the *D. nobilis* Zone (CP7). *D. okadai*, a relatively large five-rayed discoaster described by Bukry (1981), was recognized in this zone. Together with this occurrence of *D. okadai*, a smaller *Discoaster* sp.A was found. The latter was reported by Okada and Thierstein (1979) at the same stratigraphic level at Site 384 in the Atlantic Ocean. This species occurs slightly below the first occurrence of *D. okadai*; both species are considered characteristic of the *D. nobilis* Zone; and their transoceanic significance is definitely confirmed.

It was not possible to separate the *D. mohleri* (CP6) and *Heliolithus kleinpellii* (CP5) Zones in Hole 577. In Hole 577A the first occurrences of *D. mohleri* and *H. kleinpellii* were separated by an interval of only a few centimeters.

The *Fasciculithus tympaniformis* Zone (CP4) occurs in Sections 577-11-3 through 577-11-4 and in Sample 577A-10,CC through Section 577A-11-2. The first *Fasciculithus* sp. appear in Hole 577A in the upper part of Section 577A-11-6 together with *Sphenolithus* sp. In Hole 577, the first *Fasciculithus* appear slightly above

Table 4. (Continued).

Manivitella pemmatoidea	*Microrhabdulus decoratus*	*Micula murus*	*M. prinsii*	*M. staurophora*	*Parhabdolithus embergeri*	*Prediscosphaera cretacea*	*P. grandis*	*Stephanolithion munitum*	*Watznaueria barnesae*	*Zygodiscus spiralis*	*Zygodiscus* sp.	*Zygolithus tarboulensis*	Cenozoic species	*Biantholithus sparsus*	*Biscutum* cf. *romeinii*	*Chiasmolithus bidens*	*C. consuetus*	*C. danicus*	*C. subrotundus*	*Coccolithus pelagicus*	*Cruciplacolithus edwardsii*	*C. primus*	*C. tenuis*	*Cyclagelosphaera reinhardtii*	*Discolithina rimosa*	*Ericsonia cava*	*E. robusta*	*E. subpertusa*	Foraminifer debris	*Markalius astroporus*	*Neochiastozygus concinnus*	*Neocrepidolithus* sp.	*Placozygus sigmoides*	*Prinsius bisulcus*	*P. dimorphosus*	*Thoracosphaera deflandrei*	*T. operculata*	*T. saxea*	*Thoracosphaera* sp.	*Toweius* sp.	*Zygodiscus simplex*
																	F	R		C			C					A		F	F		C	C					F		
																F	F	F		C			C		R	F		A		F			C	C				F	F		
																	C	F	F	C			C			F	C	A		F			C	C					F		
														R			F	F	R	C			C			F	F	A		F			A	F	C			R	F		
														R			R	F		C			C	R		F	R	C		F			C		F						F
																		F		C			C			C		C		F			C		F			F	F	C	
				F		C			C		C			R						A	C		C	F		C	F	C		C	R					F	R	F	C	A	
	F	F		R	R	C					C			R	C					A	F	F	C	F		F		C		C	R					F	R	F	C	A	
		F		R	R	C					C				C					A	R	C	C	F		F		C		F	R					F	F	C	C	A	
	F	F		R		F			F		F			R	C					A	R	C	A	F						R	F	R				R	R	C	C	A	
		F				C			F						A					A		C	C	C						F	F	R				C	F	C	C	F	
		R							C						A					C		A	C	A						C	R	F			F	C	C	A	A		
									R		F				A					F		A	R	C						F		F				C	C	A	A		
									F		F				A							A	C	C						R		C				C	C	A	A		
		F				F			F		R			R	A							A	R	C						C						C	C	A	A		
	R	R				C			C		F	R		F	A							A		C						C		R				C		A	A		
						R			C		R				A							C		A						C						A	R	C	A		
						R			F						A							F		A					R	F						C	C	A	A		
						R			F						A							R		A					F	F						C	C	A	A		
		R							F						A									C					F	R						R	C	A	A		
		C		C		C			A		F				A									F					C	F						F	C	C	A		
	F	C		C	R	A	R		A		C				A														C							R		F	C		
	F	C		C		A			A	F	C				C									R					C							R		F	C		
	C	C		A		A	R		A	F	C	R			C														C										C		
R	C	C		C	R	A		R	A		F	R			C									F					C							C			C		
	F	C		C		A	R		A	F		R			C									R					C							C			C		
	F	C	R	C		A		F	A	C	C	F			R														C										R		
	R	C	R	C		A			A	F	C	F																	C										R		
		C	F	C	R	A	F		A	F	F	F																	C										R		
F	F	C	R	C		A		F	A	F																			F												
F	F	C	R	A		A		F	A	F																															
		A	R	A		C			C																																
	F	C		C		A		F	A			F																													
C	C	C		C		A			A																																
C	C	C		C		A	F		A	F	F																														
	C	C		C		A		F	A		F	R																													
F	C	C		C	R	A	F		A	F		R																													
	C	F		C		A			A		F																														
	C	F		C		A	F	F	A																																
F	C	R		C		A	F	F	A	F																															
F	C			C		A			A			F																													

the first occurrence of *Sphenolithus* sp. in the lower part of Section 577-11-6. The genus *Fasciculithus* is quite common and well diversified in the upper Paleocene. *F. pileatus* was the first species recognized in the upper part of the *Ellipsolithus macellus* Zone (CP3).

The first occurrence of *E. macellus* defining the base of the *E. macellus* Zone (CP3) was recognized in Samples 577-11-6, 40 cm and 577A-11-4, 40 cm. In the lower part of the *E. macellus* Zone this species is very rare and discontinuously present.

The *Chiasmolithus danicus* Zone (CP2), defined at the bottom by the first occurrence of *C. danicus* s.s. as defined by Romein (1979), occurs in Sample 577-12-2, 136 cm (sub-bottom depth 104.86 m), in Sample 577A-12-1, 95 cm (sub-bottom depth 105.35 m), in Sample 577B-1-1, 90 cm (sub-bottom depth 105.3 m) (Table 9). The first occurrence of *Cruciplacolithus edwardsii* occurs slightly below that in Sample 577-12-3, 142 cm (sub-bottom depth 106.22 m), Sample 577A-12-2, 106 cm (sub-bottom depth 106.75 m), Sample 577B-12-2, 115 cm (sub-bottom depth 106.84 m) (Tables 4, 8, and 10). This species, described by Romein (1979), is characterized by a central cross in which the bars make an angle with the axes of the ellipse in clockwise direction. Both species have been grouped together in the literature until recently.

Assemblages of the *Zygodiscus sigmoides* Zone (CP1) occur in Samples 577-12-3, 6 cm through 577-12-5, 129 cm, 577A-12-1, 126 cm through 577A-12-4, 70 cm, and 577B-1-1, 110 cm through 577B-1-4, 72 cm (Tables 4, 8, and 10).

The *C. primus* (CP1a) and the *C. tenuis* (CP1b) subzones are recognized at all three holes. The *C. tenuis* Subzone, identified by the first occurrence of *C. tenuis*

Table 5. Distribution of calcareous nannofossils in the Paleocene-Eocene in Hole 577.

Age	Nannofossil zone	Core-Section (interval in cm)	Sub-bottom depth (m)	Abundance	Preservation	Etching	Overgrowth	Reworking	*Biscutum romeinii*	*Braarudosphaera bigelowii*	*B. discula*	*Bramletteius serraculoides*	*Campylosphaera dela*	*Chiasmolithus bidens*	*C. californicus*	*C. consuetus*	*C. danicus*	*C. expansus*	*C. grandis*	*Coccolithus crassus*	*C. eopelagicus*	*C. formosus*	*C. jugatus*	*C. pelagicus*	*Crepidolithus* sp.	*Cruciplacolithus primus*	*C. subrotundus*	*C. tenuis*	*Cyclagelosphaera reinhardtii*	*Cyclicargolithus floridanus*	*Cyclicargolithus* sp.	*Cyclococcolithus gammation*	*Cyclolithella kingi*	*C. placitilis*	*Dictyococcites bisecta*	*D. scrippsae*	*Discoaster barbadiensis*	*D. diastypus*	*D. germanicus*	*D. lenticularis*
Eocene middle	CP15/16	75,130−131	61.60	A	M/P	1	1	R				C												C						F					C	F	R			
		7-6,20−21	62.00	A	M/P	2	1	R				F	R									C		C											A	F	C			
		7,CC,7−8	62.40	A	P	2	2	R				F										C		C									F		A	C	C			
		8-1,120−121	65.00	A	M	2	1					C												C									R	F	A	F	C			
		8-2,120−121	66.50	A	M	1	1	R				R						R	F					C									R		A	F	C			
Eocene early	CP14	8-3,20−21	67.00	A	M/P	2	2					R							R					C							C		R		C	C	F			
	CP12	8-3,120−121	68.00	A	M/P	1	2					R	C						R			F		C										F			C			
	CP11	8-4,20−21	68.50	A	M	1	1						A							R		C	R	F									R	F			F			
		8-4,120−121	69.50	A	M/P	1	2					R	C					R	F	C	F	C	F	F									F	C			F			
		8-5,20−21	70.00	A	P	2	2						C								C	C		R									R	F			F			
		8-5,120−121	71.00	A	M/P	1	1					R	C					F	F	C	F	C	C	C								F	F	C			F			
		8-6,20−21	71.50	A	P	2	2						A						R	C	F	F	R									R	F	R			F			
		8-6,120−121	72.50	A	M/P	1	2					R	C			R		F	F	F̲	F	F	F	F									C	C			F			
	CP10	8-7,11−12	72.91	A	P	2	2						C			F					F	R											R				F			
		8,CC,34−35	73.26	A	M/P	2	2						C			F			F		C												C				F	F	R	
		9-1,20−21	73.50	A	M/P	2	2					R	C			F					F		F	F									F				F	C		
		9-1,130−131	74.60	A	M/P	2	1						C			F					F			R														F		
	CP9b	9-2,20−21	75.00	A	M/P	1	1					F	C			F					F		F	F									C				F	C		
		9-3,20−21	76.50	A	M/P	2	2					R	C			F					C		R	F								F	F				F	F		
		9-3,130−131	77.60	A	M/P	1	2						C			R					C			F													F			
		9-4,19−20	78.01	A	M/P	1	2						C	F		F					C		R	C													C	C		
		9-5,10−11	79.50	A	M/P	2	2	R					F	F		C					C		F	C													C	C		
		9-5,117−118	80.75	A	M	1	1					F	F	F	F	F					C			C													C	C̲		
Paleocene late	CP8	9-6,10−11	81.00	A	M/P	1	2					F	C	F	F	R		R			C			F																
		9-6,120−121	82.10	A	M/P	1	2						C	F	F	F					C		F	C														R?		
		9,CC,8−9	82.28	A	M/P	1	2	R				R	F	F		F					R		C																	
		10-1,50−51	83.30	A	M/P	2	1								R	R								C																
		10-1,120−121	84.00	A	M/P	1	2							F	F									C																R
		10-2,50−51	84.80	A	M/P	2	1								F									C																R
		10-2,120−121	85.50	A	M/P	1	2							C	F		R							C																F
		10-3,20−21	86.00	A	M/P	1	2							F	F									A																F
	CP7	10-3,120−121	87.00	A	M/P	1	2							F	F		R							A																
		10-4,50−51	87.80	A	P	2	2							F	F	F	F							A																
		10-4,120−121	88.50	A	M	1	1							F	C	F								C																R
	CP5/6	10-5,20−21	89.00	A	M/P	1	1							R		F	R							C																
		10-5,120−121	90.00	A	M	1	1							F	C	F								C				R												R
		10-6,20−21	90.50	A	M	1	1							F		F	R							C				R												
		10-6,120−121	91.50	A	M	1	1	R							F	C								C																C
		10-7,30−31	92.10	A	M	1	1	R							F	C								C				F												C
		10,CC,10−11	92.40	A	M/P	2	1	R							F	C								C																C
		11-1,10−11	92.60	A	M	1	1	R							C	C								C																C
		11-1,70−71	93.00	A	M	1	1	R							C	C								C				F												F
		11-1,130−131	93.60	A	M	1	1	R							C	C								C																C
		11-2,40−41	94.20	A	M	1	1								C	C	R							C				R												C
		11-2,120−121	95.00	A	M/P	2	1	R							F	C								C																
		11-3,34−35	95.64	A	M	1	1	R								C								C				F												
	CP4	11-3,120−121	96.50	A	M	1	1	R							C	C								C			F	C												
		11-4,40−41	97.20	A	M	1	1			R					C	C								C			R	F												
		11-4,120−121	98.00	A	M	1	1					F		C	F	F								C				C												
Paleocene early	CP3	11-5,40−41	98.70	A	M	1	1							F	F	F								C				C												
		11-5,120−121	99.50	A	M	1	1							F	F	C	F							C				C	R											
		11-6,40−41	100.20	A	M/P	1	2	C				F		F	F	C	F							C		F		C												
	CP2	11-6,120−121	101.00	A	M/P	1	2	C						F	F	C	F							C		R		C												
		11,CC	101.50	A	M	1	1	C			R			C	F	F	F							C	R	F		C	R											

Note: See footnote to Table 3A for definition of symbols.

s.s., occurs in Samples 577-12-3, 6 cm through 577-12-5, 6 cm, 577A-12-1, 126 cm through 577A-12-3, 66 cm, and 577B-1-1, 110 cm through 577B-1-3, 60 cm. The *C. primus* Subzone (CP1a) yields an assemblage characterized by small *Biscutum romeinii, Z. sigmoides, Zygodiscus* sp., *C. primus, Markalius astroporus*, and *Thoracosphaera* sp. The first occurrence of *C. primus* was recognized in the three holes about 30 cm above the Cretaceous/Tertiary boundary. Reworked Cretaceous nannofossils are rare in the upper part of the *C. primus* Zone, but become more abundant downward and dominate the Tertiary species in the samples just above the Cretaceous/Tertiary boundary.

Cretaceous/Tertiary Boundary

An extended and undisturbed Cretaceous/Tertiary boundary was cored three times at Site 577 in Sections 577-12-5, 577A-12-4, and 577B-1-4 (Tables 4, 8, and 10). The lower Paleocene-upper Maestrichtian sequence is an undisturbed white to light brown nannofossil ooze

Table 5. (Continued).

D. lodoensis	D. mohleri	D. multiradiatus	D. nobilis	D. okadai	D. saipanensis	D. salisburgensis	D. sublodoensis	D. tanii	Discoaster sp. 1	Discoaster sp.	Discoasteroides kuepperi	Discolithina plana	D. rimosa	Ellipsolithus distichus	E. lajollensis	E. macellus	Ericsonia cava
					R												
					C			C		R							
					C			C				F					
					C			C				R					
					C			F									
					C			C			C						
C							C			C	C		R				
C							R?						R				
C						F		C			C		R				
C																R	
C						F		C			F		R			R	
C						R					R						
C						F				C	F		R				
C						F					R		R				
C						C					F		R		R		
C		R				C					C	R			F		F
R						F					F		R				
			F			C					F		R			R	
			F			F				F	F		F			F	
			F			R					F		F			R	
			F								F		R			R	R
		R	C			F					F		F				
		C	C			F							R			F	
		C	F			F							F	F		F	
		C	F										R	F			
	C	C	F										R	R			
	F	C	R										R	R		F	
	C	C	F										R			F	
	C	C	F										F	R		R	
	C	C	F										F			F	
	C	R	R										F			F	
			R	C					C	F			F	R		R	
	C		R	F					F				R			F	
	C		R	F					F							R	
	C			R					R				F	R		R	
	C								F				R			R	
	C								R				R	R		F	
	C									C			F	F		C	
	C									C						C	F
	C									C						F	F
	C									C			F			F	F
	C									C			F			F	
	C									C				F		C	F
	C									C			F	R		C	F
	C									C				F		F	F
	C									R							F
																	F
																	C
																F	F
																	F
																	C
													F			R	C
																	C
																	C

E. robusta	E. subpertusa	Fasciculithus hayii	F. involutus	F. pileatus	F. tympaniformis	F. ulii	Fasciculithus sp.	Heliolithus conicus	H. kleinpellii	Markalius astroporus	Neochiastozygus concinnus	Pedinocyclus larvalis	Prinsius bisulcus	P. dimorphosus	Reticulofenestra samodurovii	R. umbilica	Rhabdosphaera sp.	Sphenolithus anarrhopus	S. heteromorphus
																F			R
																C			
															C				
															F	C			
															F	F			
															F	C	R		
												F							
										R		F							
												F							
											F	C							
												F							
F										R		F							
F																			
										F									
										R									
F																			
F																			
F	R									R									
F																			
F											F							C	
	F																		
C											R							C	
C	F						F				R							C	
F	F	F	R		R	F	F				R							F	
F	F	F	F		C	F	F				F							F	
C	C	F			F	F	C				F								
C	F		F		R	F	C												
C	A	F			C		C				F							C	
C	A	F			F		C				F								
C	A	F			F		C				F							C	
C	C	F	F		C		C				F							F	
C	C				F		C				F							C	
C	C	F			F		C				F		F					C	
	C				F		C			F	F		R					C	
F	C				C		C				R							C	
	C				C		C			F	F							C	
	C				C		C		F	F	F							C	
	C				C		C		C		F								
	C				C		C		F		F							A	
F	C				C		C				C							A	
C	C				C		C		R		F							A	
C	C				C		C				F							C	
F	C				C		C		C	F								A	
F	C				C		A	F	F		F							C	
F	C	F			C		A	F			C							F	
F	C			F	C		A	F			C							F	
F	C				C		A				F								
F	C			C			A			F	C		C						
F	C			C			A			R	C		F						
F	C		F	F		F	A			F	C		F	F					
F	C			R			A			F	C		C						
R	C			F			A			F	F		F						

S. moriformis	S. primus	S. radians	S. spiniger	Sphenolithus sp.	Striatococcolithus pacificanus	Thoracosphaera deflandrei	T. operculata	T. saxea	Thoracosphaera sp.	Toweius craticulus	T. eminens	T. magnicrassus	T. tovae	Tribrachiatus contortus	T. orthostylus	Wiseorhabdus inversus	Zygodiscus sigmoides	Z. simplex	Zygodiscus sp.	Zygrhablithus bijugatus
				C											R					
R				C																F
				C											R					F
				C												R				
				C												R				
			F	C											F	C				A
			R						F											C
R		C	C						R											C
		C			R				F											C
		F			R				F											A
F		C			R				R			F								C
		C			R							F								F
F		C			F				R						C					C
R		F							R			C			C					A
F		C			F				F						F					
C		C			F							F			F	R				A
F		F							F						C					C
F		F			F				R			C			C					C
F		C			F				F			C			F					C
R		F			R				F			C			C	F				C
		C													C					C
C		C							R	F		C			C					
									R	F				R						
C									F	F							C			R
C									F	R							F			
C								R		R	C		R				F			F
C								R			C									
C											C									
										F	C									
C								F			C									
C				C				F			C							F		
C								R			C							F		
C								R			C		R							
C										F	C							R	R	
F										F	C							R		
C										C	C							C		
								F	R	F	C						C			
C									F	F	C						C		F	
C										F	C		F				C			
A										C	C		F				C		F	
A						F				C	C		F				C		F	
C										C	C		F				C			
A									F	F	C		F				C			
C								F	F		F		F				C		F	
A										F	F		F				C			
C				C							F		C				C			
C							R		F		F		C				C		F	
C	C			C						F			C				C	C		
	C			C							F		C				C			
	C			C						F	F		F				C	F		
	C			C							F						C			
	C			C						F	F						C			
	C			C													C		F	
				C						F										

(see Site 577 chapter, this volume). Except for a minor color change from a Maestrichtian white to Tertiary light brown calcareous ooze, the recovered sediments are essentially featureless with no signs of sedimentation disruption. The upper Maestrichtian is characterized by a rich Cretaceous nannofossil assemblage. This assemblage is dominated by species such as *Arkhangelskiella cymbiformis, Prediscosphaera cretacea, P. grandis, Lithraphidites quadratus, Micula staurophora, Cretarhabdus surrirellus, C. crenulatus,* and *Watznaueria barnesae. M. murus, M. prinsii,* and *L. quadratus* zones were recognized (Tables 3, 6, and 9). *M. prinsii,* a rather delicate form, characteristic of the uppermost Maestrichtian in low latitudes, was found at ~1 m below the Cretaceous/Tertiary boundary.

Preservation of Cretaceous nannofossils is moderate and becomes poor in the very early Paleocene. No significant changes in relative abundances of the Cretaceous taxa were observed from the *L. quadratus* Zone (the oldest Cretaceous sediments recovered) up to the Cretaceous/Tertiary boundary. The Cretaceous/Tertiary boundary was defined in terms of calcareous nanno-

Table 6. Distribution of calcareous nannofossils in the Neogene in Hole 577.

Age	Nannofossil zone	Core-Section (interval in cm)	Sub-bottom depth (m)	Abundance	Preservation	Etching	Overgrowth	Reworking	*Amaurolithus amplificus*	*A. delicatus*	*A. primus*	*A. tricorniculatus*	*Bramletteius serraculoides*	*Calcidiscus leptoporus*	*C. macintyrei*	*Ceratolithus acutus*	*C. cristatus*	*C. rugosus*	*C. telesmus*	*Coccolithus miopelagicus*	*C. pelagicus*	*Coronocyclus nitescens*	*Crenalithus doronicoides*	*C. productellus*	*Cricolithus jonesii*	*Cyclicargolithus* sp.	*Cyclolithella rotula*	*Dictyococcites bisecta*
Pleistocene	CN15	1-1,50−51	0.50	A	M	1	1							C			R				C			C	F			
	CN14b	1-1,125−126	1.25	A	M	1	1	R						C			R		R		F			C	C			
		1-2,40−41	1.90	A	M	1	1							C			R				F		C	C	F			
		1-2,125−126	2.75	A	M	1	1							C			R				F		C	C				
		1-3,40−41	3.40	A	M	1	1							C			R		R		R			C				
		1-4,40−41	4.90	A	M	1	1							C			R				C		C	C				
	CN13/14a	1-5,46−47	5.75	A	M	1	1							C			R				F			C	F			
		1,CC(10−11)	6.81	A	M	1	1							C			R				F		C	C				
		2-1,40−41	7.20	A	M	1	1							C			R				F		C	A				
		2-1,103−104	7.83	A	M	1	1							C			R		R		F		C	C				
		2-2,43−44	8.73	A	M	1	1							C			R		R		F		C					
		2-2,103−104	9.33	A	M	1	1							C			R				F		C					
		2-3,43−44	10.23	A	M	1	1							C			R				F		F					
		2-4,43−44	11.73	A	M	1	1							C			R				F		C		R			
		2-5,35−36	13.15	A	M	1	1							C			R	R			F		C					
		2-6,40−41	14.70	A	M	1	1							A			R				F		C					
		3-1,103−104	17.80	A	M	1	1							C	F		R				C		C					
		3-2,96−97	18.66	A	M	1	1	R						C	F		R		R		F		C		R			
		3-3,96−97	20.76	A	M	1	1							C	C		R				F		C					
late Pliocene	CN12d	3-4,96−97	21.76	A	M	1	1							C	C		R	R			F		C					
		3-5,44−45	22.74	A	M	1	1							C	C		R				F		C					
		3-5,110−111	23.40	A	M/P	2	1							C	C		R		R		F		C		R			
		3-6,30−31	24.10	A	M	1	1							C	C		R	R			F		C					
		3,CC(3−4)	25.8	A	M	1	1							C	R		R				F		A					
		4-1,33−34	26.13	A	M	1	1							C	C		R	R			C		A					
	CN12c	4-1,112−113	26.92	A	M	1	1							C	F		R		R		F		A					
		4-2,30−31	27.60	A	M	1	1							C	F		R				F		A					
	CN12b	4-2,112−113	28.42	A	M	1	1							C	F		R	R			F		A					
		4-3,25−26	29.05	A	M	1	1							C	C		R				C		C					
	CN12a	4-3,112−113	29.92	A	M	1	1							C	C		R	R			F		C					
		4-4,112−113	31.42	A	M	1	1							C	C		R				C							
		4-5,112−113	32.92	A	M	1	1							F	C		R				C							
		4,CC(14−15)	35.30	A	M	1	1							C	R		R				C							
		5-1,120−121	36.50	A	M	1	1							C	F		R	R			F							
		5-3,33−34	38.63	A	M	1	1							C	F		R				F							
		5-4,30−31	40.10	A	M	1	1	R		R				C	C			R			F							
		5-4,95−96	40.76	A	M	1	1							C	C			R			F							
early Pliocene	CN11	5-5,70−71	42.00	A	M	1	1							C	C			R			F							
		6-1,20−21	45.00	A	M	1	1	R		R		R		C	C			R			F						F	
		6-1,120−121	46.00	A	M	1	1	R		R				C	C			R			F						F	
		6-2,60−61	46.90	A	M	1	1							C	C			R			F						F	
	CN10c/d	6-2,120−121	47.50	A	M/P	2	1			R		R		C	C			R			F						F	
		6-3,20−21	48.00	A	M/P	2	1			R	R	R		C	C			R			F							
		6-3,120−121	49.00	A	M/P	2	1			R	R	R		C	F			R			C							
		6-4,60−61	49.90	A	M/P	2	1			F	R	R		C	C			R			F							
	CN10	6-4,120−121	50.50	A	M/P	2	1			F	R	R		C	C						C							
		6-5,20−21	51.00	A	M/P	2	1			R	R	F		C	C						C							
		6-5,115−116	51.95	A	M/P	2	1			F	R	R		C	C						F							
		6-6,20−21	52.50	A	M/P	2	1			R		R		C	C						F							
late Miocene		6-6,120−121	53.50	A	M/P	2	1			F		R		C	C						F							
		6-7,12−13	53.92	A	M/P	2	1			R	R	F		C	C						C							
		6,CC(15−16)	54.30	A	M/P	2	1			R	R	R		C	F	R					F							
		7-1,20−21	54.50	A	M/P	2	1			R	R	R		C	F						F							
		7-1,130−131	55.60	A	M/P	2	1			R	R	R		C	F						F							
	CN9b	7-2,20−21	56.10	A	M/P	2	1		R	R	R	R		C	F						F							
		7-2,130−131	57.10	A	M/P	2	1			R	R	R		C	F						F							
		7-3,20−21	57.60	A	M/P	1	1			R	R			C	F						C							
		7-3,130−131	58.60	A	M/P	2	1				R			C	F						F							
	CN5	7-4,43−44	59.23	A	M/P	2	1							F	F					F	F	R						
		7-4,130−131	60.10	A	M/P	2	1	R						F	F					F	F							
	CN4/5	7-5,42−43	60.72	A	M	2	1	R					F	A	R						F				F			R

Note: See footnote to Table 3A for definition of symbols.

Table 6. (Continued).

D. minutus	D. asymmetricus	Discoaster aulakos	D. barbadiensis	D. berggreni	D. blackstockae	D. brouweri	D. challengeri	D. deflandrei	D. exilis	D. intercalaris	D. multiradiatus	D. pentaradiatus	D. pseudovariabilis	D. quinqueramus	D. sanmigüelensis	D. surculus	D. tamalis	D. tanii	D. triradiatus	D. variabilis	Discoaster sp.	Discolithina japonica	Emiliana annula	E. huxleyi	E. ovata	Gephyrocapsa aperta	G. caribbeanica	G. oceanica	Gephyrocapsa sp.	Helicopontosphaera granulata	H. kamptneri	H. wallichii	Pedinocyclus larvalis	Reticulofenestra pseudoumbilica	Reticulofenestra sp.	Rhabdosphaera clavigera	Scyphosphaera globulata	Sphenolithus abies	S. heteromorphus	Sphenolithus sp.	Striatococcolithus pacificanus	Syracosphaera hystrica	Thoracosphaera sp.	Triquetrorhabdulus rugosus	Umbilicosphaera mirabilis	U. sibogae
																								C		A	C	C	C		C												F			
																					R	F					C	C	C	C		C												R			
																						F				C	C	C	C		C	F					F						F	F			F
																						F				F	C	C	C	R	C	R					R								F			F
																											C	C	C	C		C	R												F	F			
																						R				C	C	C	C	R	C						R						F	F			F
																						F	C		C	F	C	C	C		F												R	R			F
																							F		C	C		C	C		C						R								F			R
																						F	C		C	C	C	C	C	F	C						F						F	F			R
																							C		C	C	C	C	C		F						F						R	F			
																							C		C			C	C	R	F													F		R	
																						F	C		C		C	C	C		F													F			
																							C		C		F	C	A		F						F							F		R	
																						F	C		C		F	C	A	R	C													F			
																							C		C			C	A		C						R										
																						F	C		C			C	C		C													F			
																						F	C		C			C	C		F						R								R		R	
																							C		C				C		F													F			
																							C		C				C	F	F															
						F																	C		C				C	F						R											
						F																	C		C				C		F					R											R
						F													R			F	C		C				C		F													F			
						R																								F					R										
						R												F				F						C		F																R	
						F																R	C						C	R	C						R								F			
						F						F						F				C						C	F	F													F			
						F						F									R	C						C		F													F			
						C						C			F			F				C						C	R	F											R	R			
						C						C			F			F				C								R													F			
						C						F			F	F		R				C								R															
						C						C			F	F		R				C						C		R													F			
						C						C			C	C						C						F	R													F			
						C						C			C	F						C						C	F	R													R			
						C						C			C	F						F						R	R													F			
						C						F			C	C				R	C						R	R											R				
C	F						C						F			C	C						C						C												R				
C	F						C	R					F			C	F						C						F											F				
C	R						C	F					F			C	F											C		R			C						R		R				
C	R						C	F					F			F	F			F										C				C		R				F						
C	F						C	F									F				F													C						F			R			
C	C						C	F					R			F				F										R				C		R		R		F			R			
C	C						C	F					C			C				F													C				R		F						
C	C						C	F					C			C				F													C						F						
A	F					R	C	F					C			C				C										R				C						F						
A	C					R	C	F					C			C				F													C						F						
A						C	F					F			C				F													C						F						
A					R	C	F					F			C				C													C						F						
A	F						C	F					C			C				C													C						F						
A						C	F					C			C				C													C						F						
C	F					R	C	C					F			C				C													C						F						
A	R						C	F					F			C				F													C						F						
A						C	F					F			C				C													C						F						
A						C	F					F			C				C													C						F						
A						C	F					F			C				F													C						F						
C	R						C	C	R					F		F		C		F		C													C						F						
C	R						C	F	R					C		C		C				C													C						F						
C						F	F					C		C		F				F													C						F						
C						C	F			R		F	R	F		F				C													1	C						F				1		
F		R		R		C	F		F						F					C													C	R					F						
F		F	1			C	F	F	F						F					C											R	C	R					F						
		F					F	F	C	F		RR				F																	F	R				F	F	R					

Table 7. Distribution of calcareous nannofossils in the Maestrichtian in Hole 577A.

Age	Nannofossil zone	Core-Section (level or interval in cm)	Sub-bottom depth (m)	Abundance	Preservation	Etching	Overgrowth	Reworking	*Ahmuerella octoradiata*	*Arkhangelskiella cymbiformis*	*Ceratolithoides aculeus*	*Cretarhabdus conicus*	*C. crenulatus*	*C. surirellus*	*Cretarhabdus* sp.	*Cribrosphaera ehrenbergii*	*Cylindralithus serratus*	*Cylindralithus* sp.	*Discorhabdus rotatorius*	*Eiffellithus turriseiffeli*	*Glaukolithus diplogrammus*	*Lithraphidites carniolensis*	*L. quadratus*	*Manivitella pemmatoidea*	*Microrhabdulus decoratus*	*Micula murus*	*M. prinsii*	*M. staurophora*	*Parhabdolithus embergeri*	*Prediscosphaera cretacea*	*P. grandis*	*Quadrum gartneri*	*Reinhardtites anthophorus*	*Stephanolithion munitum*	*Watznaueria barnesae*	*Zygodiscus spiralis*	*Zygodiscus* sp.	*Zygolithus tarboulensis*	Foraminifer debris
Maestrichtian	*Micula prinsii*	12-4,75	109.65	A	M	2	1		F	F			R	C	C	C	C	C		C	R	C	R	R	C	C		C		A	R			R	R	F	C	F	C
		12-4,80	109.70	A	M	2	1		F	F				C	C	A	C	C		C	R	C	R	F	R	C		C	F	A	R				A	C	C	F	F
		12-4,82–83	109.72	A	M	2	1		F	R				C	C	C	C	C		C		C		R	C	C	R	A	R	A	R	F			A	C	C	C	F
		12-4,100	109.90	A	M	2	1		R	F				F	A	A	C	C		C		C	F	C	C	C		A		A	F	F			A	C	C	R	
		12-4,120	110.10	A	M	1	1		F	F				C	C	C	C	C		C	R	C		C	C	C		A		A	F	R			A	F	C		
		12-4,126–127	110.16	A	M	2	1			C			F	C	C	C	A	A		C		A	F	C	C	A	R	A		A									
		12-5,6–7	110.46	A	M/P	2	1			F				F	A	C	A	A		F	F	F	R	C	C	A		A		A	C	C	F		A			F	F
		12-5,86–87	111.26	A	M/P	2	1			R				C	A	C	A	A		F		A	F	F	C	A	R	A		A	C	C	F		A	F			
		12-5,146–147	111.86	A	M/P	2	1			R		F		C	A	F	A	A		R	F	A	F	F	F	A	R	C		A	C	F			A		F		
	Micula murus	12-6,26–27	112.16	A	M/P	2	1		F	R					A	C	A	A		F	F	A		C	F	C		C		A	C	F			A		F		
		12-6,30–31	112.20	A	M/P	2	1			F				C	A	C	A	A	R	C	C	A	F	C	C	C		C		A		F			A		C		
		12-6,80–81	112.70	A	M/P	2	1			C				C	A	C	A	A		C	C	A	F	F	C	A		C		A	F				A		C		
		12-6,130–131	113.20	A	M/P	2	1		F	C	R		F	C	A	C	A	A		C	F	A		F	C	C		F		A					A		F		
		12-6,140–141	113.40	A	M	2	1			C		C		C	A	C	A	C		C	F	A	R	C	C	A		C		A					C		F		
		12,CC	113.90	A	M	2	1		F	F	F	F	C	C	C	C	C	C		C		C		C	C	A		F		A	F				C				
		13-1,44–45	114.34	A	M	2	1			C	R	F	C	C	C	C	C	F		C	F	F	F	C	C	F		F		A					C	R	R	R	R
		13-1,106–107	114.96	A	M	2	1		F	C	R	C	C	C	C	C	C	F		C		F	F	F	C	F		F	R	A					C	R	R		
		13-2,44	115.84	A	M	2	1		F	C	F	C	C	C		C	C	C	R	C	F	F		C	C	F		C	F	A	R				C	C		R	
		13-2,106–107	116.46	A	M	2	1		F	F	F	C	C	C	F	C	C	C		C	R	C	R	C	C	C		C		A					C	C			
		13-3,44–45	117.34	A	M	2	1		F	C	F	C	C	C	F	C	C	C		C	F	C		C	C	F		C	R	A				R	C	F			
		13-3,106–107	117.96	A	M	2	1		F	C	R	C	A	C		C	C	C	R	C	F	C		C	C	F		C	F	A					C	F			
		13-4,44–45	118.84	A	M	2	1		F	F	C	C	C	C	F	C	C	A		C	F	C	F	C	C	R		C	R	A	F	F		R	C	R			
		13-4,106–107	119.46	A	M	2	1		F	R	R	F	C	C		C	C	C		C	F	C	F	C	C	F		F	R	C	F	F			C	F	R		
		13-5,44–45	120.34	A	M	2	1		F	F			C	F	C	C	F	C		C	C	C	F	C	C	F		F	F	C		F		R	C	F			
	Lithraphidites quadratus	13-5,106–107	120.96	A	M	2	1		F	F		C	C	C	F	A	F	C		C	F	C	F	C	C			F	F	C	F	F			C	F			
		13-6,44–45	121.84	A	M	1	1		F	F		C	C	C	F	A		C		C	F	C	F	C	C			F	F	C					C	C			
		13-6,106–107	122.46	A	M	1	1		F	F		C	C	F	C	A		C		C	F	A		A	C			R	F	C	F	F			C	F	F		
		13,CC	123.4	A	M	1	1		F	F	F	C	C	C		C		F		C	F	A	A	A	C			F	F					F	C	F			

Note: See footnote to Table 3A for definition of symbols.

fossils by the increased frequency of *Thoracosphera*, a calcareous dinoflagellate. *Thoracosphera* was found throughout upper Maestrichtian sediments in low latitude sections like Caravaca and El Kef (Perch-Nielsen, 1981a), but it is not present in high latitude sections such as the North Sea. At Site 577, rare species of *Thoracosphaera* appear at the very top of the Upper Cretaceous samples: 5 cm below the Cretaceous/Tertiary boundary.

The appearance and subsequent increase of *Thoracosphaera* is abrupt and occurs just at the bottom of the color change where the boundary was placed, at about 109.60 m sub-bottom depth. Immediately below the first occurrence of *Thoracosphaera* a sizable portion of "debris of forams" was observed; they have been listed in the range chart because it appears to be a characteristic feature of the Cretaceous/Tertiary boundary interval. Foraminifer fragments decrease and almost disappear about 40 cm above the Cretaceous/Tertiary boundary. The increase of *Thoracosphaera* comes together with the first occurrence of small ~1 to 3 μm *Biscutum* such as *B. romeinii*, a form described by Perch-Nielsen (1981a) in the lowermost Paleocene of the El Kef section. In my samples, these small *Biscutum* always have an empty central area. *Markalius astroporus* and *Cyclagelosphaera reinhardtii* appear slightly above the Cretaceous/Tertiary boundary. Only rare specimens of *B. bigelowi* and *B. sparsus* are found.

The first specimens of *Cruciplacolithus* belong to *C. primus*. Forms of this species vary greatly in size and in the dimensions of the central area.

Very rare forms of small *Prinsius* and *Toweius* were found together with *C. primus*. *C. tenuis, Ericsonia cava,* and *E. subpertusa* become common in the upper part of the *C. tenuis* Subzone (CP1b).

As a conclusion, if we consider the assemblage and the succession of the nannofossil events and compare them with the magnetostratigraphy (Monechi et al., this volume) we can say that the Shatsky Rise provides a well preserved and continuous Cretaceous/Tertiary boundary section. The enrichment in iridium (Michel et al., this volume) and the oxygen isotope values (Zachos et al., this volume) found just at the Cretaceous/Tertiary boundary support the statement that the Shatsky Rise sections are indeed some of the most complete sequences across the Cretaceous/Tertiary boundary.

Maestrichtian

Both Holes 577 and 577A (the lower part of Cores 12 and 13) and Hole 577B (the lower part of Core 1) contain moderately to strongly dissolved Upper Cretaceous nannofossil assemblages.

Micula prinsii, the marker of the uppermost Maestrichtian, was first found in all three holes, in Samples 577-12-6, 142 cm, 577A-12-5, 146 cm, and 577B-1-5, 120 cm (Tables 4, 7, and 10). The specimens are rare and not very well preserved. The *M. murus* Zone was recognized in all three holes. The base of this zone was reached only at Hole 577A (Sample 577A-13-5, 44 cm, Table 7).

Intermediate forms between *M. staurophora* and *M. murus* can be observed in the lower part of Core 13 in Hole 577A.

The oldest recovered nannofossil assemblage was in Hole 577A. This assemblage belongs to the middle Maestrichtian *Lithraphidites quadratus* Zone and is dominated by the following species: *L. quadratus, Arkhangelskiella cymbiformis* (few), *Ahmuerella octoradiata, Cretarhabdus surrirellus, C. crenulatus, Cylindralithus serratus, Eiffellithus turriseiffeli, Prediscosphaera grandis, M. staurophora,* and *Watznaueria barnesae*.

Site 580

Site 580 lies near the present day subarctic front (42°N), marking the northern margin of the transition zone between the subarctic and subtropical gyres (Fig. 1). Coring was intended to provide a detailed paleoceanographic record in the subtropical/subarctic gyre transition zone for the late Miocene to Recent and to document north-south migration of the frontal zone with time.

Calcareous nannofossils are absent in all the cores recovered except the core catcher of Core 13. The poorly preserved assemblage in this sample includes *Crenalithus doronicoides, Coccolithus pelagicus, Calcidiscus leptoporus, Emiliania annula, Discoaster brouweri, Ceratolithus rugosus, Gephyrocapsa* sp., and *Reticulofenestra* sp. This assemblage belongs to the late Pliocene *D. brouweri* Zone (CN12).

REMARKS ON SYSTEMATICS

***Braarudosphaera* sp. 1**
(Plate 1, Figs. 1-10, 12)

Braarudosphaera (sp. ind.) in Thierstein and Manivit, 1981 (plate 7, figs. 1-4).

Remarks. The pentaliths consist of five subradial, imbricate elements having almost straight radial sutures that meet the peripheral margin at the midpoints between adjacent apices. All specimens found are considerably overgrown; in fact the length of the elements of some specimens is doubled or even tripled by overgrowth (see Plate 1, Fig. 4). The overgrowth of the elements of the *Braarudosphaera* gives a typical rotational pattern (see Plate 1, Figs. 5 and 11). This specimen differs from *Braarudosphaera imbricata* by a star-shaped outline. *Bukryaster hayii* differs from *Braarudosphaera* sp. 1 by its central disc with orientated ridges.

Occurrence. Found in Campanian sediments in Core 576B-8 in the *Aspidolithus parcus* Zone. Thierstein and Manivit (1981) found the same forms in the Campanian deep-sea sediments at Site 462, Cores 55 and 9A (Nauru Basin).

***Rucinolithus magnus* Bukry, 1975**
(Plate 2, Figs. 1-3)

Rucinolithus magnus Bukry, 1975 (p. 690, plate 3, figs. 12-14).

Remarks. Specimens composed of large radial rosettes of six equal rhombohedral elements and tapered to points. The elements are slightly imbricate at the center. This species differs from *R. hayii* (Plate 2, Fig. 11) by its larger size and more elongate elements.

Distribution. Common in Campanian sediments in Core 576B-8.

***Discoaster* sp. A.**
(Plate 10, Fig. 2)

Discoaster sp. 1 Okada and Thierstein, 1979 (p. 523, plate 15, fig. 11).

Remarks. Discoaster composed of five to seven thick rhombohedral rays. The sutures are straight and the rays symmetrically arranged.

Distribution. Common in the upper Paleocene, *D. nobilis* Zone, at Site 577. Found at Site 384, Western North Atlantic Ocean, in upper Paleocene sediments.

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APPENDIX
Taxonomic List

Calcareous nannofossil species considered in this report are listed in alphabetical order. The bibliographic references of these species are provided in Loeblich and Tappan (1966, 1968, 1969, 1970a,b, 1971, 1973) and in the bibliography of van Heck (1979-1984).

Mesozoic

Ahmuerella octoradiata (Gorka, 1957) Reinhardt, 1964
Arkhangelskiella cymbiformis Veskina, 1959
Aspidolithus parcus (Stradner, 1963) Noël, 1969
Braarudosphaera africana Stradner, 1961
B. bigelowii (Graan and Braarud) Deflandre, 1947
B. imbricata Bukry, 1969
Braarudosphaera sp. 1
Broinsonia enormis (Shumenko, 1968) Manivit, 1971
Bukryaster hayii (Bukry, 1969) Prins, 1971
Ceratolithoides aculeus (Stradner, 1961) Prins and Sissingh, 1977
Chiastozygus litterarius (Gorka, 1957) Manivit, 1971
Cretarhabdus conicus Bramlette and Martini, 1964
C. crenulatus Bramlette and Martini, 1964
C. surrirellus (Deflandre, 1954) Reinhardt, 1970
Cretarhabdus sp.
Cribrosphaera ehrenbergii (Arkhangelsky, 1912) Deflandre, 1952
Cyclagelosphaera margerelii Noël, 1965
Cylindralithus serratus Bramlette and Martini, 1964
Cylindralithus sp.
Discorhabdus rotatorius (Bukry, 1969) Thierstein, 1973
Eiffellithus eximius (Stover, 1966) Perch-Nielsen, 1968
E. turriseiffeli (Deflandre, 1954) Reinhardt, 1965
Glaukolithus diplogrammus (Deflandre, 1954) Reinhardt, 1964
Kamptnerius magnificus Deflandre, 1959
Lithastrinus floralis Stradner, 1962
L. grillii Stradner, 1962
Lithastrinus sp.

Table 8. Distribution of calcareous nannofossils in the Paleocene-Eocene in Hole 577A.

Age	Nannofossil zone	Core-Section (level or interval in cm)	Sub-bottom depth (m)	Abundance	Preservation	Etching	Overgrowth	Reworking	*Biantholithus sparsus*	*Biscutum romeinii*	*Biscutum* sp.	*Braarudosphaera bigelowii*	*B. discula*	*Bramletteius serraculoides*	*Campylosphaera dela*	*Chiasmolithus bidens*	*C. californicus*	*C. consuetus*	*C. danicus*	*C. expansus*	*C. grandis*	*Coccolithus crassus*	*C. eopelagicus*	*C. formusus*	*C. jugatus*	*C. pelagicus*	*Crepidolithus* sp.	*Cruciplacolithus edwardsii*	*C. primus*	*C. subrotundus*	*C. tenuis*	*Cyclageolsphaera reinhardii*	*Cyclicargolithus floridanus*	*Cyclicargolithus* sp.	*Cyclococcolithus gammation*	*Cyclolithella kingi*	*C. plactilis*	*Dictyococcites bisectus*	*D. scrippsae*	*Discoaster barbadiensis*	*D. diastypus*	*D. germanicus*	*D. lenticularis*
middle Eocene	CP15	75,36–37	63.26	A	P	2	2	R						C										C		C							R					C		C			
		7-5,86–87	63.76	A	P	1	2	R						C								F		F		F												C		C			
	CP14	7-6,36–37	64.76	A	M/P	1	1							F	F					R	R		C	C	R	F												C		C			
		7-6,87–87	65.26	A	M/P	1	1							F	F						F	C	C	C	F	C								C				A		C			
early Eocene	CP12	7,CC,(2–3)	65.76	A	M/P	1	1							F	C		R			F	C	C	C	C	F	F								C	F	F				C			
	CP11	8-1,105–106	67.45	A	M/P	1	1							F	C						C	C	C	C	C	C								C	F				F	C			
		8-2,105–106	68.95	A	M/P	1	1								C		F			F	C	C	C		F	F								C		F			C	F			
		8-3,105–106	70.45	A	P	2	2							F	C		F			C	C	C	C	C	F	C								C					F	F		F	
		8-4,20–21	71.10	A	M/P	1	1							R	C	F	R				F	F	C	F	F	C								C	C	R				F			
		8-4,105–106	72.95	A	P	2	2								C	F	R			C	C	C	A	C	F	C														C			
	CP10	8-5,15–16	73.55	A	P	2	2							R	C	F	F			F	R	R	C	C												C				C		F	
		8-5,105–106	74.45	A	P	2	2							F	C	R	F	F			C		A	C	C	C										F				F			
		8-6,15–16	75.05	A	P	2	2							R	C	F	F	F		F	C		C	C	C	C										F				C			
		8,CC(5–6)	74.43	A	M/P	2	1								F	F	F				F		C	C	F	C										F				C	C		
	CP9b	9-1,30–31	76.20	A	M/P	1	2							F	F	F	F			F	F		C		R	C										F				C	C		
		9-1,97–98	76.88	A	M/P	1	2									F	F							C		C										F				A	C		C
		9-2,30–31	77.70	A	M/P	2	1							F		F	C	C						C		C														C			C
		9-2,97–98	78.38	A	M	1	1							F		F	C	C						C		C														C			C
		9-3,30–31	79.20	A	M	1	2							F		C	F	C						C		C														C	C		C
		9,CC(10–11)	79.65	A	M	1	1	R						F	C	F	F	C								C																	
late Paleocene	CP7	10-1,39–40	85.79	A	M/P	1	2											C								C																	
		10-1,120–121	86.60	A	M/P	1	2									F	F	C								A																	
		10-2,39–400	87.29	A	M/P	2	1										F									C																	
		10-2,120–121	88.10	A	M	1	1										F	C								A																	
	CP6	10-3,33–40	88.79	A	M/P	2	1										F									C																	
		10-3,120–121	89.60	A	M	1	1										F	C								A																	
		10-4,120–121	91.10	A	M	1	1										C	F								A																	
		10-5,39–40	91.79	A	M	1	1										F	C								A																	
		10-5,120–121	92.60	A	M	1	1	R									F	C								A																	
		10-5,128	92.78	A	M/P	2	2											F								C																	
	CP5	10-6,10–11	93.00	A	M	1	1									F	C	C	F							C				F													
	CP4	10,CC	95.38	A	M	1	1									F	C	C	F							C				R	C	R											
		11-1,40	95.30	A	M	1	1											C	F							C			R		C												
		11-1,110–111	96.00	A	M	1	1											C	F							C					C												
		11-2,110–111	97.50	A	M	1	1											F	F							C		R			C												
early Paleocene	CP3	11-3,39–40	98.29	A	M	1	1	R																				F															
		11-3,110–111	99.80	A	M	1	1	R										F	F							C					C												
		11-4,40	99.80	A	M/P	2	1	R																				F															
	CP2	11-4,110–111	100.50	A	M/P	2	1	C																							C												
		11-5,110–111	102.00	A	M	1	1	C											F							C		F	F		C	R											
		11-6,110–111	103.50	A	M	1	1	C	R										F							C			F		C												
		11-7,5–6	103.85	A	M	1	1	C			F		R						F							C		F	C		C	F											
		12-1,95–96	103.35	A	M/P	2	1	C			C								F							C		F	C		C												
	CP1b	12-1,126–27	105.66	A	M	1	1	C			C															C		F	C		C	C											
		12-2,26–27	106.16	A	M	1	1	C		R	C															C		F	C		C												
		12-2,66–67	106.56	A	M/P	1	1	C		C	C															C	F	F	C		C	C											
		12-2,106–107	106.96	A	M/P	2	1	C		A	C															C	F	F	C		C	C											
		12-2,146–147	107.36	A	M	1	1	C		A	F															C	C		A		C	C											
		12-3,10	107.50	A	M	1	1	C		A	F															F	C		A		C	C											
		12-3,30–31	107.70	A	M	1	1	F	R	A	F																		A		C	C											
		12-3,66–67	108.06	A	M	1	1			A	F															R	C		A		C	C											
	CP1a	12-3,106–107	108.46	A	M	1	1	F		A																			C			F											
		12-3,146–147	108.86	A	M	1	1	F		A																			A			A											
		12-4,7–8	108.97	A	M/P	2	1	F	R	A																			C			A											
		12-4,15	109.05	A	M/P	2	1	F		A																			F			A											
		12-4,26–27	109.16	A	M	1	1	C	R	A																			R			A											
		12-4,30	109.20	A	M	1	1	R	R	A																						C											
		12-4,35–36	109.25	A	P	2	1	R		A																			R			C											
		12-4,38	109.28	A	P	2	1	R	R	A		R																				C											
		12-4,41–42	109.33	A	P	2	1	R	R	A		R																	R			C											
		12-4,44	109.36	A	P	2	1	R		A																						F											
		12-4,48	109.40	A	P	2	1	R		A	R																				R	C											
		12-4,50	108.42	A	P	2	2	R		A																						C											
		12-4,51–52	109.43	R	P	2	2	R		A																					R	F											
		12-4,54–55	109.46	R	P	2	2	C		A																						C											
		12-4,56	109.48	F	P	2	1	A		A																						F											
		12-4,58	109.50	F	P	2	1	A		A	F																					F											
		12-4,59	109.51	C	P	2	1	A		A	C																					R											
		12-4,60	109.52	C	P	2	1	A		A	C																					F											
		12-4,62	109.54	C	M/P	2	1	A		A	C																																
		12-4,63	109.55	A	M/P	2	1	A		R	C																																
		12-4,65	109.57	A	M/P	2	1	A		R	F																																
		12-4,68	106.60	A	M	1	1	A		R	R																																
		12-4,70	109.62	A	M	2	1	A		R	R																																

Note: See footnote to Table 3A for definition of symbols.

Table 8. (Continued).

D. lodoensis	*D. mohleri*	*D. multiradiatus*	*D. nobilis*	*D. okadai*	*D. saipanensis*	*D. salisburgensis*	*D. sublodoensis*	*D. tanii*	*Discoaster* sp. 1	*Discoaster* sp.	*Discoasteroides kuepperi*	*Discolithina plana*	*D. rimosa*	*Ellipsolithus distichus*	*E. lajollensis*	*E. macellus*	*Ericsonia cava*	*E. robusta*	*E. subperlusa*	*Fasciculithus hayii*	*F. involutus*	*F. pileatus*	*F. tympaniformis*	*F. ulii*	*Fasciculithus* sp.	*Heliolithus conicus*	*H. kleinpellii*	*Markalius astroporus*	*Neochiastozygus concinnus*	*Neococcolithus dubius*	*Pedinocyclus larvalis*	*Prinsius bisulcus*	*P. dimorphosus*	*Reticulofenestra umbilica*	*Rhabdosphaera perlonga*	*Rhabdosphaera* sp.	*Sphenolithus anarrhopus*	*S. heteromorphus*	*S. moriformis*	*Sphenolithus primus*	*S. radians*	*S. spiniger*	*Striatococcolithus pacificanus*	*Thoracosphaera deflandrei*	*T. operculata*	*T. saxea*	*Thoracosphaera* sp.	*Toweius craticulus*	*T. eminens*	*T. magnicrassus*	*T. tovae*	*Toweius* sp.	*Tribrachiatus orthostylus*	*Wiseorhabdus inversus*	*Zygodiscus sigmoides*	*Z. simplex*	*Zygodiscus* sp.	*Zygrhablithus bijugatus*	Formanifer debris
R					C			F		F																										A					F				F				R						R	F				R	
F					C			F		F																										R					R														R	R					
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R					F																															C	R	F			F		F		F											C								
C							F					C																				F											F			C		F									C				F						C
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C											C	F	R																	R												F		C		C					F			C										C	
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A											A		F																		C													C		C					C			C			F					A	
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C											C	R	F		F														R																F		C	F	C				F	F		C			C					A	
C											C	F	F			R																												C		C	F	C					F		R			C					C	
C											F		F		C																														F		C	F												C	F				C	
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		R					C							C			F													F	F														C		C								C							C		C			A	
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		C	C											C			F	C		C										C										C		F											C					C				F	
	C	A	C	F								C		F	R		F	C		C						C																													F	C											
C			C	F					C				F	F		C	C		C								F											C														C										
C			C	C					C	C			F	F		C	C		C	C					C			F											C													C										
C			C	R																					C																																	F											
C			F	F				C		C			F	R		F	C		C	C			C															C		C											C								F				
C																										C																																					C				
C									F	C			F	R		R	C		C				C		C				F												A		C											C								C				
C										C				F		C	C		C	C			C		A								C								A		A												F										C				
C										C				F		C	C		C	F			C		A		R														C		C	C									F		F		F					C				
C										A				C		C	C		C	F			C		A		C	F													C		C	C													F					C				
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																	C	F	C			C	R	F	A			C																	C											C				A	C			
																R	C	F	C		F	C	F	C	A			C	C														C											C				A	C			
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Table 9. Distribution of calcareous nannofossils in the Neogene in Hole 577A.

Age	Nannofossil zone	Core-Section (level or interval in cm)	Sub-bottom depth (m)	Abundance	Preservation	Etching	Overgrowth	Reworking	*Amaurolithus amplificus*	*A. delicatus*	*A. primus*	*A. tricorniculatus*	*Bramletteius serraculoides*	*Calcidiscus leptoporus*	*C. macintyrei*	*Ceratolithus acutus*	*C. cristatus*	*C. rugosus*	*C. telesmus*	*Coccolithus miopelagicus*	*C. pelagicus*	*Coronocyclus nitescens*	*Crenalithus doronicoides*	*C. productellus*	*Cricolithus jonesii*	*Cyclicargolithus* sp.	*Cyclolitella rotula*	*Dictyococcites bisectus*	*D. minutus*
	CN15	1-1,100−101	1.0	A	M	1	1							C			R		R		F			C	C				
		1-2,100−101	2.50	A	M	1	2	R						C							C			C	F				
	CN14b	1-3,100−101	4.00	A	M	1	1							F			R				C		C	C	C				
		1-4,100−101	5.5	A	M	1	1							F			R				C			A					
		1-5,100−101	7.00	A	M	1	1	R						R			F		R		F		C	C					
		1-6,100−101	8.50	A	M	1	1							F			R		R		F		C	A					
Pleistocene		1-2,29−30	9.29	A	M	1	1							F							C		C	C					
		1,CC,4−5	9.40	A	M	1	1							C			R				A		C		F				
		2-1,15	9.55	A	M	1	1	R						C	1		R				C		C						
	CN13/14a	2-2,30−31	11.20	A	M	1	1							C			R				C		A						
		2-3,30−31	12.70	A	M	1	1							C							F		A						
		2-4,30−31	14.20	A	M	1	1							A							R		C						
		2-4,135−136	15.25	A	M	1	1			1				C			R				F		F						
		2-5,100−101	16.40	A	M	1	1							F					R		R		C						
		2-6,95−96	17.35	A	M	1	1							C				R	R		R		C						
		3-1,90−91	19.80	A	M/P	1	1							C	F		RR	R			F		A						
		3-2,90−91	21.30	A	M	1	1							F	C								A		R				
		3-3,60−61	22.50	A	M	1	1							C	F		R	R					A						
		3-4,79−80	24.19	A	M/P	1	1							C	R		RR				C		A						
	CN12d	3-5,50−51	25.40	A	M	1	1	R						C	C		R				C		A						
	CN12c	3,CC,13−14	25.90	A	M	1	1							C	C				R		C		A		R				
	CN12b	4-1,80−81	29.20	A	M	1	1							C	C						F		A						
		4-2,80−81	30.70	A	M	1	1							C	C			R			F		C						
		4-3,80−81	32.20	A	M	1	1							C	C		F				R								
Pliocene late		4-4,80−81	33.70	A	M	1	1							C	C						C								
		4-5,80−81	35.20	A	M	1	1																						
		4-6,80−81	36.70	A	M	1	1																						
		4,CC,17−18	37.87	A	M	1	1							C	A		R	R			C								C
		5-1,30−31	38.20	A	M	1	1			R				C	C						C								C
		5-1,100−101	38.90	A	M	1	1							C	C		R	R			C								C
	CN12a	5-2,100−107	40.40	A	M	1	1			R				C	C						F								C
		5-3,.0−31	41.20	A	M	1	1	R				R		C	C			R			F								C
		5-3,1[illegible]−101	41.90	A	M	1	1							C															C
		5-4,30−41	42.70	A	M	1	1							C	A			R											C
		5-4,100−101	43.40	A	M	1	1							C	C			F											C
		5-5,30−31	44.20	A	M	1	1							C	C			F											C
		5-5,100−101	44.90	A	M	1	1	R		R				C	C			F	R										C
Pliocene early		5-6,30−31	45.70	A	M	1	1			R				C	C			F											C
		5,CC,16−17	46.56	A	M/P	1	1	R		R				C	C		R	R	R								C		C
	CN11	6-1,15−16	47.55	A	M/P	1	1						F	C	C		F	C			F						F		A
		6-2,15−16	49.05	A	P	2	1			F	R	F		C	C			F			C						F		A
		6-3,15−16	50.55	A	M/P	1	1	R		F	R	F		C	C			C			C	R					F		A
	CN10c/d	6-4,15−16	52.05	A	M/P	2	1	R	R	F	R	F		C	F			R			C								A
		6-5,15−16	53.55	A	M/P	1	1	R		F	R	C		C	F	R		R			C								A
		6-6,15−16	55.05	A	M/P	1	1			F	F	F		C	C			R?			C								A
	CN10a/b	6-7,15−16	56.55	A	M/P	1	1			F	F	F		C	F						C								A
		6,CC,30−31	57.15	A	M/P	1	1			F	R			F	F						C								C
Miocene late		7-1,86−87	57.76	A	M/P	1	1			F	F	F		C	F						C	F							C
	CN9b	7-2,86−87	59.26	A	M/P	1	1			F	R			C	F						C								F
		7-3,86−87	60.26	A	M	1	1	F			1			C	F					C	F	F							
	CN5/4	7-4,86−87	62.26	A	M	1	1	R					R	C	F					F	F					F		F	

Note: See footnote to Table 3A for definition of symbols.

Lithraphidites carniolensis Deflandre, 1963
Lithraphidites quadratus Bramlette and Martini, 1964
Manivitella pemmatoidea (Deflandre ex Manivit, 1965) Thierstein, 1971
Microrhabdulus decoratus Deflandre, 1959
Micula murus (Martini, 1961) Bukry, 1973
M. prinsii Perch-Nielsen, 1979
M. staurophora (Gardet, 1955) Stradner, 1963
Parhabdolithus embergeri (Noël, 1959) Stradner, 1963
Prediscosphaera cretacea (Arkhangelsky, 1912) Gartner, 1968
P. grandis Perch-Nielsen, 1979
P. spinosa (Bramlette and Martini, 1964) Gartner, 1968
Quadrum gartneri Prins and Perch-Nielsen, 1977 in Manivit et al.
Q. gothicum (Deflandre, 1959) Prins and Perch-Nielsen, 1977 in Manivit et al.
Q. trifidum (Stradner, 1961) Prins and Perch-Nielsen, 1977 in Manivit et al.
Reinhardtites anthophorus (Deflandre, 1959) Perch-Nielsen, 1968
Rucinolithus hayii Stover, 1966
R. irregularis Thierstein, 1972
R. magnus Bukry, 1975

Table 9. (Continued).

Discoaster asymmetricus	D. aulakos	D. barbadiensis	D. berggreni	D. blackstockae	D. brouweri	D. challengeri	D. deflandrei	D. exilis	D. intercalaris	D. multiradiatus	D. pentaradiatus	D. pseudovariabilis	D. quinqueramus	D. sanmiguelensis	D. surculus	D. tamalis	D. tanii	D. triradiatus	D. variabilis	Discoaster sp. A	Discoaster sp.	Discolithina japonica	Emiliania annula	E. huxleyi	E. ovata	Gephyrocapsa aperta	G. caribbeanica	G. oceanica	Gephyrocapsa sp.	Helicopontosphaera granulata	H. kamptneri	H. wallichii	Pedinocyclus larvalis	Reticulofenestra pseudoumbilica	R. umbilica	Rhabdosphaera clavigera	Scyphosphaera globulata	Sphenolithus abies	S. heteromorphus	Sphenolithus sp.	Striatococcolithus pacificanus	Syracosphaera hystrica	Thoracosphaera sp.	Triquetrorhabdulus rugosus	Umbilicosphaera mirabilis	U. sibogae	Zygrhablithus bijugatus
																					F		C		C	C	A			C																
																				R	F					A	A	C			C													F				
																									C	A	C			F	F				R											C	
																						F		C̄	A	A	A			F						F						F				C	
																			R	R	F		C		A	C			C						R						F	F				
																						A		A	F	F	C	C		C												F	R			F	
																					C	A		A	C	F	C	C		C						C						F	F			F	
																					F	C		C	C	C	C	C		C						C											F	
																				R	F	C		C	C	A	F	C		C						F						F	R			F	
																					C	C		F		C		C		C																		
																					F	C		F		F		F		F														F				
																					F	C		C				C		F																		
																						C		C				C		F						R							F				
																					R	C		C				C		C						R									F		
																					R	C		C				C		F																		
																						C		F				C		F																		
																						F		F				C		R																		
					F̄													F					C		F				C		F						R							R				
					R													R			R	F						C							R										
					C													R		R		C						F		R															
					F						R̄										R		F								F														C	F	
					F						F				F̄			R					C								F						R									F		
					C						F				C	F̄							F						C		F																
	F					C						C				F	R							F						C		R																
	R					C						C				F	C							F						C		F																
																	C	C							F																							
																	F	C							F																							
	C					F						C				F	C							C																							
	C					C						C				F	C							C							R	R															
	C					C						C				C	C							C							R	R															
	C					C						F				C	C		F				R	C							R	R													R	
	C					C						F				A	C		R				R	C							R	R												R					
	C					C						R				C	F							C																							
	C					C						F				F	C							F																							
	C					C						F				A	F							?C						C																	
	F					C	R					F				C	F							?C						C													F					
	F					C	C					C				C					R	R								C				C̄			R					F	F				
	C					C	R					C				C														R	R			C			R										
	C					C	F					C				C														F	F			C										F				
	C					C						C				C	R			F										F				A														
	F					C	F					C	F			C													R				C				F									
	C					C	F				R	C	F			C			C													A	R		R			R							
	C					C	F					C	F			C			C													A													
	R				R	C	F					C				C			C	F										F				C													
	F				R	C	C					C	F			C			C											F				C						C							F
	R				R	F	C					C				F			C											F				C						C			R			
					C	F					C		F̄		F				C															C												
					C	F	R				F		C		R				C										R				C												
					C	C					F		C		F				C										R				A							F			R			
			R		F	F	R	R	R		F		F						C										R			C	C				R									
		F	1						C	C				F			F			R		C													F		R				F		F							

Stephanolithion munitum Perch-Nielsen, 1973
Watznaueria barnesae (Black, 1959) Perch-Nielsen, 1968
Zygodiscus spiralis Bramlette and Martini, 1964
Zygodiscus sp.
Zygolithus tarboulensis Shafik and Stradner, 1971

Cenozoic

Amaurolithus amplificus (Bukry and Percival, 1971) Gartner and Bukry, 1975
A. delicatus Gartner and Bukry, 1975
A. primus (Bukry and Percival, 1971) Gartner and Bukry, 1975
A. tricorniculatus (Gartner, 1967) Gartner and Bukry, 1975
Biantholithus sparsus Bramlette and Martini, 1964
Biscutum romeinii Perch-Nielsen, 1981
Biscutum sp.
Braarudosphaera discula Bramlette and Riedel, 1954
Bramletteius serraculoides Gartner, 1969
Calcidiscus leptoporus (Murray and Blackman, 1898) Loeblich and Tappan, 1978
C. macintyrei (Bukry and Bramlette, 1969) Loeblich and Tappan, 1978
Campylosphaera dela (Bramlette and Sullivan, 1961) Hay and Mohler, 1967

Table 10. Distribution of calcareous nannofossils in the late Maestrichtian-early Paleocene in Hole 577B.

Age	Zone	Core-Section (level in cm)	Sub-bottom depth (m)	Abundance	Preservation	Etching	Overgrowth	Reworking	*Ahmuerella octoradiata*	*Arkhangelskiella cymbiformis*	*Cretarhabdus crenulatus*	*Cretarhabdus surirellus*	*Cretarhabdus* sp.	*Cribrosphaerella ehrenbergii*	*Cylindralithus serratus*	*Cylindralithus* sp.	*Eiffellithus turriseiffeli*	*Glaukolithus diplogrammus*
Paleocene	CP2	1-1,10	104.50	A	M	1	1	F										
		1-1,30	104.70	A	M	1	1	C										
		1-1,70	105.10	A	M	1	1	C										
		1-1,90	105.30	A	M	1	1	C										
	CP1b	1-1,110	105.50	A	M	1		C										
		1-2,15	106.05	A	M	1	1	C										
		1-2,35	106.25	A	M	1	1	C										
		1-2,55	106.45	A	M	1	1	C										
		1-2,75	106.65	A	M	1	1	C										
		1-2,85	106.75	A	M	1	1	C										
		1.2,95	106.85	A	M	2	1	C										
		1-2,115	107.05	A	M	2	1	C										
		1-2,135	107.25	A	MI	1	1	C										
		1-2,145	107.35	A	M	1	1	C										
		1-3,10	107.50	A	M	1	1	C										
		1-3,20	107.60	A	M	1	1	F										
		1-3,30	107.70	A	M	1	1	R										
		1-3,40	107.80	A	M	1	1	R										
		1-3,50	107.90	A	M	1	1											
		1-3,60	108.00	A	M	1	1	R										
	CP1a	1-3,70	108.10	A	M	1	1	F										
		1-3,80	108.20	A	M	1	1	R										
		1-3,90	108.30	A	M	1	1	R										
		1-3,100	108.40	A	M	1	1	R										
		1-3,110	108.50	A	M/P	2	1	R										
		1-3,120	108.60	A	M	2	1	F										
		1-3,130	108.70	A	M	1	1	F										
		1-3,140	108.80	A	M	1	1	F										
		1-3,145	108.85	A	M	1	1	R							R			
		1-4,10	109.00	A	M	1	1	R							R		R	
		1-4,20	109.10	A	M	1	1	F							F			
		1-4,30	109.20	A	M	1	1	R							R		R	
		1-4,35	109.25	A	M	1	1	R							R			
		1-4,38	109.28	A	M/P	1	1	R							R		R	
		1-4,45	109.35	A	M/P	2	1	R						R	R		R	
		1-4,48	109.38	A	M/P	2	1	F				R			R	R		
		1-4,50	109.40	A	M/P	2	1	F						R	F		R	
		1-4,52	109.42	R	P	2	2	C				R			F			
		1-4,56	109.46	F	P	2	2	C				R	R	F	F	R		
		1-4,58	109.48	C	P	2	2	A				F		F	F		R	
		1-4,60	109.50	C	P	2	2	A	R			F	F	F	F	R	F	
		1-4,62	109.52	C	M/P	2	2	A				F		F	F		F	
		1-4,66	109.56	A	M/P	2	1	A	R			F	F	C	F	R	F	
		1-4,68	109.58	A	M/P	2	1	A				C		C	F	C	F	
		1-4,70	109.60	A	M/P	2	1	A	R			C	R	C	C	C	F	
		1-4,72	109.62	A	M/P	2	1	A	R	F		C		C	C	C	C	R
Maestrichtian	*Micula prinsii*	1-4,74	109.64	A	M/P	2	1		R	R	F	C		C	C	C	C	R
		1-4,75	109.65	A	M/P	2	1		R	R		C		A	F	C	C	R
		1-4,76	109.66	A	M/P	2	1			R	R	C		C	C	C	F	
		1-4,78	109.68	A	M/P	2	1		F	F		C		C	C	C	F	
		1-4,80	109.70	A	M/P	2	1		R	R		C		C	F	C	F	
		1-4,85	109.75	A	M	1	1			F	R	C		C	C	C	C	
		1-4,90	109.80	A	M	1	1		F	R		C		C	C	C	F	
		1-4,100	109.90	A	M/P	2	1		F	R	R	C		C	C	C	C	
		1-6,120	110.10	A	M/P	2	1		F			F		C	C	C	F	R
		1-4,140	110.30	A	M/P	2	1			R		C		C	C	C	F	R
		1-5,10	110.50	A	M/P	2	1		R			C		C	C	C	F	
		1-5,60	111.00	A	M/P	2	1		R	R		C		C	C	C	F	F
		1-5,120	111.60	A	M/P	2	1		R	F	R	C	R	C	C	C	F	F
	Micula murus	1-6,10	112.00	A	M/P	2	1		R		F	C		C	C	C	F	
		1-6,60	112.50	A	M	1	1			R		C		C	C	C	R	F
		1-6,130	113.20	A	M/P	2	1		R		R	C	F	C	C	C	R	F
		1-7,10	113.50	A	M	2	1			R		C		C	C	C	F	F
		1-7,40	113.80	A	M	2	1				F	C		C	A	C	F	F
		1-7,CC	113.90	A	M/P	2	2		R	R	F	C	F	C	A	C	F	F

Core-Section (level in cm)	*Lithraphidites carniolensis*	*Lithraphidites quadratus*	*Microrhabdulus decoratus*	*Micula murus*	*Micula staurophora*	*Prediscosphaera cretacea*	*Prediscosphaera grandis*	*Zygodiscus spiralis*	*Zygodiscus* sp.	*Watznaueria barnesae*	*Quadrum gartneri*	*Zygolithus tarboulensis*	*Stephanolithion munitum*	*Micula prinsii*	Foraminifer debris
1-1,10															
1-1,30															
1-1,70															
1-1,90															
1-1,110															
1-2,15															
1-2,35															
1-2,55															
1-2,75															
1-2,85															
1.2,95															
1-2,115															
1-2,135															
1-2,145															
1-3,10															
1-3,20															
1-3,30															
1-3,40															
1-3,50															
1-3,60															
1-3,70															
1-3,80															
1-3,90															
1-3,100															
1-3,110															
1-3,120															
1-3,130															
1-3,140															
1-3,145															
1-4,10				1		R									
1-4,20				R		R				R					
1-4,30				R		R									R
1-4,35				R						R					F
1-4,38				R		R									F
1-4,45			R	R		R				R					F
1-4,48				R		F			F	F			R		F
1-4,50	R					F				F					F
1-4,52				R		F			F	F					F
1-4,56						F			F	C					F
1-4,58	R		R	F		F			F	C			R		C
1-4,60			R	F	F	F			F	C					C
1-4,62				F		F			C	C					C
1-4,66	R		R	F	F	C			C	C					C
1-4,68				F	F	C			C	C					C
1-4,70	F		R	F	F	C	R		C	A			R		C
1-4,72	F	R	F	F	C	A	R	F	C	A		R			C
1-4,74	C	R	F	C	C	A	R	F	C	A			R		C
1-4,75	C	R	F	C	C	A	R	F	C	A		R			F
1-4,76	C		C	C	C	A	R	C	C	A					F
1-4,78	F	R	F	C	C	C	R	F	C	A		F			R
1-4,80	C	R	F	C	C	C	F	F	C	A				R	
1-4,85	C		C	C	A	C	F	C	F	A		F			
1-4,90	C		C	C	C	C	F	C	C	A				R	
1-4,100	F	R	C	C	C	C	F	F	C	A		F		R	
1-6,120	F		C	C	C	C	F		F	A	F	R	R		
1-4,140	C	R	F	C	C	C	C		F	A	F			R	
1-5,10	C		C	C	C	C	C	F	C	A	F				
1-5,60	C		C	C	C	C	F		C	A	F			R	
1-5,120	F	R	R	A	C	C	F	F	C	A	F		1	R	
1-6,10	F	R	F	A	C	C			C	A	F	R			
1-6,60	C		F	C	F	C	F	F	F	A	F				
1-6,130	C	R	F	C	F	C	C		F	C	F				
1-7,10	C		F	C	C	C				C	F				
1-7,40	C	R	F	C	F	C	F		F	C	F				
1-7,CC	C	R	F	C	F	C	F		F	C	F				

Core-Section (level in cm)	*Thoracosphaera* sp.	*Thoracosphaera deflandrei*	*Biscutum romeinii*	*Biscutum* sp.	*Markalius astroporus*	*Cyclagelosphaera reinhardtii*	*Thoracosphaera operculata*	*Thoracosphaera saxea*	*Braarudosphaera bigelowi*	*Cruciplacolithus primus*	*Biantholithus sparsus*	*Placozygus sigmoides*	*Coccolithus pelagicus*	*Cruciplacolithus tenuis*	*Ericsonia subpertusa*	*Ericsonia cava*	*Cruciplacolithus edwardsii*	*Prinsius dimorphosus*	*Neochiastozygus concinnus*	*Chiasmolithus danicus*
1-1,10	F											C	C	C	C	C			F	R
1-1,30	F	R						F		F		A	C	C	C	C	R		F	F
1-1,70	F	R		F				F		C		C	C	C	C	C	R			F
1-1,90	F	R		F				C		C		A	C	C	C	C	F		F	F
1-1,110	C			F			R	C		C		A	C	C	C	C	R			
1-2,15	C	R		C			R	C		C		C	C	C	C	C	F			
1-2,35	C	R		C				C		F		C	C	F	C	C	R			
1-2,55	C	R	F	C			F	C		F		C	C	C	C	C	F			
1-2,75	C	R		C			F	F		F		C	C	C	C	C	F	F		
1-2,85	C	R	F	C			F	F		F		C	C	F	C	C	F	F		
1.2,95	C	R	F	C			F	C		C		C	C	C	C	A	F	F		
1-2,115	C		F	C				F		C		C	F	C	C	A	F			
1-2,135	C	R	F	C		F	F	F		C		C	C	C	C	A				
1-2,145	C	R	F	C			F	C		C		C	C	C	C	C				
1-3,10	F	R	F	C			R	C		C		C	C	C	C					
1-3,20	F	F	F	C				C		C		C	F	F	F					
1-3,30	F	F	F	C			R	C		C		F	C	C	F					
1-3,40	C	F	F	C			F	C		C		C	C	F						
1-3,50	C	F	C	C				C		C		C	F	F						
1-3,60	F	F	C	C			F	F		C		C	F	F						
1-3,70	C	R	C	C	F		F	F		C		R	F							
1-3,80		R	C	C	F		F	F		C			F							
1-3,90	C		C	C	C		C	C		C		F								
1-3,100	C		F	C	C	R	C	C		A		F								
1-3,110	C	F	F	C	F		C	C		A		F								
1-3,120	C	R	C	C	F		F	C		A		R								
1-3,130	C		C	C	F	F	F	C		C		R								
1-3,140	F	R	C	C	F	F		F		C										
1-3,145	F		C	C	F	F	R	F		F										
1-4,10	F	F	C	A	F	F	F	C		C										
1-4,20	C	R	C	A	F	C	F	F		C										
1-4,30	C		C	A	R	C		C		C										
1-4,35	C	R	C	A	F	F	R	C		C										
1-4,38	C		C	A	F	F	F	C		F	R									
1-4,45	A	R	C	A	R	F	C	C		F	R									
1-4,48	A		C	C	R	F		C	R	F	R									
1-4,50	A		C	A	R	R	F	C		F	R									
1-4,52	C		C	A	R	R		A												
1-4,56	C		C	A	R	R	F	C			R									
1-4,58	C	R	C	A	R		F	C	1	R										
1-4,60	C	F	C	A	R	R	R	F												
1-4,62	C	R	F	C	R															
1-4,66	C	R	F	C	R															
1-4,68	C	R	R	C																
1-4,70	F	R	R	R																
1-4,72	F	R	R	R																
1-4,74	F																			
1-4,75	R																			
1-4,76																				
1-4,78																				
1-4,80																				
1-4,85																				
1-4,90																				
1-4,100																				
1-6,120																				
1-4,140																				
1-5,10																				
1-5,60																				
1-5,120																				
1-6,10																				
1-6,60																				
1-6,130																				
1-7,10																				
1-7,40																				
1-7,CC																				

Note: See footnote to Table 3A for definition of symbols.

Ceratolithus acutus Gartner and Bukry, 1975
C. cristatus Kamptner, 1954
C. rugosus Bukry and Bramlette, 1968
C. telesmus Norris, 1975
Chiasmolithus bidens (Bramlette and Sullivan, 1961) Hay and Mohler, 1967
C. californicus (Sullivan, 1964) Hay and Mohler, 1967
C. consuetus (Bramlette and Sullivan, 1961) Hay and Mohler, 1967
C. danicus (Brotzen, 1959) Hay and Mohler, 1967
C. expansus (Bramlette and Sullivan, 1961) Gartner, 1970
C. grandis (Bramlette and Riedel, 1954) Radomski, 1968
Coccolithus crassus Bramlette and Sullivan, 1961
C. eopelagicus (Bramlette and Riedel, 1954) Bramlette and Sullivan, 1961
C. formosus (Kamptner, 1963) Wise, 1973
C. jugatus (Perch-Nielsen, 1967) Proto Decima et al., 1975
C. miopelagicus Bukry, 1971
C. pelagicus (Wallich, 1877) Schiller, 1930
Coronocyclus nitescens (Kamptner, 1963) Bramlette and Wilcoxon, 1967
Crenalithus doronicoides (Black and Barnes, 1961) Roth, 1973
C. productellus Bukry, 1975
Crepidolithus sp.

Cricolithus jonesii Cohen, 1965
Cruciplacolithus edwardsii Romein, 1979
C. primus Perch-Nielsen, 1977
C. subrotundus (Perch-Nielsen, 1969) Perch-Nielsen, 1972
C. tenuis (Stradner, 1961) Hay and Mohler, 1967
Cyclagelosphaera reinhardtii (Perch-Nielsen, 1968) Romein, 1977
Cyclicargolithus floridanus (Roth and Hay, 1967) Bukry, 1971
Cyclicargolithus sp.
Cyclococcolithus gammation (Bramlette and Sullivan, 1961) Sullivan, 1964
Cyclolithella kingi Roth, 1970
C. plactilis Bukry and Percival, 1971
C. rotula (Kamptner, 1956) Haq and Berggren, 1978
Dictyococcites bisecta (Hay, Mohler, Wade, 1966) Bukry and Percival, 1971
D. minutus (Haq, 1973) Haq, 1976
D. scrippsae Bukry and Percival, 1971
D. asymmetricus Gartner, 1969
Discoaster aulakos Gartner, 1967
D. barbadiensis Tan Sin Hok, 1927
D. berggrenii Bukry, 1971
D. blackstockae Bukry, 1973
D. brouweri Tan Sin Hok, 1927
D. challengeri Bramlette and Riedel, 1954
D. deflandrei Bramlette and Riedel, 1954
D. diastypus Bramlette and Sullivan, 1961
D. exilis Martini and Bramlette, 1963
D. germanicus Martini, 1958
D. intercalaris Bukry, 1971
D. lenticularis Bramlette and Sullivan, 1961
D. lodoensis Bramlette and Riedel, 1954
D. mohleri Bukry and Percival, 1971
D. multiradiatus Bramlette and Riedel, 1954
D. nobilis Martini, 1961
D. okadai Bukry, 1981
D. pentaradiatus Ten Sin Hok, 1927
D. pseudovariabilis Martini and Worsley, 1971
D. quinqueramus Gartner, 1969
D. saipanensis Bramlette and Riedel, 1954
D. salisburgensis Stradner, 1961
D. sanmiguelensis Bukry, 1981
D. sublodoensis Bramlette and Sullivan, 1961
D. surculus Martini and Bramlette, 1963
D. tamalis Kamptner, 1967
D. tanii Bramlette and Riedel, 1954
D. triradiatus Ton Sin Hok, 1927
D. variabilis Martini and Bramlette, 1963
Discoaster sp.A
Discoaster sp.
Discoasteroides kuepperi (Stradner, 1959) Bramlette and Sullivan, 1961
Discolithina japonica Takayama, 1967
D. plana (Bramlette and Sullivan, 1961) Levin, 1965
D. rimosa (Bramlette and Sullivan, 1961) Sullivan, 1964
Ellipsolithus distichus (Bramlette and Sullivan, 1961) Sullivan, 1964
E. lajollensis Bukry and Percival, 1971
E. macellus (Bramlette and Sullivan, 1961) Sullivan, 1964
Emiliania annula (Cohen, 1964) Bukry, 1971
E. huxleyi (Lohmann, 1902) Hay and Mohler, 1967
E. ovata Bukry, 1973
Ericsonia cava (Hay and Mohler, 1967) Perch-Nielsen, 1969
E. robusta (Bramlette and Sullivan, 1961) Perch-Nielsen, 1977
E. subpertusa Hay and Mohler, 1967
Fasciculithus hayii Bukry, 1971
F. involutus Bramlette and Sullivan, 1961
F. pileatus Bukry, 1973
F. tympaniformis Hay and Mohler, 1967
F. ulii Perch-Nielsen, 1971
Fasciculithus sp.
Gephyrocapsa aperta Kamptner, 1963
G. caribbeanica Boudreaux and Hay, 1967
G. oceanica Kamptner, 1943
Gephyrocapsa sp.
Helicopontosphaera granulata Bukry and Percival, 1971
H. kamptneri Hay and Mohler, 1967
H. wallichii (Lohmann, 1902) Okada and McIntyre, 1976
Heliolithus conicus Perch-Nielsen, 1977
H. kleinpellii Sullivan, 1964
Isthmolithus recurvus Deflandre in Deflandre and Fert, 1954
Markalius astroporus (Stradner, 1963) Hay and Mohler, 1967
Neochiastozygus concinnus (Martini, 1961) Perch-Nielsen, 1971
Neococcolithus dubius (Deflandre, 1954) Black, 1967
Neocrepidolithus sp.
Pedinocyclus larvalis (Bukry and Bramlette, 1969) Loeblich and Tappan, 1978
Prinsius bisulcus (Stradner, 1963) Hay and Mohler, 1967
P. dimorphosus (Perch-Nielsen, 1969) Perch-Nielsen, 1977
Reticulofenestra pseudoumbilica (Gartner, 1967) Gartner, 1969
R. samodurovii (Hay, Mohler, and Wade, 1966) Roth, 1960
R. umbilica (Levin, 1965) Martini and Ritzkoski, 1968
Reticulofenestra sp.
Rhabdosphaera clavigera Murray and Blackman, 1898
R. perlonga (Deflandre, 1952) Bramlette and Sullivan, 1961
Rhabdosphaera sp.
Scyphosphaera globulata Bukry and Percival, 1971
Sphenolithus abies Deflandre, 1954
S. anarrhopus Bukry and Bramlette, 1969
S. editus Perch-Nielsen, 1978 in Perch-Nielsen et al.
S. heteromorphus Deflandre, 1953
S. moriformis (Brönnimann and Stradner, 1960) Bramlette and Wilcoxon, 1967
S. primus Perch-Nielsen, 1977
S. radians Deflandre, 1952
S. spiniger Bukry, 1971
Sphenolithus sp.
Striatococcolithus pacificanus Bukry, 1971
Syracosphaera hystrica Kamptner, 1941
Thoracosphaera deflandrei Kamptner, 1953
T. operculata Bramlette and Martini, 1964
T. saxea Stradner, 1961
Thoracosphaera sp.
Toweius craticulus Hay and Mohler, 1967
T. eminens (Bramlette and Sullivan, 1971) Romein, 1979
T. magnicrassus (Bukry, 1971) Romein, 1979
T. tovae Perch-Nielsen, 1971
Toweius sp.
Tribrachiatus contortus (Stradner, 1958) Bukry, 1972
T. orthostylus Shamrai, 1963
Triquetrorhabdulus rugosus Bramlette and Wilcoxon, 1967
Umbilicosphaera mirabilis Lohmann, 1902
U. sibogae (Weber von Bosse, 1901) Gaarder, 1970
Wiseorhabdus inversus (Bukry and Bramlette, 1969; emend. Wise and Constans, 1976) Bukry, 1981
Zygodiscus sigmoides Bramlette and Sullivan, 1961
Z. simplex (Bramlette and Sullivan, 1961) Hay and Mohler, 1967
Zygodiscus spp.
Zygrhablithus bijugatus (Deflandre, 1954) Deflandre, 1959

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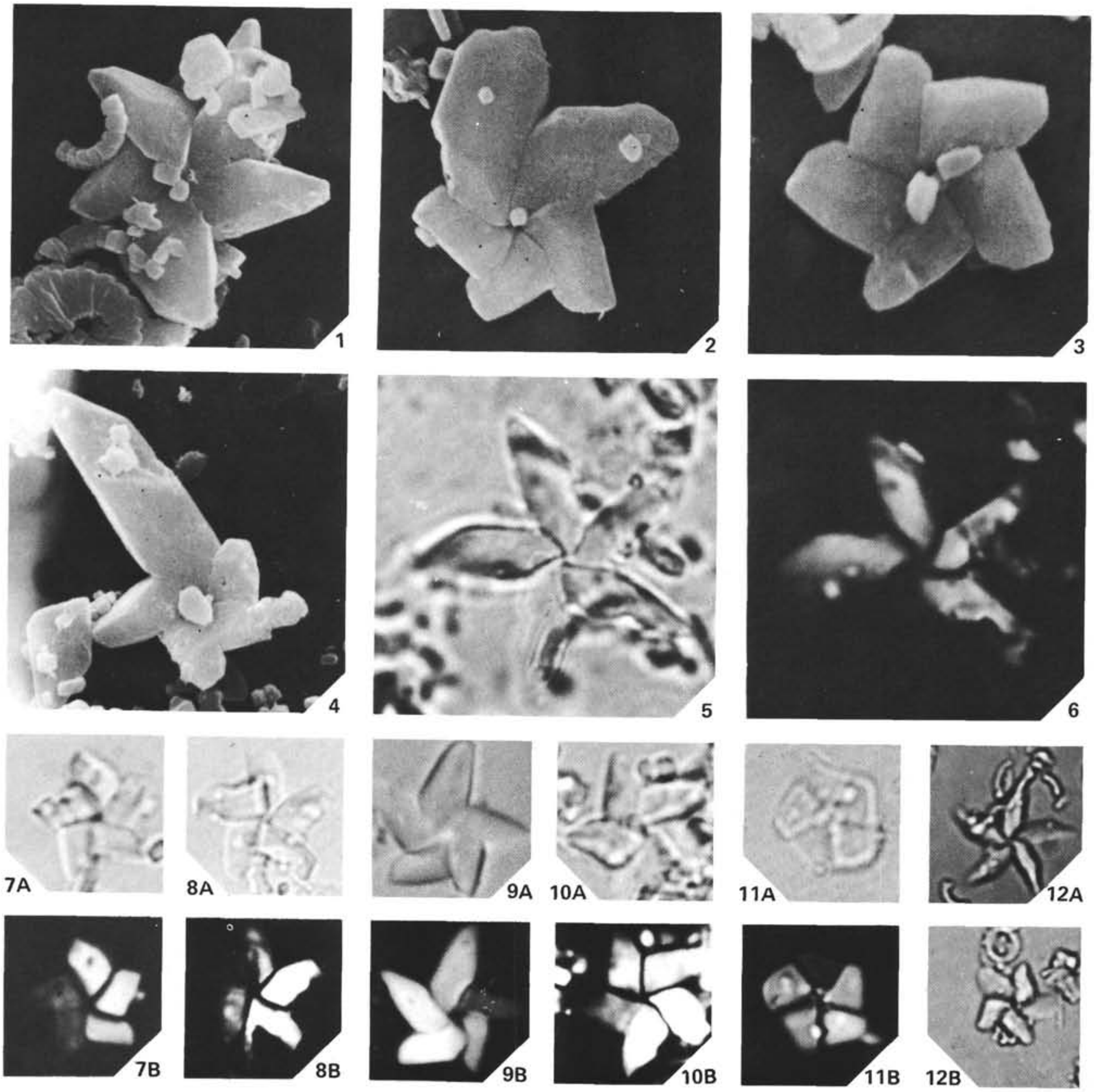

Plate 1. (The abbreviations XN and OL denote cross-polarized and transmitted light.) **1, 3.** *Braarudosphaera* sp. 1, Sample 576B-8-5, 120–121 cm, electron micrograph, ×7000. **2.** *Braarudosphaera* sp. 1, Sample 576B-8-5, 120–121 cm, electron micrograph, ×5000. **4.** *Braarudosphaera* sp. 1, Sample 576B-8-5, 120–121 cm, electron micrograph, ×3500. **5, 6, 7.** *Braarudosphaera* sp. 1, Sample 576B-9,CC (5, 7A) OL, (6, 7B) XN, ×2800. **8.** *Braarudosphaera* sp. 1, Sample 576B-8-4, 95 cm, (8A) OL, (8B) XN ×2260. **9.** *Braarudosphaera* sp. 1, Sample 576B-8-6, 7 cm, (9A) OL, (9B) XN, ×2800. **10.** *Braarudosphaera* sp. 1, Sample 576B-8-7, 35 cm, (10A) OL, (10B) XN, ×2800. **11.** *Braarudosphaera imbricata* Bukry, Sample 576-8,CC (11A) OL, (11B) XN, ×2800. **12.** *Braarudosphaera* sp. 1, Sample 576-8,CC (12A, B) OL, ×2800.

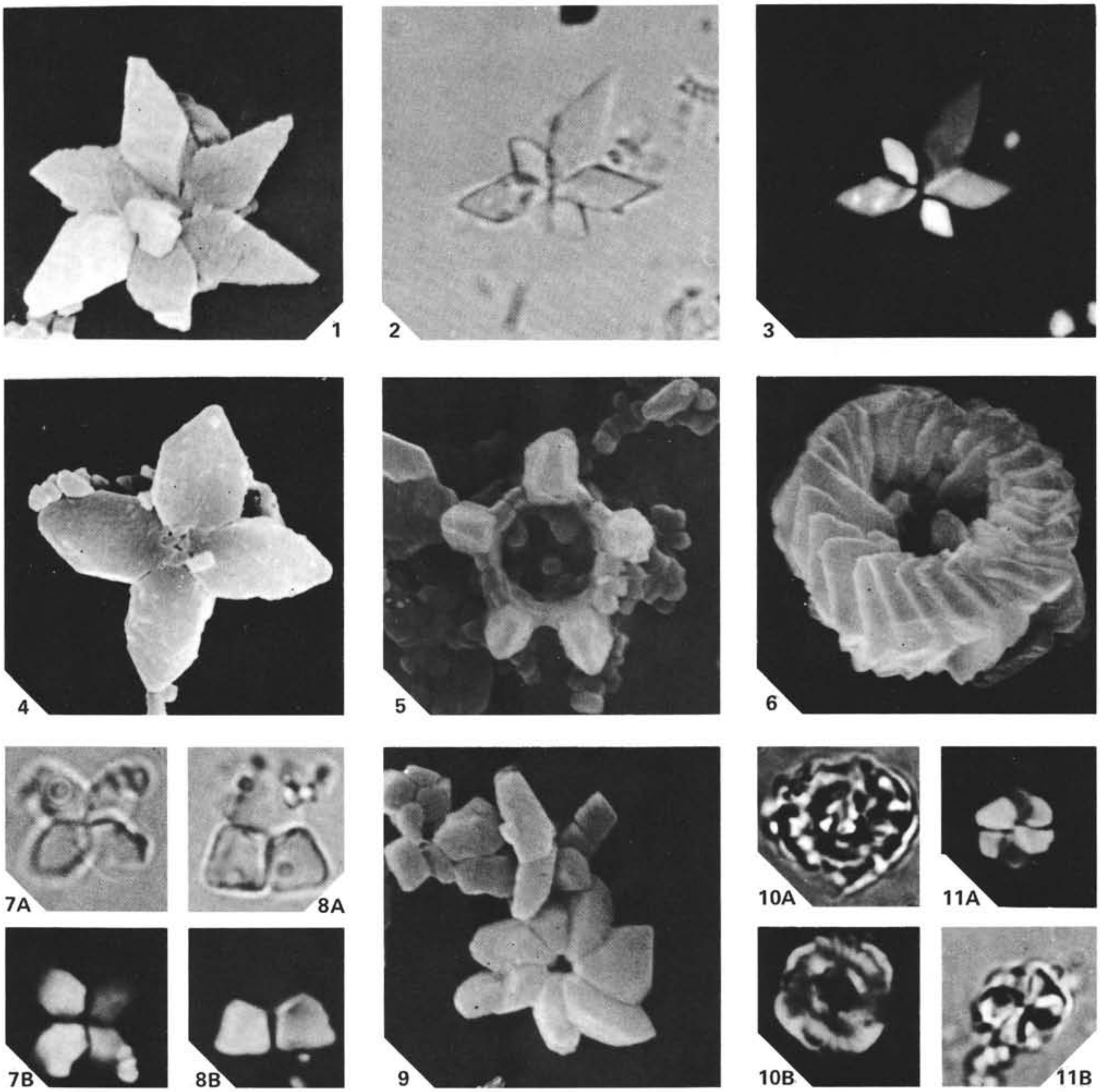

Plate 2. (The abbreviations XN and OL denote cross-polarized and transmitted light. All light microscope pictures are ×2800.) **1, 2, 3.** *Rucinolithus magnus* (Bukry), (1) Sample 576-8-6, 13–14 cm, ×8400, (2) OL, Sample 576-8-7, 35 cm, (3) XN. **4, 7.** *Quadrum gothicum* (Deflandre), Sample 576-8,CC, 16–17 cm, ×4200, (7A) Sample 576-8-7, 35 cm, OL, (7B) XN. **5.** *Stephanolithion munitum* (Perch-Nielsen), Sample 577A-12-4, 57–58 cm, ×7000. **6, 10.** *Cylindralithus* sp., Sample 577A-12-6, 146–147 cm, ×5600, (10A) OL, (10B) XN. **8.** *Quadrum trifidum* (Stradner), Sample 576B-9,CC, (8A) OL, (8B) XN. **9.** *Rucinolithus* sp. Sample 576B-8-5, 120–121 cm, ×7000. **11.** *Rucinolithus hayii* Stover, Sample 576-8,CC, 16–17 cm, (11A) OL, (11B) XN.

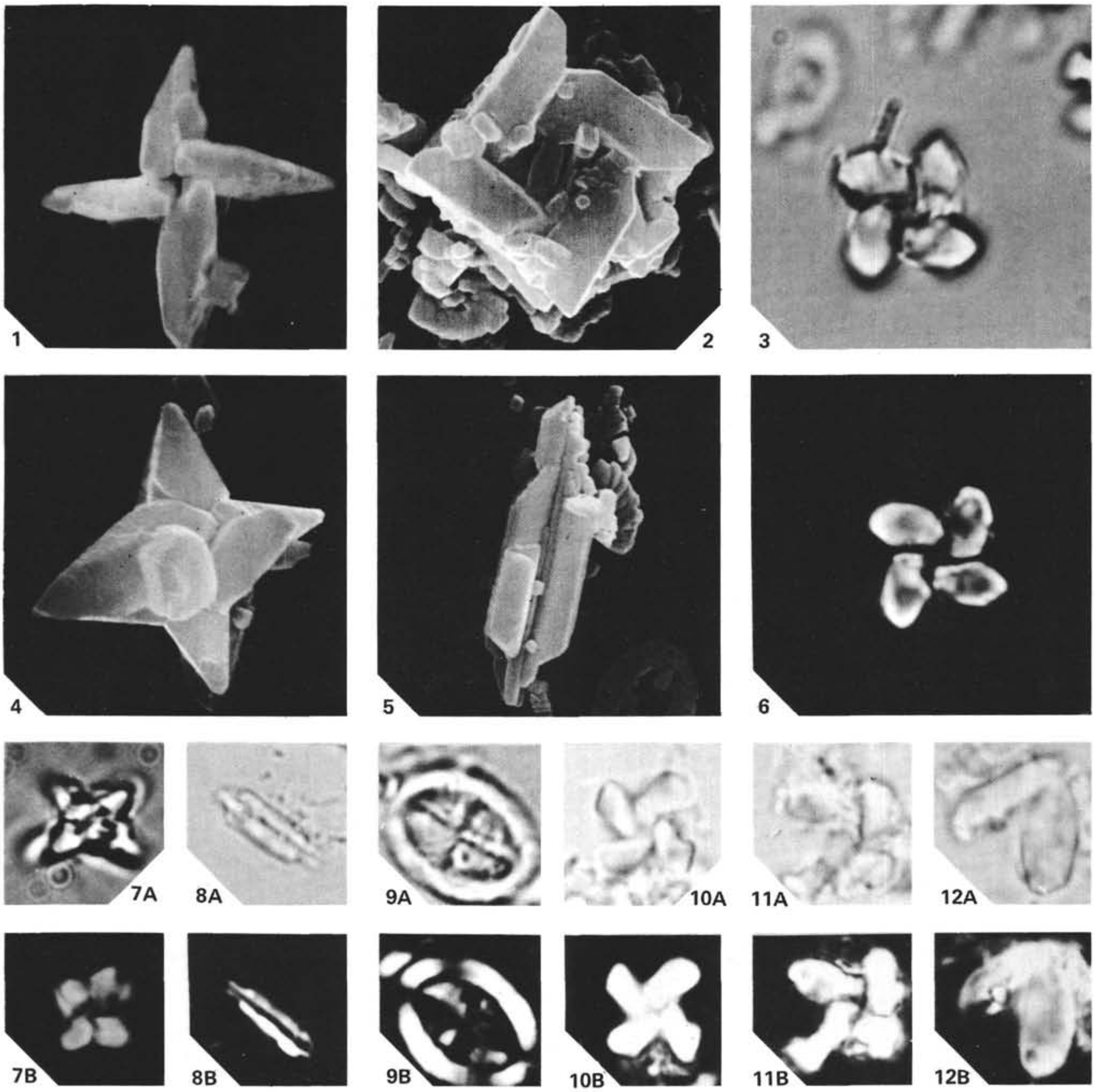

Plate 3. (The abbreviations XN and OL denote cross-polarized and transmitted light. Magnification for light microscope photos is ×2800.) **1.** Distal end of the central process of *Prediscosphaera cretacea*, Sample 577A-12-6, 146–147 cm, ×7000. **2.** *Micula murus* Martini, Sample 577-12-5, 136–137 cm, ×4200. **3, 6.** *Micula murus* Martini, Sample 577-12-5, 136–137 cm, (3) OL, (6) XN. **4, 7.** *Micula staurophora* (Gardet), Sample 577A-12-6, 146–147, (4) ×7000, (7A) OL, same specimen as Fig. 4, (7B) XN. **5, 8.** *Lithraphidites quadratus* (Bramlette and Martini), (5) Sample 577A-12-3, 106–107 cm, ×5000, (8A) Sample 577-12-5, 120–121 cm, OL, (8B) XN. **10.** *Micula murus* (Martini), Sample 577-12-5, 120–121 cm, (10A) OL, (10B) XN. **9.** *Arkhangelskiella cymbiformis* Veskina, Sample 577-12-5, 136–137 cm, (9A) OL, (9B) XL. **11, 12.** *Micula prinsii* Perch-Nielsen, (11A) OL, (11B) XN, Sample 577B-1-4, 68 cm, (12A) OL, (12B) XN, Sample 577-12-5, 120–121 cm.

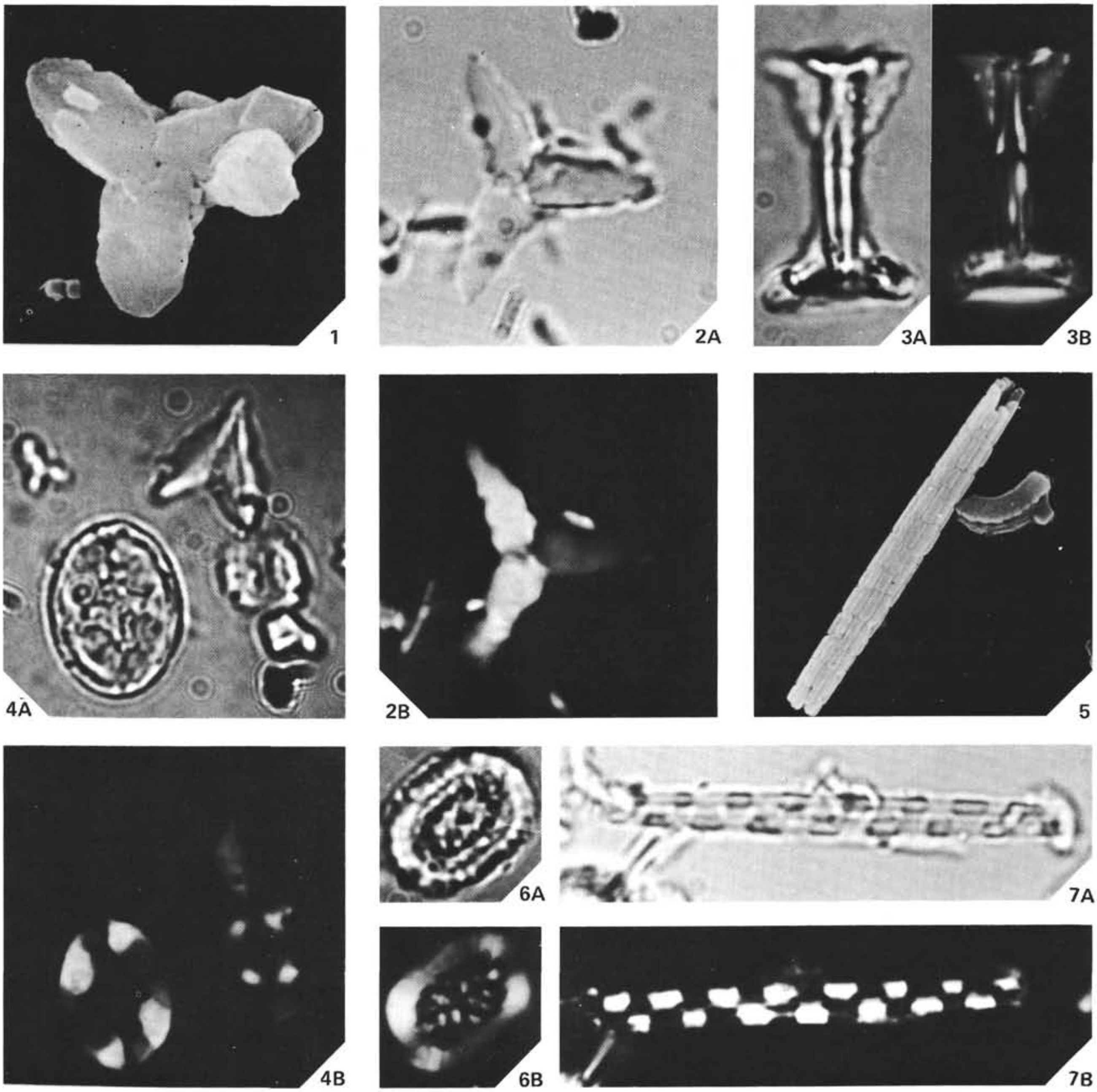

Plate 4. (The abbreviations XN and OL denote cross-polarized and transmitted light. All light microscope pictures are ×2800.) **1, 2A, B.** *Quadrum trifidum* (Stradner), (1) Sample 576-8,CC (16–17 cm), ×5600, (2) Sample 576-8-7, 35 cm, (2A) OL, (2B) XN. **3A, B.** *Prediscosphaera cretacea* (Arkhangelsky), Sample 576-8-6, 13–14 cm, (3A) OL, (3B) XN. **4A, B.** *Ceratolithoides aculeus* (Stradner) and *Eiffellithus eximius* (Stover), Sample 576-8,CC (16–17 cm), (4A) OL, (4B) XN. **6A, B.** *Cretarhabdus surrirellus* (Deflandre), Sample 577A-12-5, 136–137 cm, (6A) OL, (6B) XN. **5, 7A, B.** *Microrhabdulus decoratus* (Deflandre), (5) Sample 577A-12-6, 146–147 cm, ×2800, (7) Sample 576-8-6, 13–14 cm, (7A) OL, (7B) XN.

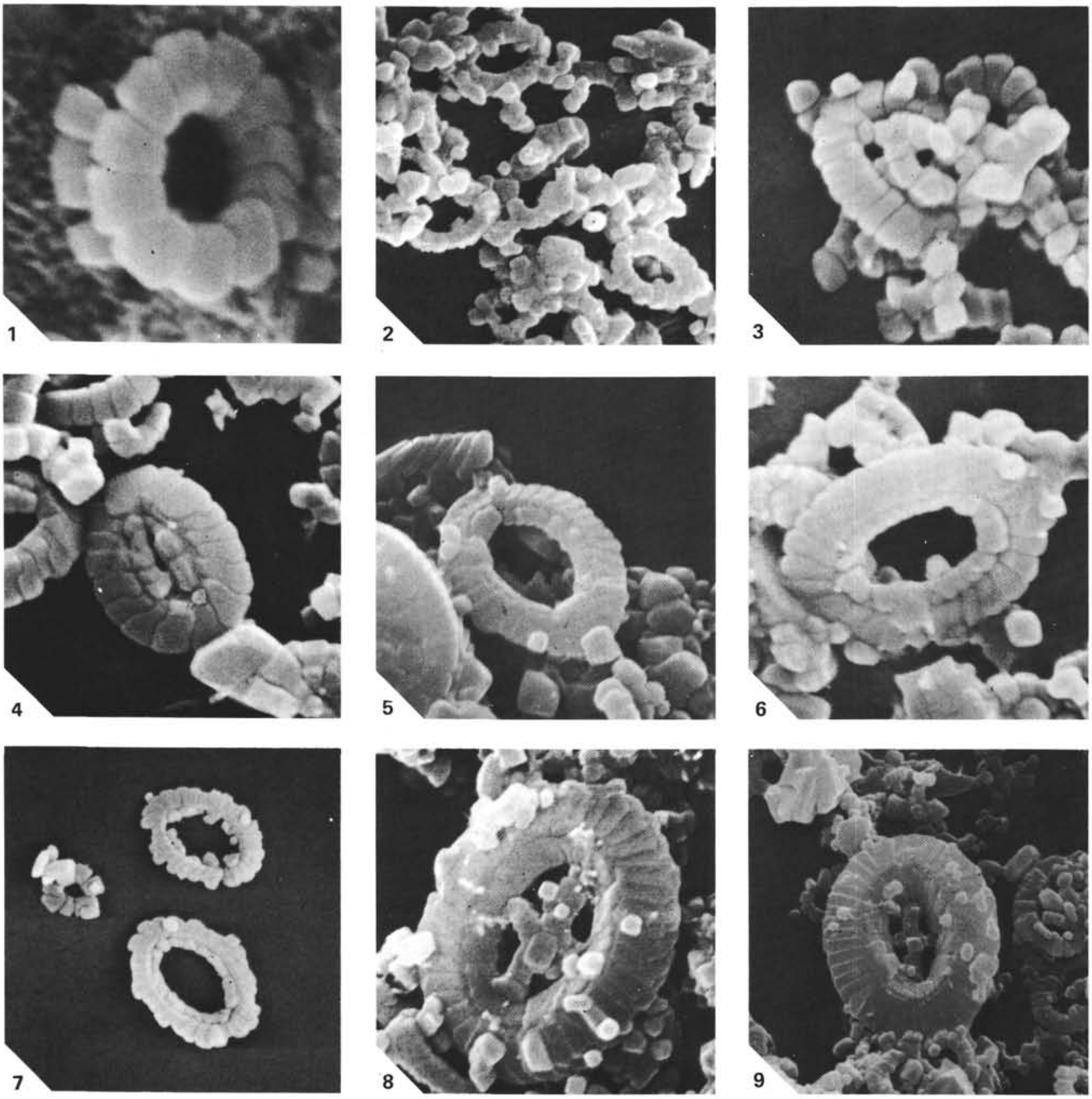

Plate 5. (All electron microscope photographs.) **1.** *Biscutum* sp. Sample 577-12-5, 120–121 cm, ×20,000. **2.** *Biscutum* sp. Sample 577-12-5, 111–112 cm, ×5600. **3.** *Biscutum* sp. Sample 577A-12-4, 57–58 cm, ×14,000. **4.** *Biscutum parvulum* Romein, Sample 577A-12-4, 7–8 cm, ×11,200. **5, 6.** *Biscutum romeinii* Perch-Nielsen, Sample 577A-12-4, 56–57 cm, (5) ×700, (6) ×11,200. **7, 8, 9.** *Cruciplacolithus primus* Perch-Nielsen, (7) Sample 577A-12-4, 7–8 cm, (8) ×7000, (9) ×4200, Sample 577-12-4, 56–57 cm.

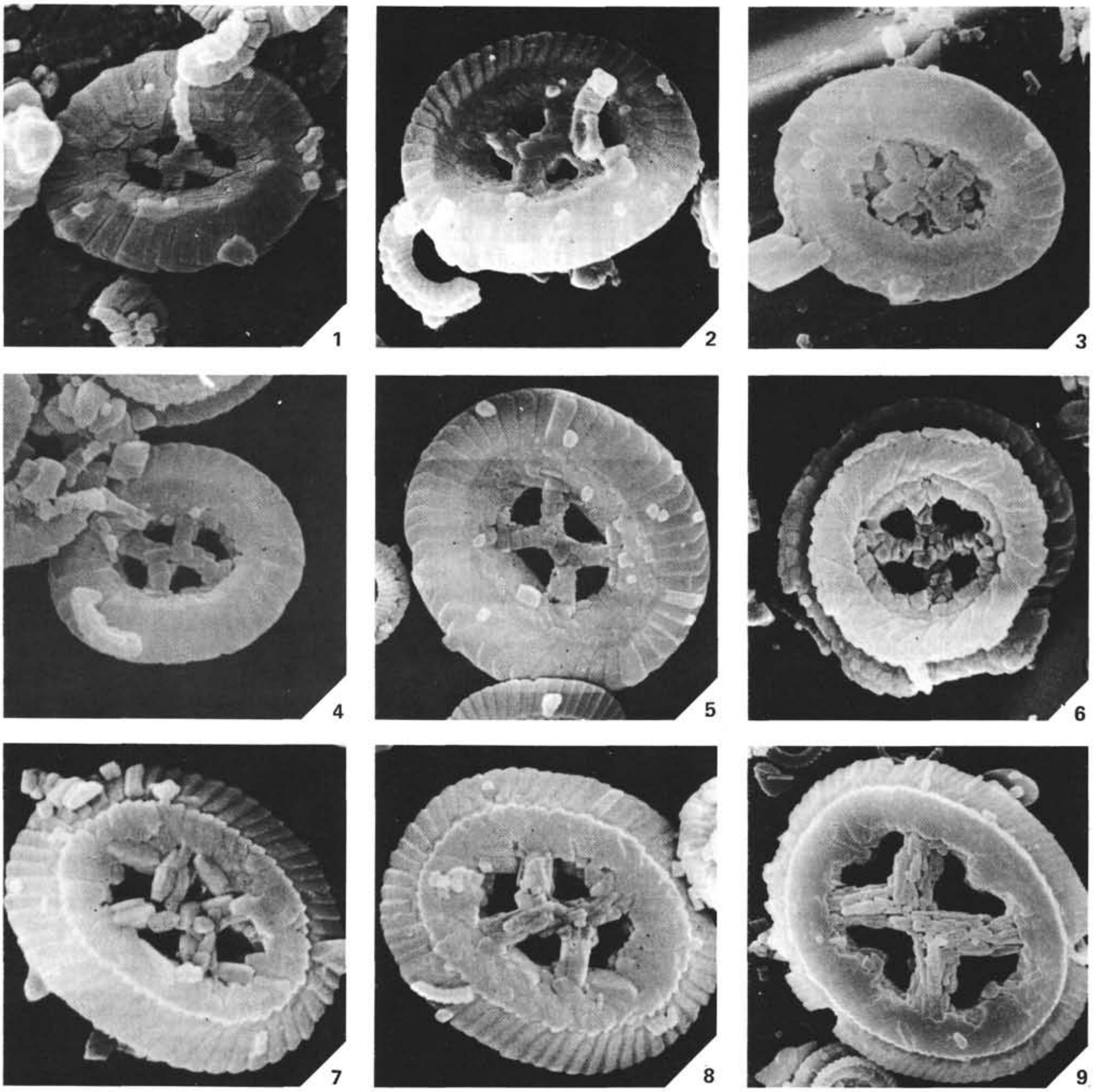

Plate 6. (All electron microscope photographs.) **1.** *Cruciplacolithus edwardsii* Romein, Sample 577A-12-2, 66–67 cm, ×4200. **2.** *Chiasmolithus danicus* (Brotzen), Sample 577-11-2, 18–19 cm, ×4200. **3, 4.** *Chiasmolithus consuetus* (Bramlette and Sullivan), Sample 577A-9,CC (10–11 cm), ×4200. **5.** *Chiasmolithus californicus* (Sullivan), Sample 577-10-4, 140–141 cm, ×4200. **6.** *Cruciplacolithus subrotundus* (Perch-Nielsen), Sample 577-10-1, 110–111 cm, ×4200. **7.** An intermediate form between *Chiasmolithus danicus* and *Chiasmolithus bidens* (Bramlette and Sullivan), Sample 577-10-1, 110–111 cm, ×7000. **8.** *Chiasmolithus bidens,* Sample 577-10-1, 110–111 cm, ×4200. **9.** *Chiasmolithus grandis* (Bramlette and Riedel), Sample 577A-7-6, 86–87 cm, ×2100.

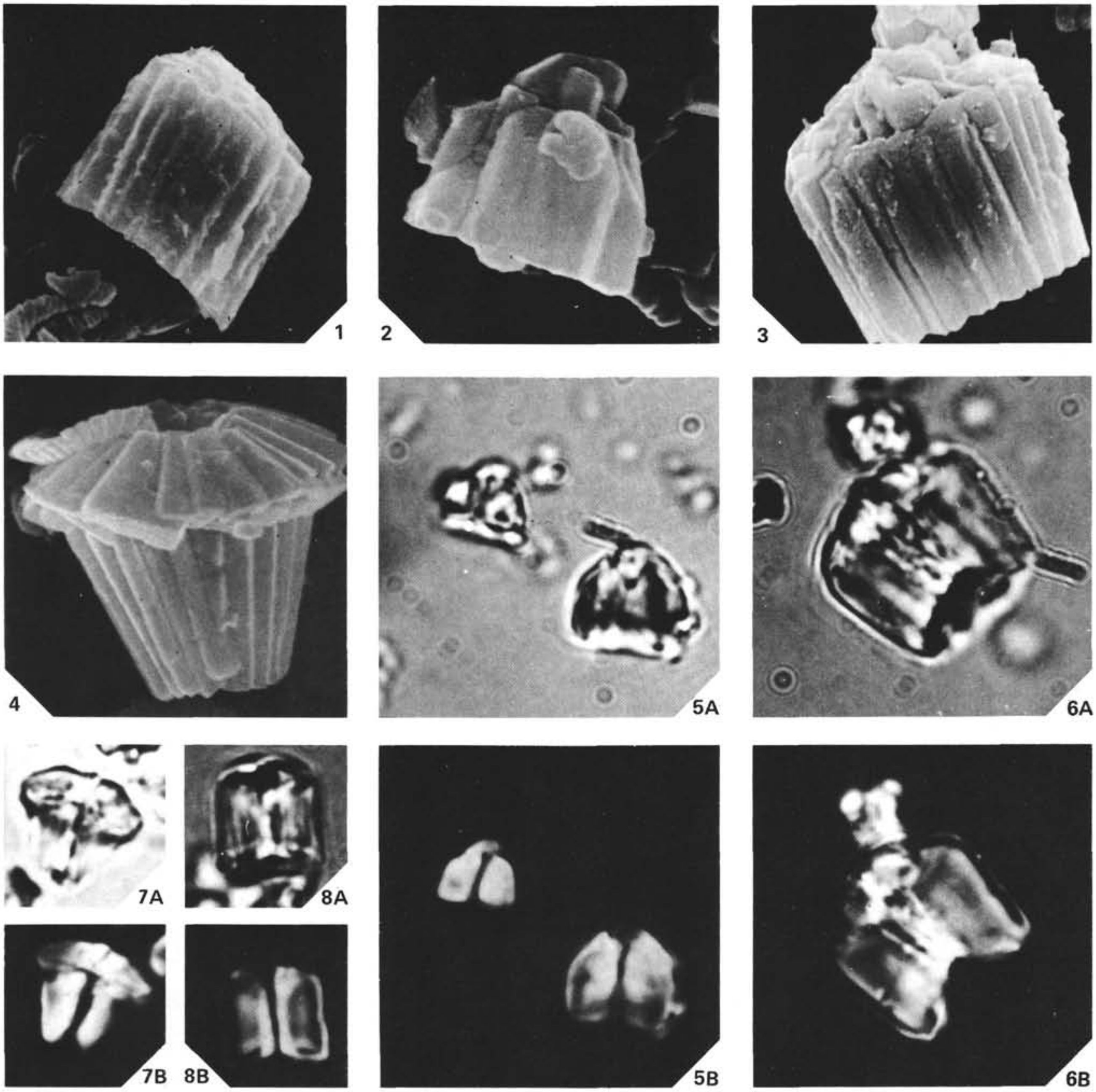

Plate 7. (The abbreviations XN and OL denote cross-polarized and transmitted light. All light microscope photographs are ×2800.) **1, 8.** *Fasciculithus tympaniformis* (Hay and Mohler), Sample 577A-10-6, 39–40 cm, (1) ×5600, (8) same specimen as Fig. 1, (8A) OL, (8B) XN. **2, 5.** *Fasciculithus clinatus* (Bukry) Sample 577-11-2, 18–19 cm, (2) ×9800, (5) same specimen as Fig. 2, (5A) OL, (5B) XN. **3, 6.** *Fasciculithus ulii* (Perch-Nielsen), Sample 577A-10-6, 39–40 cm, (3) ×4200, (6) same specimen as Fig. 3, (6A) OL, (6B) XN. **4, 7.** *Fasciculithus pileatus* (Bukry), Sample 577-10-1, 110–111 cm, (4) ×7000, (7) same specimen as Fig. 4, (7A) OL, (7B) XN.

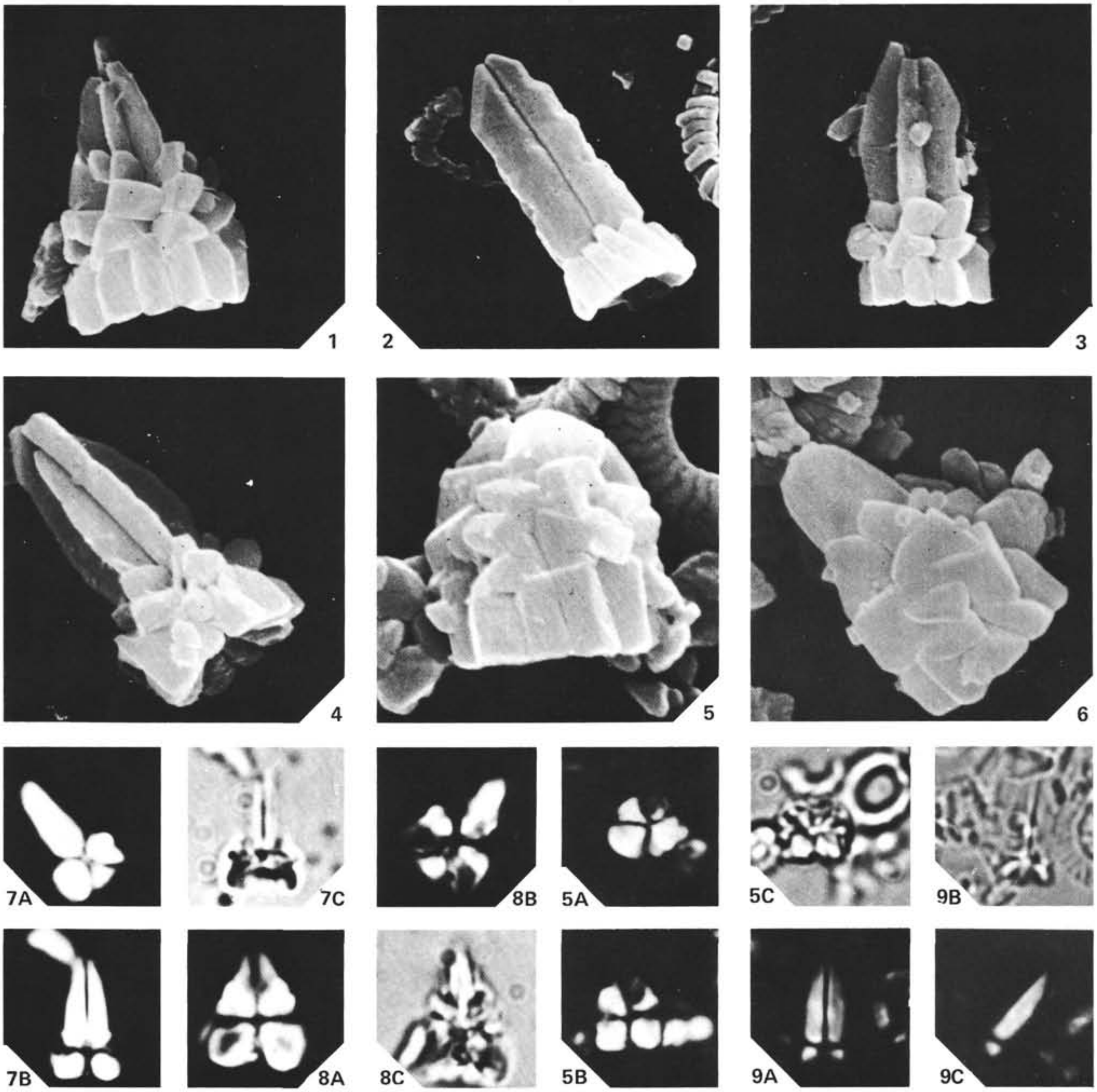

Plate 8. (The abbreviations XN and OL denote cross-polarized and transmitted light.) **1, 8.** *Sphenolithus editus* Perch-Nielsen, Sample 577A-8-6, 15–16 cm, (1) ×5600, (8A) XN, (8B) XN (45°), (8C) OL, same specimen as Fig. 1. **2.** *Sphenolithus* cf. *obtusus* (Bukry), Sample 577A-7-6, 86–87 cm, ×8400. **3, 4, 7.** *Sphenolithus pseudoradians* (Bramlette and Wilcoxon), Sample 577A-7-6, 86–87 cm, (3, 4) ×8400, (7) same specimen as Fig. 4, (7A) OL, (7B) XN. **5, 8.** *Sphenolithus primus* Perch-Nielsen, Sample 577-11-2, 18–19 cm, (8) same specimen as Fig. 5, (8A) XN, (8B) XN (45°), (8C) OL. **6.** *Sphenolithus* cf. *anarrhopus* (Bukry and Bramlette), Sample 577-10-4, 140–141 cm, ×7000. **9.** *Sphenolithus obtusus* (Bukry), Sample 577A-7-6, 86–87 cm, (9A) XN, (9B) XN (45°), (9C) OL.

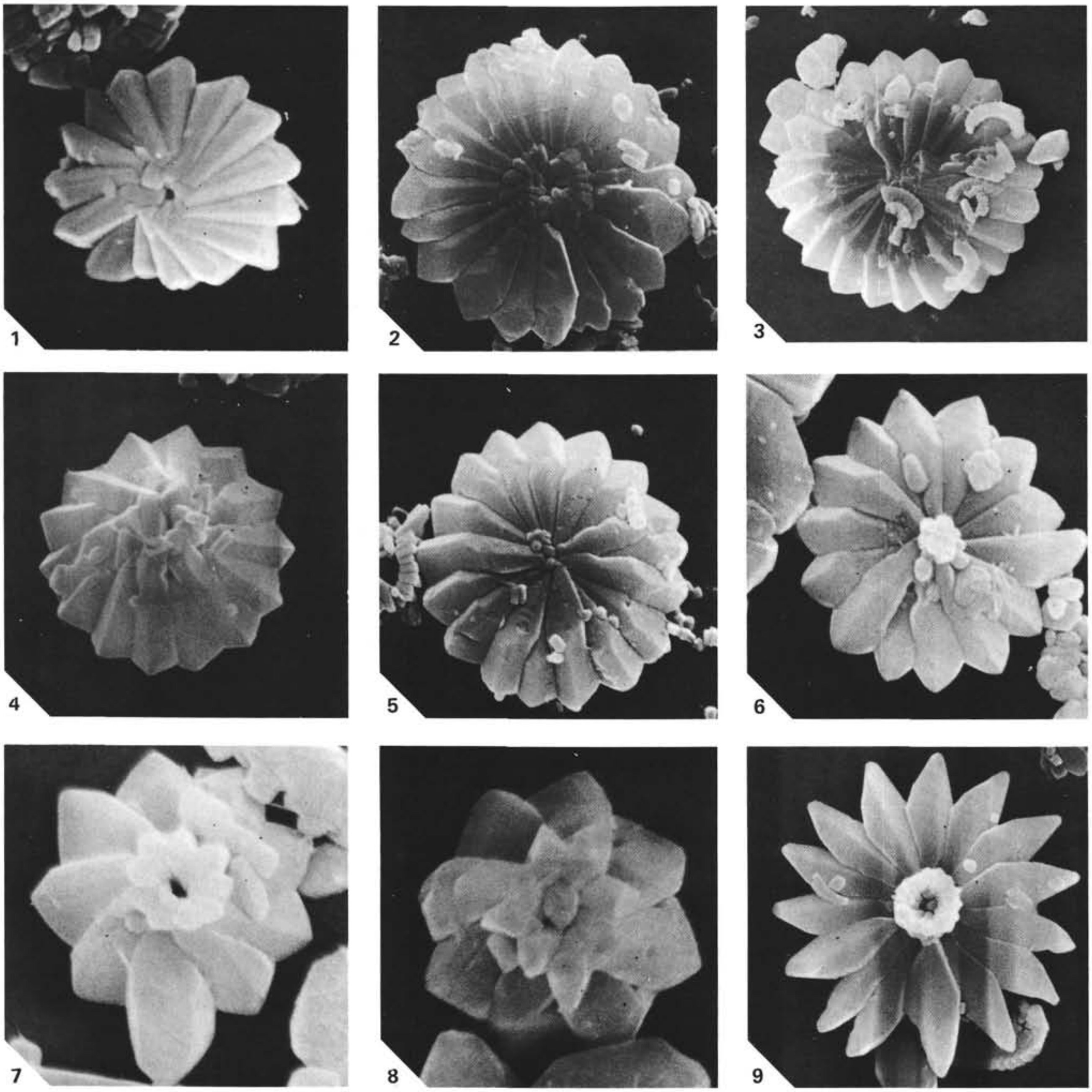

Plate 9. (The abbreviations XN and OL denote cross-polarized and transmitted light.) **1, 4.** *Discoaster mohleri* Bukry and Percival, (1) Sample 577A-9,CC (10–11 cm), ×7000, (4) Sample 577-9-5, 117–118 cm, ×4200. **2, 3, 5.** *Discoaster multiradiatus* Bramlette and Riedel, (2, 5) Sample 577A-9,CC, 10–11 cm, ×4200, (3) Sample 577-9-5, 117–118 cm, ×2100. **6.** *Discoaster barbadiensis* Tan Sin Hok, Sample 577-8-3, 120–121 cm, ×4200. **7, 8.** *Discoasteroides kuepperi* (Stradner), Sample 577-8-3, 120–121 cm, ×7000. **9.** *Discoaster diastypus* Bramlette and Sullivan, Sample 577A-8,CC, ×3500.

Plate 10. (The abbreviations XN and OL denote cross-polarized and transmitted light.) **1.** *Discoaster nobilis* Martini, Sample 577-10-3, 120–121 cm, ×3000. **2.** *Discoaster* sp. 1, Sample 577-10-3, 120–121 cm, ×3000. **3, 4, 5.** *Discoaster okadai* Bukry, (3) Sample 577-10-3, 120–121 cm, ×3000, (4) Sample 577A-10-2, 39–40 cm, ×1960. **6, 7, 8.** *Discoaster lodoensis* Bramlette and Riedel, Sample 577-8-3, 120–121 cm, (6) ×3500, (7, 8) ×2800. **9.** *Discoaster sublodoensis* Bramlette and Sullivan, Sample 577-8-3, 120–121 cm, ×3500.

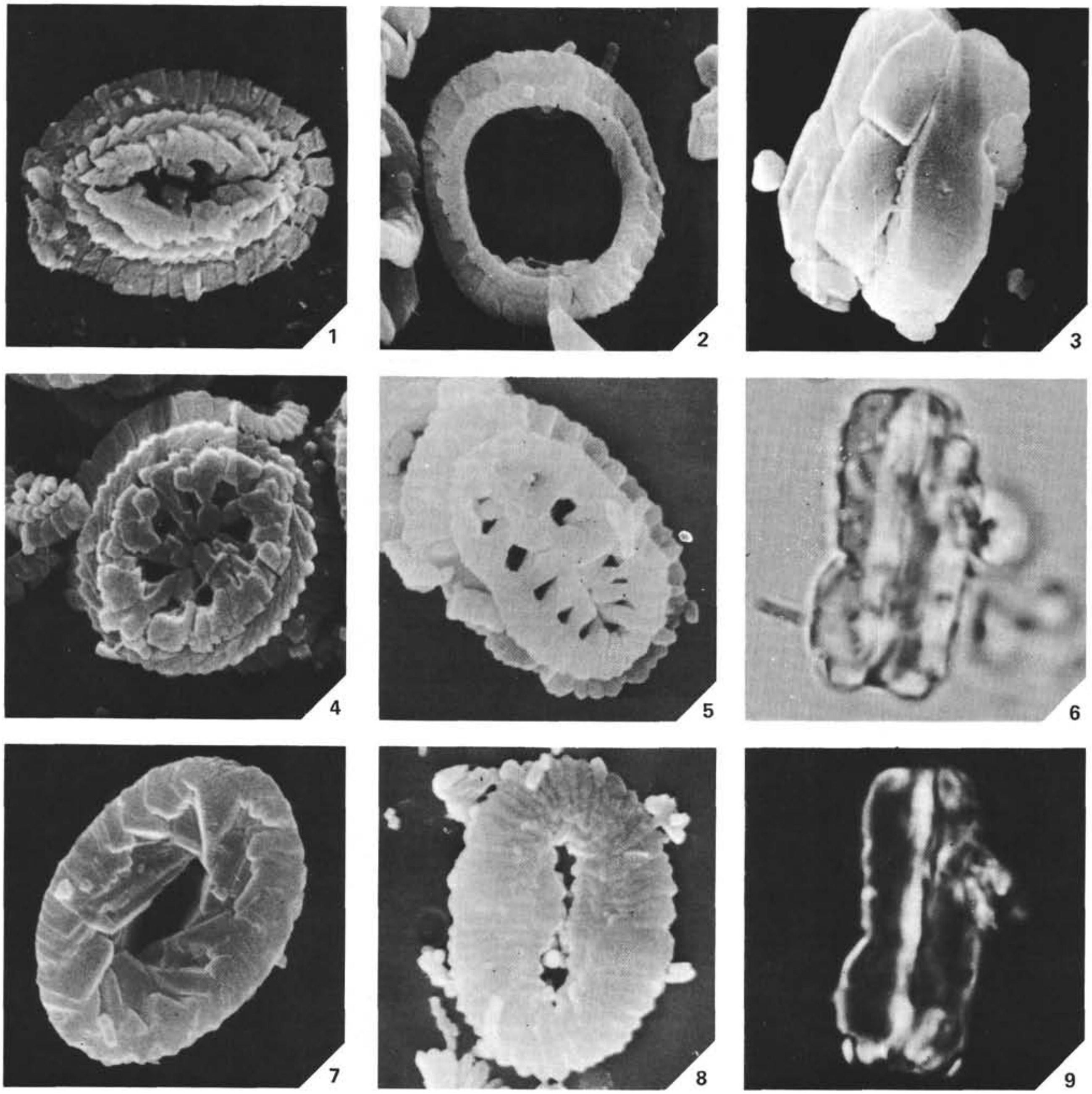

Plate 11. (The abbreviations XN and OL denote cross-polarized and transmitted light.) **1.** *Prinsius bisulcus* (Stradner), Sample 577A-10-6, 39–40 cm, ×4900. **2.** *Campylosphaera dela* (Bramlette and Sullivan) Hay and Mohler, Sample 577-8-3, 120–121 cm, ×4200. **3, 6, 9.** *Zygrhablithus* cf. *bijugatus* (Deflandre) Deflandre, (3) Sample 577A-8,CC, ×5600, (6) OL, (9) XN, Sample 577A-9-1, 30–31 cm, overcalcified specimen. **4.** *Toweius tovae* Perch-Nielsen, Sample 577-10-1, 110–111 cm, ×5600. **5.** *Ellipsolithus distichus* (Bramlette and Sullivan), Sample 577-10-3, 120–121 cm, ×4200. **7.** *Discolithina rimosa* (Bramlette and Sullivan), Sample 577-11-2, 18–19 cm, ×5600. **8.** *Ellipsolithus macellus* (Bramlette and Sullivan), Sample 577A-9,CC (10–11 cm), ×4200.

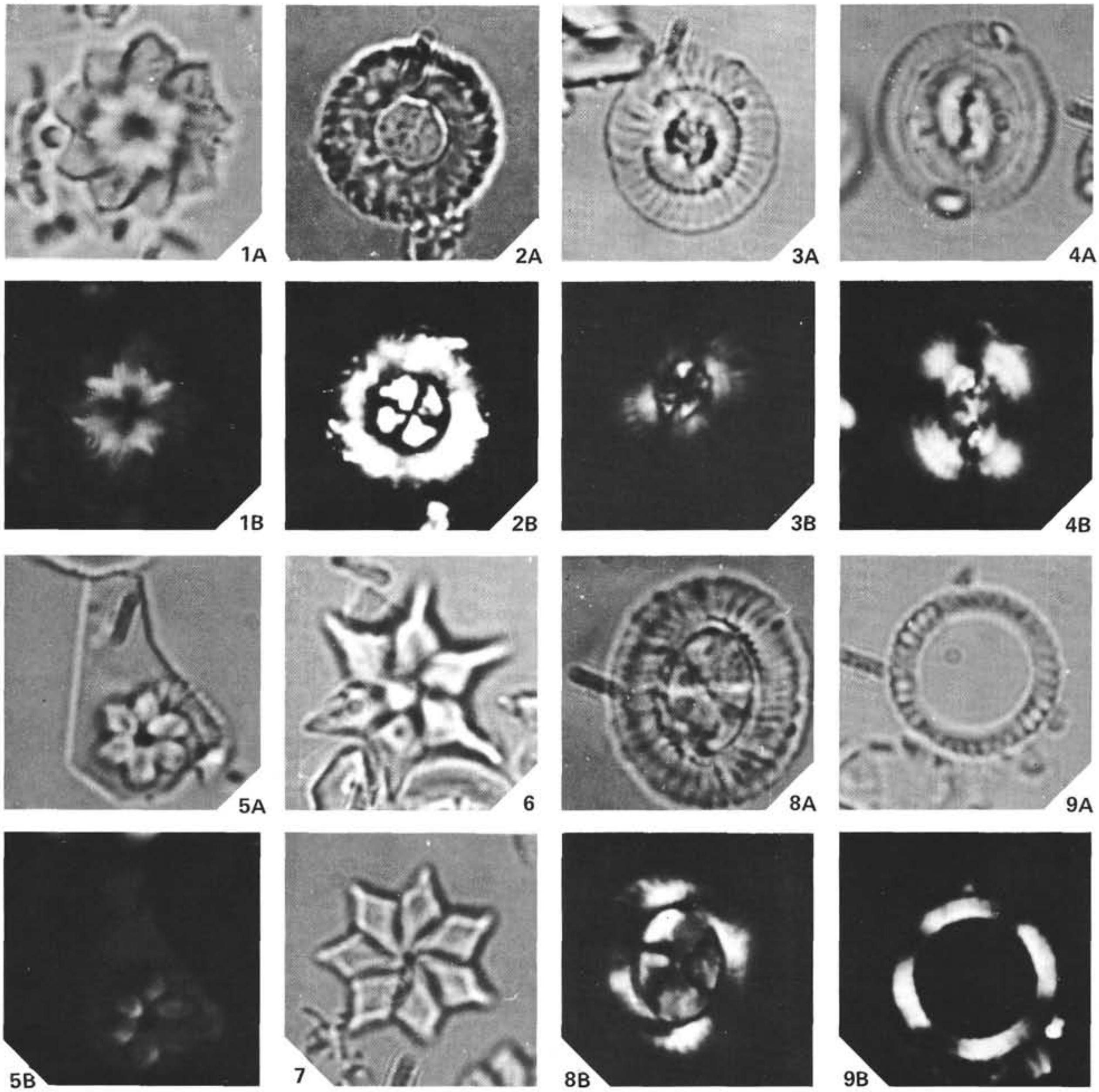

Plate 12. (The abbreviations XN and OL denote cross-polarized and transmitted light.) **1.** *Discoasteroides kuepperi* (Stradner), Sample 577A-8-2, 15–16 cm, (1A) OL, (1B) XN. **2.** *Markalius astroporus* (Stradner), Sample 577A-12-2, 66–67 cm, (2A) OL, (2B) XN. **3.** *Striatococcolithus pacificanus* Bukry, Sample 577A-8-6, 15–16 cm, (3A) OL, (3B) XN. **4.** *Dictyococcites bisecta* (Hay, Mohler, and Wade), Sample 577A-7-6, 86–87 cm, (4A) OL, (4B) XN. **5.** *Bramletteius serraculoides* Gartner, Sample 577A-7-5, 36–37 cm, (5A) OL, (5B) XN. **6.** *Discoaster saipanensis* Bramlette and Riedel, Sample 577A-7-5, 36–37 cm, OL. **7.** *Discoaster* cf. *saipanensis,* Sample 577A-7-5, 36–37 cm. **8.** *Coccolithus jugatus* (Perch-Nielsen), Sample 577A-8-1, 105–106 cm, (8A) OL, (8B) XN. **9.** *Coronocyclus nitescens* (Kamptner), Sample 577A-7-3, 86–87 cm, (9A) OL, (9B) XN.

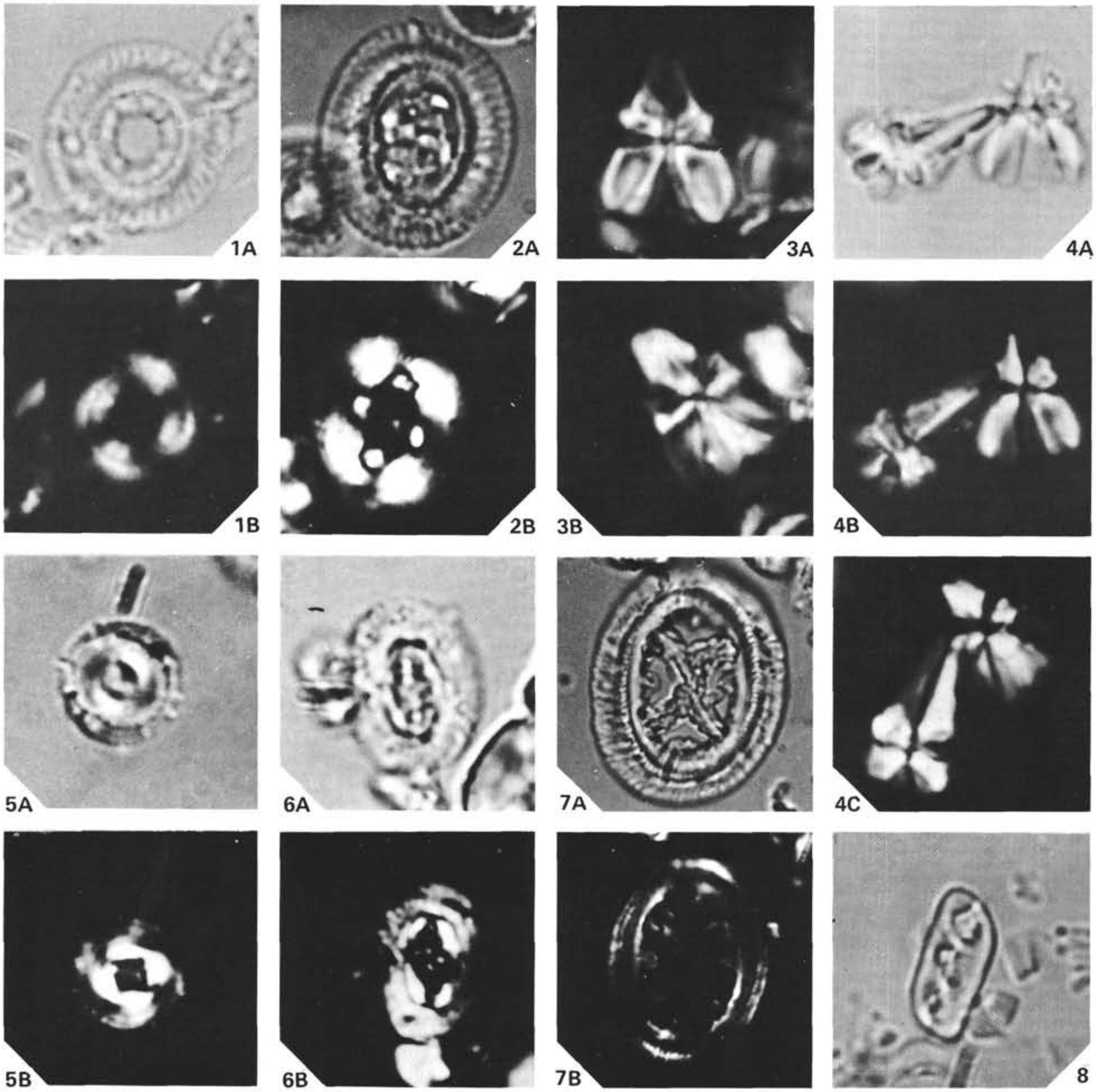

Plate 13. (The abbreviations XN and OL denote cross-polarized and transmitted light. All photographs are ×2800, only Fig. 7 is ×1500.) **1.** *Coccolithus formosus* (Kamptner), Sample 577A-8,CC (5–6 cm). **2.** *Cruciplacolithus tenuis* (Stradner), Sample 577A-8,CC (5–6 cm). **3, 4.** *Sphenolithus spiniger* Bukry, Sample 577-8-4, 120–121 cm. (3A) XN, (3B) XN (45°), (4A) OL, (4B) XN, (4C) XN (45°). **5.** *Toweius craticulus* Hay and Mohler, Sample 577A-9,CC (10–11 cm), (5A) OL, (5B) XN. **6.** *Campylosphaera eodela* Bukry, Sample 577A-9,CC, (6A) OL, (6B) XN. **7.** *Chiasmolithus grandis* (Bramlette and Riedel), Sample 577A-7,CC, (7A) OL, (7B) XN. **8.** *Isthmolithus recurvus* Deflandre, Sample 577A-7-6, 20–21 cm.

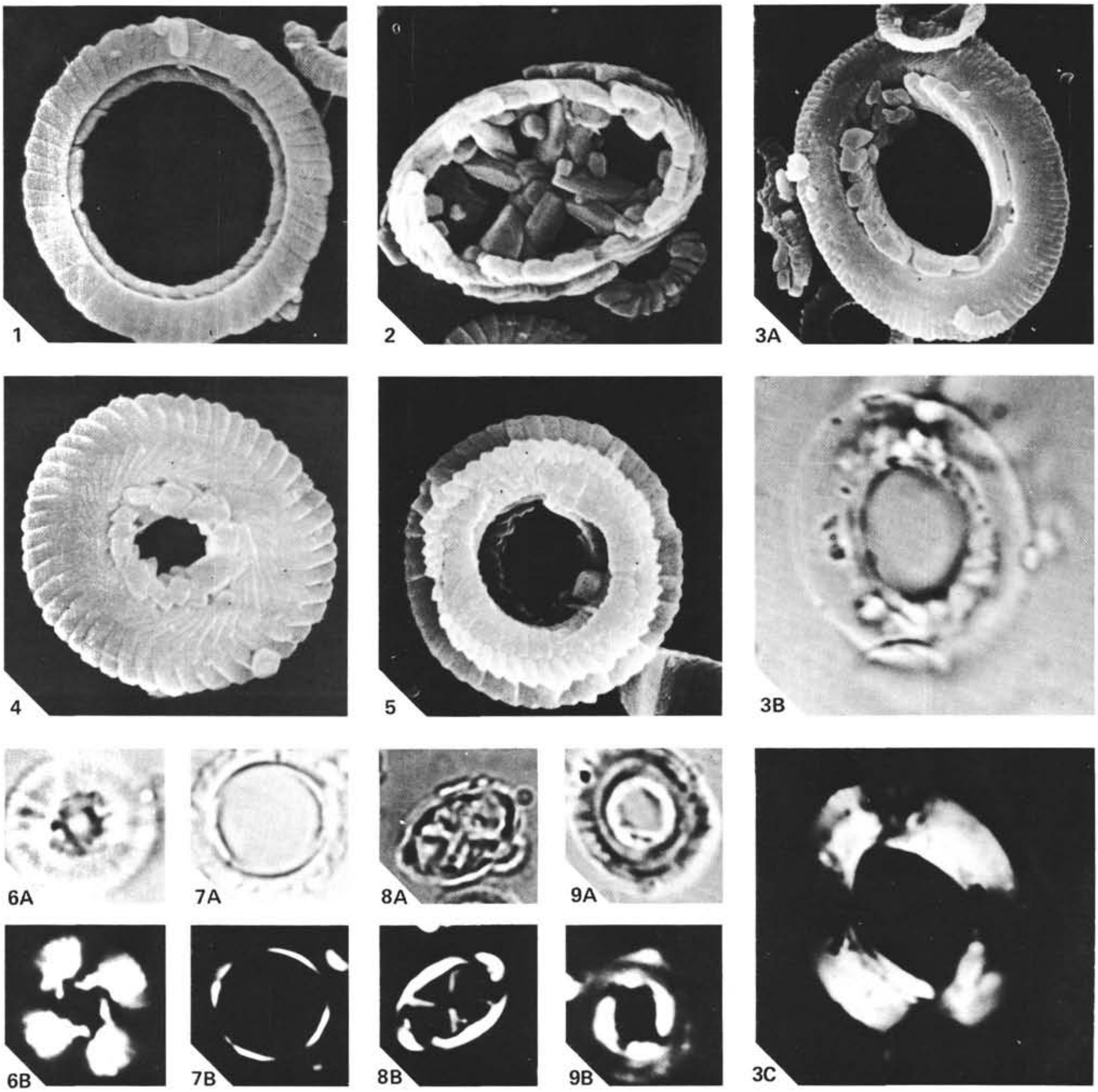

Plate 14. (The abbreviations XN and OL denote cross-polarized and transmitted light. All light microscope photographs are ×2800.) **1, 7.** *Cyclolithella kingi* (Roth), Sample 577A-7,CC, (1) ×5600, (7) same specimen as Fig. 1, (7A) OL, (7B) XN. **2, 8.** *Neochiastozygus concinnus* (Martini), Sample 577-11-2, 18–19 cm, (2) ×7000, (8) same specimen as Fig. 2, (8A) OL, (8B) XN. **3.** *Reticulofenestra umbilica* (Levin), Sample 577A-7-6, 86–87 cm, (3A) ×3500, (3B) OL, (3C) XN. **4, 6.** *Reticulofenestra* cf. *dictyoda* (Deflandre and Fert), Sample 577A-7,CC, (4) ×5600, (6) same specimen as Fig. 4, (6A) OL, (6B) XN. **5, 9.** *Coccolithus formosus* (Kamptner), Sample 577A-8-6, 15–16, (5) ×5600, (9) same specimen as Fig. 5, (9A) OL, (9B) XN.