9. CRETACEOUS TO RECENT CALCAREOUS NANNOPLANKTON FROM THE CENTRAL PACIFIC OCEAN (DSDP LEG 33)

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INTRODUCTION

During Leg 33 of the Deep Sea Drilling Project, five sites (314 to 318) were occupied and eight holes drilled between Hawaii and Tahiti in the Central Pacific Ocean (Figure 1). All sites with the exception of Site 314 yielded common calcareous nannoplankton at most intervals cored. Nannoplankton assemblages encountered and age assignments are discussed below for each site. As the distribution of Neogene and Quaternary nannoplankton is similar to or the same as that found during Leg 7 in the Equatorial Pacific, fossil lists are given only for the Paleogene and part of the Cretaceous.

Geographical positions of the DSDP holes drilled during Leg 33 are as follows (Figure 1):

Site 314	lat 15°54.76'N, long 168°28.07'W, water depth 5213 meters
Holes 315, 315A	lat 4°10 26'N, long 158°31.52'W, and 158°31.54'W, water depth 4152 meters
Site 316	lat 0°05.44'N, long 157°07.71'W, water depth 4451 meters
Holes 317 317A 317B	lat 11°00.09'S long 162°17.78'W, water depth 2598 meters
Site 318	lat 14°49.63'S long 146°51.51'W, water depth 2641 meters

CALCAREOUS NANNOPLANKTON ZONATION

In the Tertiary and Quaternary the standard calcareous nannoplankton zonation (Martini, 1971) was used (Table 1). Due to the equatorial position of some sites or due to poor preservation of the calcareous nannoplankton, the following deviations were necessary.

NN 20/21 (Combined *Gephyrocapsa oceanica/Emiliania huxleyi* Zone)

Definition: Interval above the last occurrence of *Pseudoemiliania lacunosa* (Kamptner).

Remarks: As *Emiliania huxleyi* (Lohmann) is not easily recognizable in the area investigated because tropical forms lack the spinose appearance which can be seen with the light microscope, the two uppermost nannoplankton Zones NN 20 and NN 21 are tabulated as one unit in Holes 315, 316, 317B, and 318. In Hole 317 *E. huxleyi* is at least present in Sample 317-1-1, 5-6 cm as indicated by SEM pictures figured on Plate 10 (Figures 1, 2).

NN 4/5 (combined *Helicosphaera ampliaperta/Sphenolithus heteromorphus* Zone)

Definition: Interval from the last occurrence of *Sphenolithus belemnos* Bramlette and Wilcoxon to the last occurrence of *Sphenolithus heteromorphus* Deflandre.

Remarks: As the guide fossil *Helicosphaera ampliaperta* seems to be absent in the Equatorial Pacific, *Discoaster exilis* Martini and Bramlette was taken to define the top of Zone NN 4 (Martini and Worsley, 1971). In part of Hole 315A preservation is too poor to recognize *Discoaster exilis* with certainty due to overcalcification, and a combined NN 4/5 Zone is more realistic.

NP 25 (*Sphenolithus ciperoensis* Zone)

Definition: Interval from the last occurrence of *Sphenolithus distentus* (Martini) to the last occurrence of *Sphenolithus ciperoensis* Bramlette and Wilcoxon.

Remarks: The guide fossil *Helicosphaera recta* (Haq) (= *H. truncata* Bramlette and Wilcoxon) is not present in the Equatorial Pacific as already noted by Martini and Worsley, 1971. *Sphenolithus ciperoensis* was used as a substitute species, and its last occurrence marks the top of Zone NP 25 in Leg 33 usage.

NP 19/20 (combined *Isthmolithus recurvus/Sphenolithus pseudoradians* Zone)

Definition: Interval from the last occurrence of *Chiasmolithus grandis* (Bramlette and Riedel) to the last occurrence of *Discoaster saipanensis* Bramlette and Riedel.

Remarks: *Sphenolithus pseudoradians* Bramlette and Wilcoxon, the marker species for the base of Zone NP 20 was found to have its first occurrence in the Equatorial Pacific much earlier than in high latitudes (Bukry, 1971). *Isthmolithus recurvus* Deflandre is an extra-tropical species (Martini and Worsley, 1971) and accordingly does not occur in the present material. *Chiasmolithus grandis*, an easily recognizable species, is present in low as well as in high latitudes and has its last occurrence consistently above the first occurrence of *Isthmolithus recurvus* in high latitudes according to data from Deep Sea Drilling and from land-based sections in Germany, Italy, and Russia. It is therefore taken as a substitute species in low latitudes to define the base of Zone NP 19.

NP 17/18 (combined *Discoaster saipanensis/Chiasmolithus oamaruensis* Zone)

Definition: Interval from the last occurrence of *Chiasmolithus solitus* (Bramlette and Sullivan) to the last occurrence of *Chiasmolithus grandis* (Bramlette and Riedel).

Remarks: *Chiasmolithus oamaruensis* (Deflandre) has not been encountered as yet in low latitudes in the Pacific; therefore, a differentiation between standard Zones NP 17 and NP 18 in this area does not seem possible. The top of the combined Zone NP 17/18 is marked by the last occurrence of *Chiasmolithus grandis* as discussed above.

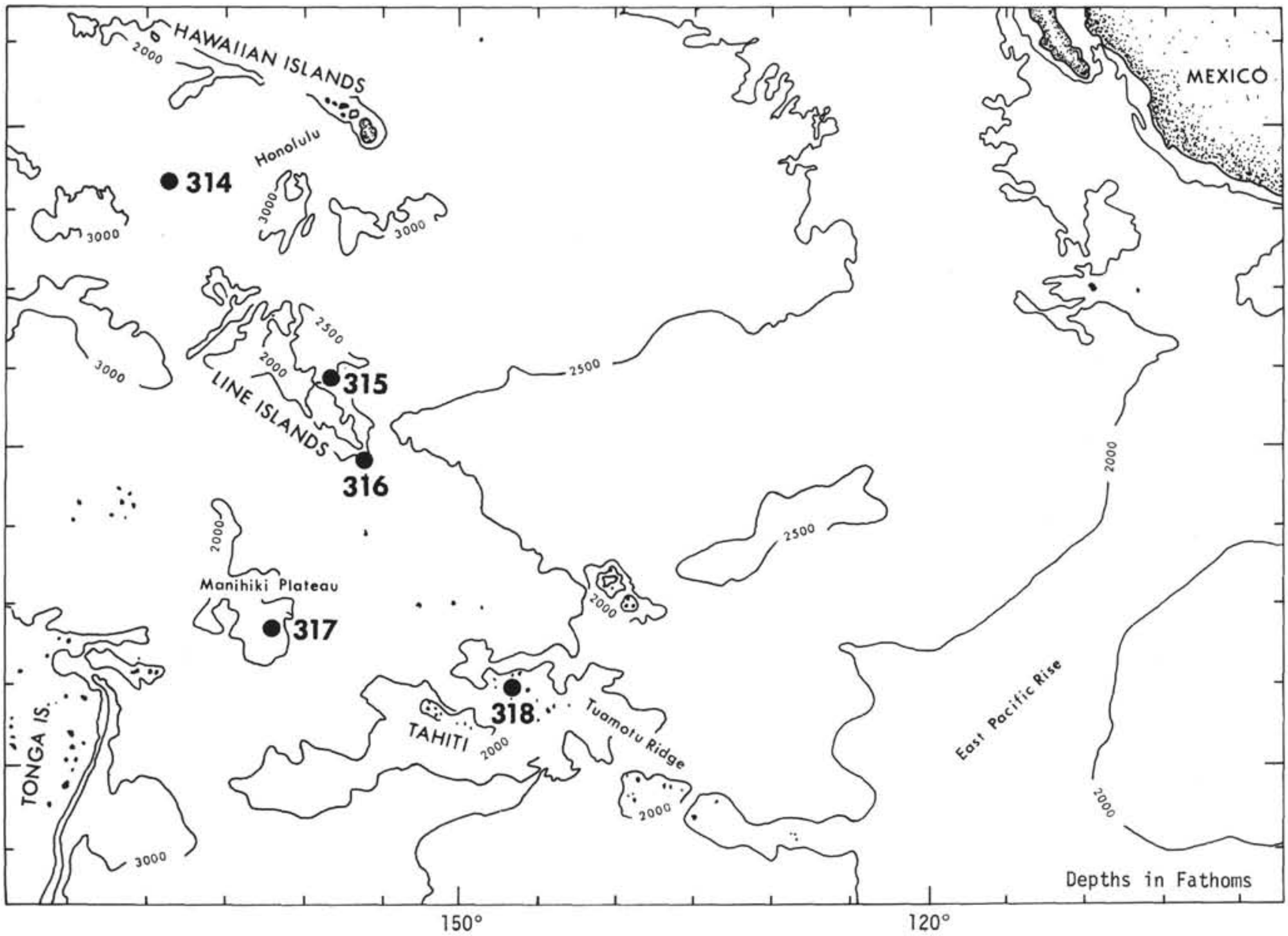

Figure 1. *Location of sites drilled during Leg 33.*

NP 3/4 (combined *Chiasmolithus danicus/Ellipsolithus macellus* Zone)

Definition: Interval from the first occurrence of *Chiasmolithus danicus* (Brotzen) to the first occurrence of *Fasciculithus tympaniformis* Hay and Mohler.

Remarks: The preservation of calcareous nannoplankton in the early Paleocene of Site 316 does not allow a differentiation of Zones NP 3 and NP 4 on the basis of the first occurrence of *Ellipsolithus macellus*, as this species is among the less solution-resistant forms, which are missing in the present material. Other helpful species like those from the *Zygolithus* (=*Neococcolithus*) group are probably missing due to the equatorial position of this hole.

In the Cretaceous a detailed zonation is possible only in the Campanian/Maestrichtian interval (Table 2). In cores recovered below the Campanian preservation is too poor, and assemblages found are reduced in species by dissolution; accordingly, a zonation was not attempted. Zones and intervals recognized in the Cretaceous are the following:

Tetralithus murus Zone

Definition: Interval from the first occurrence of *Tetralithus murus* Martini to the last occurrence of *Arkhangelskiella cymbiformis* Vekshina and other Cretaceous species (Cretaceous extinction plane).

Author: Martini, 1969.

Stratigraphic position: Upper Maestrichtian.

Remarks: Not recovered in the present cores due to an unconformity at the Maestrichtian/Tertiary boundary. In the type Maestrichtian recognizable as *Nephrolithus frequens* Zone approximately 10 meters above base of Maestricht Chalk onwards (see sample ENCI-Quarry 12 in Bramlette and Martini, 1965).

Lithraphidites quadratus Zone

Definition: Interval from the first occurrence of *Lithraphidites quadratus* Bramlette and Martini to the first occurrence of *Nephrolithus frequens* Gorka in high latitudes or *Tetralithus murus* Martini in low latitudes.

Authors: Cepek and Hay, 1969.

Stratigraphic position: Middle Maestrichtian.

Remarks: In the type Maestrichtian this zone is present in the uppermost Gulpen Chalk and in the lower part of the Maestricht Chalk. During Leg 33 encountered in Holes 315A, 316, and 317A.

Arkhangelskiella cymbiformis Zone

Definition: Interval from the last occurrence of *Tetralithus trifidus* (Stradner) to the first occurrence of *Lithraphidites quadratus* Bramlette and Martini.

Author: Perch-Nielsen, 1972, amended this paper.

Stratigraphic position: Middle Maestrichtian.

TABLE 1
Tertiary and Quaternary Standard Nannoplankton Zonation and Indication of Estimated Time Relations

Series	Subseries	Calcareous Nannoplankton Zones		Age
Miocene		NN1	*Triquetrorhabdulus carinatus* Zone	24.0*
Oligocene	Upper	NP25	*Sphenolithus ciperoensis* Zone	26.0*
Oligocene	Upper / Middle	NP24	*Sphenolithus distensus* Zone	32.0
Oligocene	Middle	NP23	*Sphenolithus predistentus* Zone	34.0
Oligocene	Lower	NP22	*Helicopontosphaera reticulata* Zone	
Oligocene	Lower	NP21	*Ericsonia? subdisticha* Zone	36.5 37.5*
Eocene	Upper	NP20	*Sphenolithus pseudoradians* Zone	41.0
Eocene	Upper	NP19	*Isthmolithus recurvus* Zone	42.0*
Eocene	Upper	NP18	*Chiasmolithus oamaruensis* Zone	42.5
Eocene	Upper / Middle	NP17	*Discoaster saipanensis* Zone	45.5
Eocene	Middle	NP16	*Discoaster tani nodifer* Zone	47.3
Eocene	Middle	NP15	*Chiphragmalithus alatus* Zone	48.5*
Eocene	Middle	NP14	*Discoaster sublodoensis* Zone	49.2
Eocene	Lower	NP13	*Discoaster lodoensis* Zone	50.0
Eocene	Lower	NP12	*Marthasterites tribrachiatus* Zone	51.5
Eocene	Lower	NP11	*Discoaster binodosus* Zone	52.5
Eocene	Lower	NP10	*Marthasterites contortus* Zone	53.0*
Paleocene	Upper	NP9	*Discoaster multiradiatus* Zone	55.0
Paleocene	Upper	NP8	*Heliolithus riedeli* Zone	56.0
Paleocene	Middle	NP7	*Discoaster gemmeus* Zone	57.0
Paleocene	Middle	NP6	*Heliolithus kleinpelli* Zone	58.0
Paleocene	Middle	NP5	*Fasciculithus tympaniformis* Zone	59.5*
Paleocene	Lower	NP4	*Ellipsolithus macellus* Zone	61.0
Paleocene	Lower	NP3	*Chiasmolithus danicus* Zone	63.5
Paleocene	Lower	NP2	*Cruciplacolithus tenuis* Zone	64.0
Paleocene	Lower	NP1	*Markalius inversus* Zone	65.0*

TABLE 1 – *Continued*

Series	Subseries	Calcareous Nannoplankton Zones		Age
Quat.		NN21	*Emiliania huxleyi* Zone	0.2
Quat.		NN20	*Gephyrocapsa oceanica* Zone	0.6
Quat.		NN19	*Pseudoemiliania lacunosa* Zone	1.8*
Pliocene	Upper	NN18	*Discoaster brouweri* Zone	2.5
Pliocene	Upper	NN17	*Discoaster pentaradiatus* Zone	2.7
Pliocene	Upper	NN16	*Discoaster surculus* Zone	3.5
Pliocene	Lower	NN15	*Reticulofenestra pseudoumbilica* Zone	3.8
Pliocene	Lower	NN14	*Discoaster asymmetricus* Zone	4.0
Pliocene	Lower	NN13	*Ceratolithus rugosus* Zone	4.6
Pliocene	Lower	NN12	*Ceratolithus tricorniculatus* Zone	5.0*
Miocene	Upper	NN11	*Discoaster quinqueramus* Zone	9.5
Miocene	Upper	NN10	*Discoaster calcaris* Zone	11.0*
Miocene	Middle	NN9	*Discoaster hamatus* Zone	12.0
Miocene	Middle	NN8	*Catinaster coalitus* Zone	12.2
Miocene	Middle	NN7	*Discoaster kugleri* Zone	13.0
Miocene	Middle	NN6	*Discoaster exilis* Zone	14.0
Miocene	Middle / Lower	NN5	*Sphenolithus heteromorphus* Zone	17.0
Miocene	Lower	NN4	*Helicopontosphaera ampliaperta* Zone	18.5
Miocene	Lower	NN3	*Sphenolithus belemnos* Zone	19.0
Miocene	Lower	NN2	*Discoaster druggi* Zone	20.5
Miocene	Lower	NN1	*Triquetrorhabdulus carinatus* Zone	24.0*
Oligoc.				

Remarks: In the type Maestrichtian this zone can be recognized in the Gulpen Chalk (C to E), but due to the high latitudinal position of the type Maestrichtian, the lower boundary is indicated by the last occurrence of *Broinsonia parca* (Stradner) as discussed below, because *Tetralithus trifidus* is not present in this area. During Leg 33 the *A. cymbiformis* Zone was found in Holes 315A, 316, and 317A.

Tetralithus trifidus Zone

Definition: Interval from the first to the last occurrences of *Tetralithus trifidus* (Stradner).

Authors: Bukry and Bramlette, 1970.

Stratigraphic position: Lower Maestrichtian to upper Campanian.

Remarks: In the type Maestrichtian *T. trifidus* is not represented, but *Broinsonia parca* (Stradner) may be taken as a substitute species for defining the upper boundary of the *T. trifidus* Zone in high latitudes. The last occurrence of *B. parca* is just below the last occurrence of *T. trifidus* in DSDP Holes 165A, 167, 170, 171, 315A, 316, and 317A, indicating that the lowest part of the type Maestrichtian (lower part of the Gulpen Chalk) in which *B. parca* is present can be correlated with the upper part of the *T. tridifus* Zone elsewhere. During Leg 33 the *T. trifidus* Zone was encountered in Holes 315A, 316, and 317A.

TABLE 2
Upper Cretaceous Calcareous Nannoplankton Zonation Used During Leg 33 and Leg 17, Range of Marker Species, and Indication of Estimated Time Relations

Stages	Ages (m.y.)	Stratotypes	Nannoplankton Zones Leg 33 (Martini)	*T. murus* / *L. quadratus* / *A. cymbiformis* / *T. trifidus* / *T. gothicus* / *T. aculeus* / *M. furcatus*	Nannoplankton Zones Leg 17 (Roth; Bukry)
Maestrichtian	65	E.N.C.I.	*T. murus* Zone		*M. mura* Zone
	67		*L. quadratus* Zone		*L. quadratus* Zone
	69		*A. cymbiformis* Zone		
	71		*T. trifidus* Zone		*T. trifidus* Zone
Campanian	74		*T. gothicus* Zone		(*B. parca* Z.)
	77	?			*E. eximius* Zone
			T. aculeus Zone		(*G. obliquum* Z.)
Santon.	80		*M. furcatus* Zone		*M. furcatus* Zone

Tetralithus gothicus Zone

Definition: Interval from the first occurrence of *Tetralithus gothicus* Deflandre to the first occurrence of *Tetralithus trifidus* (Stradner).

Author: Martini, this paper.

Stratigraphic position: Middle Campanian.

Remarks: Correlation to the type section of the Campanian at present is impossible as the nannoplankton assemblages of the type Campanian at Aubeterre are still incompletely known. In the present material found in Holes 315A, 316, and 317A.

Tetralithus aculeus Zone

Definition: Interval from the last occurrence of *Marthasterites furcatus* Deflandre to the first occurrence of *Tetralithus gothicus* Deflandre.

Authors: Cepek and Hay 1969, emended, this paper.

Stratigraphic position: Lower Campanian.

Remarks: *T. aculeus* seems to have a different range in some areas (compare Manivit, 1971), and the correlation of this zone to the type Campanian has to be investigated. During Leg 33 encountered in Holes 315A and 316, where the first occurrence of *T. aculeus* is approximately at the level of the last occurrence of *Marthasterites furcatus.*

Marthasterites furcatus Zone

Definition: Interval from the first to the last occurrence of *Marthasterites furcatus* Deflandre.

Authors: Cepek and Hay, 1969, emended, Roth, 1973.

Remarks: As mentioned by Roth (1973), some species used by Cepek and Hay to define the boundaries of their Upper Cretaceous nannoplankton zones are absent in this area or are not dissolution resistant. The total range of *M. furcatus* probably includes the Coniacian and the Santonian, but exact correlation to the stratotypes is not known. In the present material the *M. furcatus* Zone was found in Hole 315A overlain by the *T. aculeus* Zone, and in Hole 317A where it was probably separated by unconformities from the overlying *T. gothicus* Zone and the underlying "lower Turonian to Cenomanian." Both occurrences are considered to be of Santonian age.

Barremian to Turonian

In the recovered Lower Cretaceous and lower Upper Cretaceous the preservation of the calcareous nannoplankton is very poor and only solution-resistant species are left. A detailed zonation such as suggested by Thierstein, 1971, therefore is impossible in this interval. *Micula staurophora, Eiffellithus turriseiffeli, Predicosphaera cretacea, Lithastrinus floralis, Cruciellipsis cuvillieri,* and an undescribed form were used to define a "Cenomanian to lower Turonian" (interval between the last occurrence of an undescribed form and the first occurrence of *M. staurophora*), an "upper Albian to Cenomanian (interval between the first occurrence of *E. turriseiffeli* and the last occurrence of an undescribed form), a lower to middle Albian" (interval between the first occurrence of *P. cretacea* and the first occurrence of *E. turriseiffeli*), and a "Barremian to Aptian" (interval between the last occurrence of *Cruciellipsis cuvillieri* to the first occurrence of *P. cretacea*). Within the upper part of the "Barremian to Aptian" the first occurrence of *Lithastrinus floralis* was noted in Core 9 of Hole 317A, which may be related to a position in the late Aptian.

HOLE SUMMARIES

Site 314—Johnston Island Trough

Sediment recovered from core catcher 1 (7.5 m) is barren of calcareous nannoplankton (Table 3). Zeolitic clay sampled from outside the barrels at 11 meters and 13 meters above the core bit after the bottom core assemblage had been brought onboard yielded rare but fairly well preserved calcareous nannoplankton of various ages: late Neogene to Quaternary (*Discoaster surculus, D. variabilis, D. brouweri, Coccolithus pelagicus, Cyclococcolithus leptoporus, Ceratolithus cristatus,* in total 78%); Eocene (*Reticulofenestra umbilica, Chiasmolithus bidens,* in total 16.6%); Paleocene (*Chiasmolithus danicus,* in total 2.7%); and Upper Cretaceous (*Micula staurophora,* in total 2.7%); indicating that the nannoplankton assemblage may represent a late Neogene or Quaternary turbidite from somewhere within the interval from 0 to approximately 35 meters.

No nannofossils were present in the clays retrieved from core catcher 3 (45 m), but thin sections of associated porcellanite yielded partially recrystallized calcareous nannoplankton with ranges from the middle Eocene to lower Oligocene (e.g., *Reticulofenestra umbilica, Chiasmolithus grandis,* and also *Coccolithus pelagicus* or *Dictyococcites dictyodus*), indicating that a late Eocene age for this sample is most likely.

Hole 315—Line Islands

The four cores taken from Hole 315 contain well-preserved calcareous nannoplankton assemblages. The Quaternary (standard Zones NN 19, NN 20, and NN 21) and uppermost Pliocene (Zone NN 18) occur in the upper three cores down to a depth of 18.5 meters. The Plio-Pleistocene boundary (last occurrence of *Discoaster brouweri*) is between 2, CC and 3, CC, which were the only available samples from these cores as there was otherwise no recovery. Species present include *Emiliania huxleyi* (only in the upper part of Core 1), *Gephyrocapsa oceanica, Cyclococcolithus leptoporus, Helicosphaera carteri, Ceratolithus cristatus, Pseudoemiliania lacunosa, Coccolithus pelagicus* in Cores 1 and 2, and *Discoaster brouweri* and *Ceratolithus rugosus* in core catcher 3. In Core 4 (56.5-65.0 m) lower Pliocene assemblages were encountered (Zones NN 13 to NN 15), in which the occurrence of *Discoaster altus* in Sections 2 to 5 is of special interest. *D. altus* (Plate 12, Figures 17, 18) has been originally described from the same stratigraphic interval (Zones NN 14 and NN 15) from Leg 25 in the Western Indian Ocean by Müller, 1974. Sample 4, CC contained *Ceratolithus rugosus, C. tricorniculatus,* and *Discoaster surculus,* but *Discoaster asymmetricus* has not been found, consequently this sample was placed in Zone NN 13 (*Ceratolithus rugosus* Zone). Assemblages found are otherwise identical with those listed for several holes of the Equatorial Pacific Leg 7 (Martini and Worsley, 1971), and species will not be tabulated for this interval in the present report.

Hole 315A—Line Islands

Ten survey cores drilled in Hole 315A down to 740 meters below the sea floor yielded calcareous nannoplankton assemblages from the Quaternary to the upper Eocene.

The first three cores in Hole 315A contain moderately preserved nannoplankton of Zone NN 11, with *Ceratolithus tricorniculatus* present in Cores 1 and 2. From Core 4 downward, which can be attributed to the middle Miocene Zone NN 6, preservation becomes increasingly poor, with solution effects on coccoliths and excess calcite on discoasters, making species assignment difficult or impossible. Core 5 yielded nannoplankton of Zone NN 5 with abundant *Sphenolithus heteromorphus.* The upper part of Core 6 can be attributed either to Zones NN 5 or NN 4, as the marker species *Helicosphaera ampliaperta* of the boundary between NN 4 and NN 5 is not present in the Equatorial Pacific, and *Discoaster exilis*, which was used as a substitute species during Leg 7, cannot be identified with certainty due to overcalcification. In Section 2 of Core 6 a mixed NN 4/5 and NN 1 (with *Coccolithus abisectus* fairly common) assemblage was found; the core-catcher contains a good lower NN 1 assemblage, indicating a possible hiatus within this core. Cores 7 to 9 represent Zone NN 1 with *Triquetrorhabdulus carinatus* rather abundant. The base of Core 9 contains a nannoplankton assemblage indicative of the Oligocene Zone NP 24. In Core 10 nannoplankton of lower Oligocene Zones NP 21 and NP 22 were found, and the Eocene/Oligocene boundary was encountered in Section 6 between 39 and 52 cm, also showing a sharp sedimentary change. The upper Eocene nannoplankton assemblages are restricted to sturdy forms with heavy excess calcite and represent the combined Zones NP 19/20 above the last occurrence of *Chiasmolithus grandis*, with abundant *Discoaster barbadiensis* and *D. saipanensis.* Nannoplankton from Cores 11 to 14 are not available due to the recovery only of chert. The lowest Tertiary in this hole can be dated as upper Paleocene, which was recovered in Core 15 with moderately preserved nannoplankton indicating Zones NP 8 and NP 9. The Cretaceous/Tertiary boundary is between this core and Core 16, in which a poorly preserved nannoplankton assemblage of middle Maestrichtian age (*Lithraphidites quadratus* Zone) was found. Calcareous nannoplankton down to Core 26 show poor preservation throughout with heavy solution effects and overgrowth, especially in *Micula staurophora.* The assemblages are rather meager with only a few species left. The occurrences of *Tetralithus aculeus, T. trifidus, T. gothicus,* and *Marthasterites furcatus* were used to subdivide the Upper Cretaceous of this hole into a middle Maestrichtian in Core 16 to upper part of Core 19, an upper Campanian to lower Maestrichtian in the lower part of Core 19 to Core 21, a middle Campanian in Core 24 (lower part) to upper part of Core 26. The Santonian with *Marthasterites furcatus* present was encountered in the lower part of Core 26. Species present in a number of reference samples from the Upper Cretaceous interval are tabulated in Table 4, together with indication of preservation and nannoplankton zones. Cores 27 to 29, and Core 30, in which basalt was recovered, proved to be barren of nannofossils.

Site 316—Line Islands

In Hole 316 five survey cores were taken between 0 and 450 meters, followed by more or less continuous

TABLE 3
Calcareous Nannoplankton Stratigraphy of Holes Drilled During Leg 33[a]

	Zones	314	315	315A	316	317	317A	317B	318
Quat.	NN21		1		1	1		1	1
	NN20					1			
	NN19		2		1	1			2
Pliocene	NN18		3					2	2
	NN17							2	
	NN16							3	
	NN15		4					4-5	3
	NN14		4					5	4
	NN13		4					5-6	
	NN12							7-8	5
Miocene	NN11			1-3	2			9-11	6-7
	NN10				3			11-12	
	NN9				░		(1)	12-13	8-9
	NN8				░			14	░
	NN7				░			15	░
	NN6			4	3			16	░
	NN5			5 | 6	3			17-19	░
	NN4							19	░
	NN3			░				20	░
	NN2			░				20	10
	NN1			6-9	4	2+(3)		21-25	11-12
Oligocene	NP25				░			26-28	13-14
	NP24			9	░			28-30	14-15
	NP23				░			31-33	15
	NP22			10	4			34	
	NP21			10	5			34-35	16
Eocene	NP20			10	░	3		35-37	16-18
	NP19				░				
	NP18	(3)		*	░			37-39	19
	NP17			*	░				
	NP16			*	5			39-40	20-21
	NP15			*	*		1	40-42	22-26
	NP14			*	7			42-43	26-28*
	NP13			*	*			44	30-32
	NP12			*	9		(2)	45	
	NP11			*	10				
	NP10			*					
Paleocene	NP9			15	11-14				
	NP8			15	14				
	NP7			░	░				
	NP6			░	░				
	NP5			░	15-16				
	NP4			░	16-17				
	NP3			░					
	NP2			░	░				
	NP1			░	░				
Maest.	*T. murus* Z.			░	░				
	L. quadratus Z.			16-17	18-20		2		
	A. cymbiformis Z.			18-19	20-22		3-4		
Camp.	*T. trifidus* Z.			19-21	22-27		4-5		
	T. gothicus Z.			23-24	27-30		6		
	T. aculeus Z.			24-26	30		░		
Santonian				26			7		
Coniacian							░		
Upper Turonian							░		
L. Turonian/Cenomanian							7		
Cenomanian/U. Albian							8		
Low./Mid. Albian							9		
Aptian/Barremian							10-15*		

[a]Numbers refer to cores. Numbers in brackets indicate displaced material. * = cores barren of calcareous nannoplankton. ░ = missing intervals due to unconformities.

TABLE 4
Calcareous Nannoplankton From the Santonian to Maestrichtian Interval of Hole 315A, and Indication of Nannoplankton Zones[a]

Sample (Interval in cm)	*Ahmuellerella octoradiata*	*Arkhangelskiella cymbiformis*	*Broinsonia parca*	*Chiastozygus amphipons*	*Cretarhabdus crenulatus*	*Cribrosphaerella ehrenbergi*	*Cylindralithus gallicus*	*Cylindralithus serratus*	*Eiffellithus eximius*	*Eiffelithus turriseiffeli*	*Glaukolithus diplogrammus*	*Lithastrinus floralis*	*Lithraphidites carniolensis*	*Lithraphidites helicoideus*	*Lithraphidites quadratus*	*Manivitella pemmatoidea*	*Marthasterites furcatus*	*Microrhabdulus decoratus*	*Micula staurophora*	*Predicosphaera cretacea*	*Tetralithus aculeus*	*Tetralithus gothicus*	*Tetralithus* cf. *obscurus*	*Tetralithus trifidus*	*Watznaueria barnesae*	*Zygodiscus* sp.	Preservation	Nannoplankton Zones
16-2, 122-123		X		X	X	X				X					X				X	X					X		P	*L. quadratus*
17-2, 56-57		X			X	X	X								X				X	X	X				X		P	
18-1, 57-58					X		X												X		X				X		P	*A. cymbiformis*
18-4, base					X														X		X				X		P	
19-1, 125-126		X			X	X	X									X			X		X	cf.			X		P	
19-4, 87-88					X	X		X											X		X	cf.		X	X		P	*T. trifidus*
19-6, base			X		X	X	X	X					X			X		X	X		X	X	X	X	X		P	
20-2, 58-59			X		X			X											X		X	X		X	X		P	
20-5, base		X	X		X											X		X	X	X	X	X		X	X		P	
21-6, base			X		X								X			X			X		X	X		X	X	X	P	
22-1, 103-104			X		X											X			X		X	X			X		P	*T. gothicus*
22-4, 39-40			X		X	X								X		X			X	X	X	X			X		P	
23-4, base	X	X	X	X	X	X			X	X				X		X		X	X	X	X	X			X	X	M	
24-6, 50-51			X						X					X					X		X	X			X		P	
24, CC					X														X		X				X		P	*T. aculeus*
25-1, 120-121			X		X	X													X	X	X				X		P	
25, CC	X		X	X	X	X			X		X			X		X			X	X	X				X		M	
26-1, 32-33			X		X	X			X	X				X				X	X	X	X				X		P	
26-2, 20-21												X				X	X		X	X					X		P	*M. furcatus*
26, CC					X					X		X					X		X	X					X		P	

[a]Preservation: P = poor, PM = poor to moderate, M = moderate. Note that *Gartnerago obliquum* was erroneously omitted from the list but occurs in Sample 25, CC.

coring down to the terminal depth of 837 meters, with a larger spacing in the lower part of the section. Nannoplankton found in the 30 cores recovered indicate a succession from Recent to the uppermost lower Campanian, with some major unconformities in the Tertiary.

Core 1 (0 to 9.5 m) contains calcareous nannoplankton of the Quaternary Zones NN 19 to NN 21. In Core 2 (154 to 163.5 m) *Discoaster quinqueramus* was found, indicating the presence of the upper Miocene Zone NN 11. The upper part of Core 3 (267 to 276.5 m) belongs to Zone NN 10, whereas the lower part contains nannoplankton of the middle Miocene Zones NN 5 and NN 6. In Core 4 (390.5 to 400 m) another unconformity is present, as indicated by the calcareous nannoplankton of the lower Miocene Zone NN 1 in the upper part and of lower Oligocene age (Zone NP 22) in the lower part. A third unconformity occurs in Core 5 (447.5 to 457 m), between the lower Oligocene Zone NP 21 and the middle Eocene Zone NP 16. Except for Cores 1, 2, and part of Core 3, preservation of the calcareous nannoplankton is poor, with dissolution-affected assemblages and heavy excess calcite on discoasters. The lower Eocene and Paleocene section was continuously cored, although assemblages encountered are poorly preserved and several samples in Cores 6 to 8 lack calcareous nannoplankton. The preservation in the Paleocene is slightly improved, probably a result of a shallower depositional depth during this interval. Between Cores 14 and 15 another unconformity may be present at approximately 505 meters, as nannoplankton Zones NP 6 and NP 7 are missing. The lowest core in the Paleocene is Core 17 (571.0 to 580.5 m), in which a nannoplankton assemblage of Zone NP 3/4 was encountered. As Hole 316 revealed the best although rather fragmentary data on early Paleogene nannofossils obtained during Leg 33, the interval between Core 9 and Core 17 is chosen as reference for the Paleocene to lower Eocene interval, and species found are tabulated in Table 5 together with an indication of nannoplankton zones recovered.

The Cretaceous/Tertiary boundary may be represented in the upper part of Core 18, although a lithologic change cannot be seen. Samples from Sections 1 to 3 of Core 18 show a mixed Maestrichtian/Paleocene nannoplankton assemblage with *Cruciplacolithus tenuis, Zygodiscus sigmoides, Chiasmolithus danicus,* and *Ericsonia cava* occurring fairly frequently together with a middle Maestrichtian nannoplankton assemblage of the *Lithraphidites quadratus* Zone.

Cores 18 to 30 penetrated Maestrichtian to lower Campanian, which was encountered only in the lowest core. The Cretaceous nannoplankton is poorly preserved and heavily reduced in species by dissolution throughout most of the section, with some improvements within volcanic sandstones in the Campa-

TABLE 5
Calcareous Nannoplankton From the Paleocene to Lower Eocene Interval of Hole 316, and Indication of Standard Nannoplankton Zones[a]

Sample (Interval in cm)	*Chiasmolithus bidens*	*Chiasmolithus californicus*	*Chiasmolithus consuetus*	*Chiasmolithus danicus*	*Chiasmolithus* aff. *gigas*	*Chiasmolithus grandis*	*Coccolithus pelagicus*	*Cruciplacolithus tenuis*	*Cyclococcolithus formosus*	*Discoaster barbadiensis*	*Discoaster binodosus*	*Discoaster diastypus*	*Discoaster gemmeus*	*Discoaster lodoensis*	*Discoaster multiradiatus*	*Ellipsolithus macellus*	*Ericsonia cava*	*Fasciculithus involutus*	*Fasciculithus tympaniformis*	*Heliolithus* sp.	*Heliolithus cantabriae*	*Heliolithus riedeli*	*Markalius inversus*	*Marthasterites tribrachiatus*	*Neochiastozygus concinnus*	*Prinsius bisulcus*	*Sphenolithus conspicuus*	*Sphenolithus radians*	*Sphenolithus* sp.	*Thoracosphaera* sp.	*Toweius cracticulus*	*Toweius eminens*	Reworking	Preservation	Nannoplankton Zones
9-1, 120-121			X		X	X	X		X	X	X			X										cf.			X	X	X				p c	P	NP12
10-1, 134			X				X				X	X			X									X			X						P	P	NP11
11-1, 80-81	X		X			cf.	X				X	X	X		X		X		X		X								X					P	
11, CC	X		X				X					cf.	X		X		X		X		cf.								X		X			PM	
12, CC	X	X	X				X						X		X		X		X										X	X	X	X		M	NP9
13, CC	X	X	X				X	X					X		X	X	X		X				X						X		X	X		PM	
14-1, 125-126		X						X					cf.		X		X	X	X		X								X		X	X		P	
14, CC		X	X				X	X					cf.				X		X			X	X		X						X	X		P	NP8
15-1, 130-131		X		X				X									X		X	X											X	X		P	
15, CC				X				X									X		X	X											X			P	NP5
16-1, 140-141				X				X									X		X							X					X			P	
16, CC				X				X									X									X					X		C	P	
17-1, 81-82				cf.				X									X									X					X			P	NP3/4
17, CC				X				X									X									X				X	X			P	

[a]Preservation: P = poor, PM = poor to moderate, M = moderate. Reworking: (P) = minor content of reworked Paleocene forms.

nian interval. The Upper Cretaceous nannoplankton zones of Roth as well as Bukry (Leg 17) were found to be of partial use only, with some zones not existing according to their definition. Consequently, the same marker species (*Marthasterites furcatus, Tetralithus aculeus, T. gothicus, T. trifidus,* and *Lithraphidites quadratus*) as for Hole 315A were used to subdivide the Maestrichtian and Campanian (Table 2). Ranges of species found in the Upper Cretaceous interval of Site 316 are identical with those found in Hole 315A, and reference is made to Table 4 in which species of selected samples from Hole 315A are listed.

Hole 317—Manihiki Plateau

In Hole 317 three survey cores were taken. Core 1 just below the sea floor contains Quaternary calcareous nannoplankton (Zone NN 19 to NN 21). Core 2 from approximately 185 meters yielded nannoplankton from the lowest Miocene Zone NN1, with *Coccolithus abisectus* present. In the deepest core of this hole from approximately 300 meters, calcareous nannoplankton of the upper Eocene Zone NP 19/20 was found in chalk attached to a piece of chert recovered in the core catcher, overlain by 50 cm of obviously misplaced NN1 sediments.

Hole 317A—Manihiki Plateau

In Hole 317A a survey core was taken at approximately 410 meters, which yielded calcareous nannoplankton indicative of the middle Eocene Zone NP 15, overlain by some 10 cm of misplaced lowest upper Miocene (Zone NN 9). From 554 meters downward, continuous coring with some spacing in the lower part took place down to the terminal depth of 943.5 meters. The sequence revealed middle Maestrichtian, with approximately 60 cm of misplaced lower Eocene (nannoplankton Zone NP 12) on top (Core 2), to Barremian-Aptian (?) sediments in Cores 10 to 15. The calcareous nannoplankton in all Cretaceous cores with the exception of part of the Maestrichtian are badly preserved, and assemblages are diminished by solution, with *Watznaueria barnesae* and *Parhabdolithus embergeri* the only remaining identifiable species in the lower cores. In the Maestrichtian-Albian interval *Tetralithus trifidus* (FO, LO) T. aculeus (FO), *Marthasterites furcatus* (FO, LO), *Micula staurophora* (FO), *Eifellithus turriseiffeli* (FO), *Lithastrinus floralis* (FO), and *Predicosphaera cretacea* (FO) were among species used for age determination. Unconformities might be present between the middle Campanian and the Santonian (Core 6/Core 7) and the Santonian and lower Turonian (Core 7/Core 8), but due to low recovery and an obviously condensed section, this cannot be affirmed on the basis of the present material. *Watznaueria barnesae* is common or abundant in all samples down to Core 12, and then occasionally present down to Core 15. The first occurrence of *Eiffellithus turriseiffeli* is in Sample 317A-8, CC, where it is associated with common *Lithastrinus floralis* and frequent *Manivitella pemmatoidea.* The first occurrence of *L. floralis* was noted in Sample 317A-9-1, 29-30 cm, whereas *M. pemmatoidea* was found to have its first occurrence in Sample 317A-9-2, 127 cm. Other forms occasionally encountered are similar to *Zygodiscus erectus* and *Z. bussoni,* also *Parhabdolithus embergeri* was frequently noted especially in samples from Cores 7 to 10, and in samples from Cores 7 to 9 rare specimens occur which may be related to the form described as "*Markalius circumradiatus* (Stover) Perch-Nielsen" in

Manivit, 1971. However, due to the poor preservation and rare occurrence of species other than *W: barnesae* and *L. floralis*, a detailed study was not attempted. Below Core 9, sediments recovered do not contain *Predicosphaera cretacea* nor *Cruciellipsis cuvillieri*, which are reported as solution resistant. The interval between the last occurrence of *C. cuvillieri* and the first occurrence of *P. cretacea* thus is assigned to the Barremian and Aptian; however, Cores 10 to 15 may not represent this entire interval. Cores 16 to 30, below which basalt was encountered, proved to be barren of calcareous nannoplankton.

Hole 317B—Manihiki Plateau

Hole 317B is one of the best continuously sampled sections, as 45 cores were recovered from the sea floor to approximately 425 meters. All nannoplankton ones from the Recent NN 21 to the upper Eocene NP 17/18 (Core 39 at 358 m) were recovered with the exception of Zone NN 19 and part of Zone NN 18 due to recoring Core 2, which in a first attempt proved to be void. In Core 35 the Eocene/Oligocene boundary as indicated by Zones NP20/NP21 was penetrated four times, which probably is due to resampling and disturbance of material within the liner. Below Core 40 the recovery dropped to a minimum as abundant chert layers occurred at various depth. The lowest sample taken from the bit of Core 45 at 424.5 meters contained mixed material from the Pliocene, lower Oligocene, and mid-Eocene, but also contained a few forms from the lower Eocene listed in Table 6, among those the new species *Sphenolithus conspicuus* indicating Zone NP 12 (*Marthasterites tribrachiatus* Zone). Also, nannofossils show solution effects and heavy calcite overgrowth in certain genera, making age assignments less reliable. Preservation of the calcareous nannoplankton is poor throughout up to the upper Miocene, with a slight improvement in the Oligocene interval. In the higher parts of the upper Miocene and in the lower Pliocene preservation is moderate, tending to good in the upper Pliocene and Quaternary. Several species such as *Helicosphaera ampliaperta* in the Miocene, *Helicosphaera recta* in the Oligocene, *Isthmolithus recurvus* in the upper Eocene and lower Oligocene are missing in the tropical Pacific, as previously noted in the Leg 7 report (Martini and Worsley, 1971). In the Quaternary and Neogene the distribution of nannoplankton species is similar or identical with that reported in extensive fossil lists from the Equatorial Pacific Leg 7, and fossil lists will not be given in this report for the Neogene and Quaternary. Some remarks, however, seem necessary concerning the distribution of some species only recently described and which were not included in the Leg 7 fossil lists.

Discoaster altus (Plate 12, Figures 17, 18), first reported by Müller, 1974, from Zone NN 14 to lower part of Zone NN 15 in the western Indian Ocean, is present in samples between 317B-4-3, 30-31 cm and 317B-5-1, 30-31 cm, all assignable to the lower part of Zone NN 15, as *Ceratolithus tricorniculatus* was not found in these samples. *Sphenolithus delphix* (Plate 8, Figures 4-6; Plate 13, Figures 22-24), originally described from the eastern Equatorial Pacific from uppermost Oligocene (NP 25) to lowermost Miocene (NN 1, lower part) by Bukry (1973), was noted in samples from Core 25, belonging in the *Triquetrorhabdulus carinatus* Zone (NN 1). *Sphenolithus capricornutus* reported by Bukry and Percival (1971) from the same interval in the south Atlantic Ocean, is present in small specimens in Cores 22 and 23 (Zone NN 1), but is better developed in samples of equivalent age at Site 318. *Sphenolithus dissimilis* (Plate 8, Figures 2, 3; Plate 13, Figures 19-21) was found to range from Core 20 (NN 2) to Core 27 (NP 25), which is in accordance with the range published for the Blake Plateau in the Atlantic and for the Northwestern Pacific Ocean by Bukry and Percival (1971), and which was also reported from the *Catapsydrax dissimilis* Zone of the Cipero Formation in Trinidad. The occurrence of *Coccolithus abisectus* in the present material leaves some doubt of the usefulness of this species for the subdivision of the *Triquetrorhabdulus carinatus* Zone (Bukry, 1971), as several common occurrences were noted within Zone NN 1 (Cores 22 to 25) and it seems to occur far above NN 1 in the Mediterranean region in fair quantities.

Hole 318—Tuamotu Ridge

At Site 318 32 cores were recovered during spot coring from the sea floor down to the terminal depth of 745 meters. Only part of the middle Eocene was continuously cored (Cores 22 to 27). As full coverage of the history was not attempted due to operational considerations, only a limited number of calcareous nannoplankton zones were encountered in the lower Eocene to Recent sequence. According to the cores recovered and nannoplankton zones present, the Quaternary, Pliocene, and upper Miocene seem to be present without interruptions from 0 to approximately 250 meters (Core 9, standard nannoplankton Zone NN 9). Reworded middle Eocene nannoplankton species do occur in Core 2 (26 to 35.5 m) in layers with reefal debris, and include *Discoaster lodoensis, D. binodosus, D. barbadiensis, Cyclococcolithus formosus, Campylosphaera dela, Chiasmolithus grandis, Spehnolithus radians, Zygrhablithus bijugatus, Helicosphaera seminulum.* Between Core 9 (235.5 to 245 m) and Core 10 (265 to 273.5 m) a major unconformity is present, indicated by the absence of nannoplankton Zones NN 3 to NN 8, equivalent to the middle Miocene and part of the lower Miocene. Also core catcher 9 as well as the upper part of Core 10 contain a remarkable amount of redeposited nannoplankton from the NP 25 and lower NN 1 interval, nearly masking the true age. Probably part of Zone NN 1 is missing between Cores 10 and 11, as the upper NN 1 was not found in Core 11, but according to the thickness of zones identified should be present if continuous coring took place. Below Core 11 (at approximately 300 m) an obviously complete sequence was cored down to the lower Eocene Zone NP 13. At approximately 690 meters the otherwise calcareous sediments changed to green siltstones and limestones, with an increase of sedimentation rate, and are almost barren of calcareous nannoplankton in the basal part of the sedimentary sequence with a few exceptions. From the lowpr Oligocene downwards (Core 16, at approximately 440 m) nannoplankton assemblages indicate "nearshore environments," with *Zygrhablithus bijugatus* and representatives of the genera *Braarudosphaera, Micrantholithus,* and *Discolithina* occurring quite frequently.

TABLE 6
Calcareous Nannoplankton From the Lower Eocene to Upper Oligocene Interval in Hole 317B, and Indication of Standard Nannoplankton Zones[a]

Sample (Interval in cm)	*Bramletteius serraculoides*	*Campylosphaera dela*	*Chiasmolithus gigas*	*Chiasmolithus grandis*	*Chiasmolithus solitus*	*Chiasmolithus titus*	*Chiphragmalithus acanthodes*	*Chiphragmalithus alatus*	*Chiphragmalithus cristatus*	*Coccolithus abisectus*	*Coccolithus eopelagicus*	*Coccolithus pelagicus*	*Cyclococcolithus floridanus*	*Cyclococcolithus formosus*	*Cyclococcolithus gammation*	*Dictyococcites dictyodus*	*Discoaster barbadiensis*	*Discoaster deflandrei*	*Discoaster binodosus*	*Discoaster distinctus*	*Discoaster lodoensis*	*Discoaster saipanensis*	*Discoaster sublodoensis*	*Discoaster tani*	*Discolithina* sp.	*Ericsonia fenest./subdist.*	*Helicosphaera heezeni*	*Helicosphaera lophota*	*Helicosphaera seminulum*	*Lophodolithus nascens*	*Lophodolithus rotundus*	*Pedinocyclus larvalis*	*Reticulofenestra umbilica*	*Scyphosphaera expansa*	*Sphenolithus ciperoensis*	*Sphenolithus conspicuus*	*Sphenolithus dissimilis*	*Sphenolithus distentus*	*Sphenolithus furcatolithoides*	*Sphenolithus intercalaris*	*Sphenolithus obtusus*	*Sphenolithus orphanknolli*	*Sphenolithus pacificus*	*Sphenolithus predistentus*	*Sphenolithus pseudoradians*	*Sphenolithus radians*	*Sphenolithus* sp.	*Thoracosphaera prolata*	*Thoracosphaera* sp.	*Triquetrorhabdulus carinatus*	*Triquetrorhabdulus inversus*	*Zygrhabdolithus bijugatus*	Reworking	Preservation	Nannoplankton Zones
26-2, 95-96										X	cf.	X	X					X						cf.	X	cf.									X		X						X							X				PM	
26, CC										X		X	X					X						cf.	X	cf.									X		X						X							X				PM	NP25
27, CC										X	X	X	X					X						cf.		cf.									X		X						X							X				PM	
28-2, 55-56										X	X	X	X					X						cf.		cf.									X			X					X							?				PM	
28, CC										X	X	X	X					X						cf.	X	cf.									X			X					X	X						?				PM	NP24
29, CC										X	X	X	X					X						X		X									X			X					X	X	X									PM	
30, CC										X	X	X	X					X						X		X									X			X					X	X	X									PM	
31-1, 30-31										cf.	X	X	X			X		X						X		X							cf.					X					X	X										PM	
32, CC										cf.	X	X	X			X		X						X									cf.										X	X	X							cf.		PM	NP23
33, CC											X	X	X			X		X						X		X							cf.										X	X	X									P	
34-1, 30-31											X	X	X			X		X						X		X							X										X	X	X							X		P	NP22
34-6, 60-61	X										X	X	X	X		X								X		X							X										X	X	X									P	
34, CC	X										X	X	X	X		X								X		X							X										X	X										PM	NP21
35-6, 128-129	X										X	X	X	X		X								X									X							X			X	X										PM	
35, CC	X										X	X		X		X	X					X		X									X							X			X	X	X				X					PM	
36, CC	X										X	X		X		X	X					X		X									X							X			X		X				X					P	NP19/20
37-5, 75-76	X										X	X		X		X	X		X			X		X			X						X							X			X		X				X			cf.		PM	
37-6, 55-56	X			X							X	X		X		X	X					X		X	X								X							X			X		X							cf.		PM	
37, CC	X			X							X	X		X		X	X					X		X									X							X			X		X				X					PM	
38-1, 137-138	X	X		X							X	X		X		X	X					X		X			X	cf.				X	X							X	X		X		X				X		X			PM	NP17/18
38, CC	X	X		X		X					X	X		X		X	X					X		X			X					X	X							X	X		X		X	cf.			X		X	X		PM	
39-1, 30-31	X	X		X	X						X	X		X		X	X		X			X		X			X					X	X						X	X	X	X	X		X	X					X	X		PM	
39-2, 30-31		X		X	X	X					X	X		X			X		X			X		X	X							X	X	X					X			X	X		X	X		X	X		X	X		PM	NP16
39, CC		X		X	X	X					X	X		X			X		X					X	X		X		X			X	X						X			X				X	X	X	X		X	X		PM	
40-2, 30-31		X	X	X	X	X					X	X		X			X		X	X				X								X	X						X			X				X	X	X	X		X	X	(P)	PM	
40, CC		X	X	X	X	X		X	X		X	X		X			X							X				X					X						X			X				X	X	X	X		X			P	
41, CC		X	X	X	X						X	X		X			X		X					X				X					X						X			X				X	X	X	X		X	X		P	NP15
42-3, 1-2		X		X	X			X			X	X		X			X						X										cf.						X			X				X	X	X			X			P	
42, CC		X		X	X		X				X	X		X	X		X		X				X		X			X			X			X								X				X	X				X			P	NP14
43, CC		X		X	X		X				X	X		X	X		X		X				X							X												X				X	X				X			P	
44, CC		X			X						X	X		X			X		X		X																					X				X			X					P	NP13
45, CC				X	X							X					X				X															X										X								P	NP12

[a]Preservation: P = poor, PM = poor to moderate, M = moderate. Reworking: C = Upper Cretaceous, P = Paleocene.

In the Quaternary and Neogene occurrences of species are identical with those of Hole 317B and the Leg 7 material. Noteworthy is the occurrence of specimens of *Ceratolithus tricorniculatus* with a conspicuous horn (Plate 12, Figures 19, 20) in the higher part of Core 4, best developed in Sample 318-4-1, 30-31 cm, assignable to Zone NN 14 (*Discoaster asymmetricus* Zone). *Discoaster altus* was found to occur only in Section 6 and the core catcher of Core 4, also assignable to Zone NN 14, thus having a slightly different range as in Hole 317B, but still within the range reported by Müller, 1974. *Sphenolithus delphix* and *S. capricornutum* are present in Cores 11 and 12, and are figured in Plate 8, Figures 5, 6 and Figures 7-9, respectively. Both cores belong in the *Triquetrorhabdulus carinatus* Zone (NN 1). In the Oligocene and Eocene the distribution of nannoplankton species is the same as in Hole 317B, and Table 6 can be consulted for the ranges of particular species. Additional species not found in Hole 317B are *Cruciplacolithus staurion*, present in Sample 318-25, CC (Zone NP 15), *Chiasmolithus expansus*, found in Sample 318-28, CC (Zone NP 14), and *Discoaster mirus*, encountered in Sample 318-31-1, 106-107 cm (Zone NP 13). In the Quaternary and Pliocene part of the sequence the calcareous nannoplankton are well preserved, but become moderate to poor in the Miocene, as solution effects and heavy overgrowth on discoasters can be seen throughout the Miocene. In the Oligocene and upper Eocene solution effects are less obvious, but overgrowth is present in all nannoplankton species. With the change to the silty sedimentation in the middle Eocene preservation becomes very poor and species identification at certain levels is extremely difficult or impossible.

OLDEST NANNOPLANKTON ASSEMBLAGES RECOVERED ALONG THE LINE ISLANDS

Part of the drilling during Leg 33 was dedicated to provide data relative to the hot-spot problem (Schlanger et al., 1974). In this respect Sites 315 and 316 together with Site 165 of Leg 17 were of special interest, and as the nannoplankton was the fossil group on which the age determination of the termination of volcanism in this area was based, some comments on the lowest occurrences of nannofossils in Holes 165A, 315A, and 316 seem necessary. According to the hot-spot theory and the sea-floor spreading the northwestern Hole 165A should reveal the oldest nannoplankton assemblage and Hole 316 at the southeastern end of the Line Islands the youngest nannoplankton assemblage above the basalt.

In Hole 165A the oldest reliable nannoplankton assemblage was recovered in Core 21 (368 to 396 m) and was placed in the *Eiffellithus eximius* Zone by Roth (1973, p. 707). A nannoplankton assemblage found in cavings in Core 25 was also placed in the *Eiffellithus eximius* Zone, but nannoplankton from the Eocene was also noted in this particular core. The *Eiffellithus egimius* Zone was not used on Leg 33 due to the lack or scarcity of *E. eximius* and *Gartnerago obliquum*. The equivalent zones in Leg 33 usage are the *Tetralithus gothicus* Zone and *Tetralithus aculeus* Zone (Table 2), the boundary between these is indicated by the first occurrence of *T. gothicus*. Table 3A of Roth (1973, p. 707) shows the occurrence of *T. gothicus*, *B. parca*, and *E. eximius* in Sample 21, CC, thus belonging in the *T. gothicus* Zone, and according to the first occurrence of *Tetralithus trifidus* in Core 19 (321 to 340 m) probably in the lower part of the zone in question. Cores 22 to 24 were barren of nannofossils (Roth, 1973, p. 702), and examination of some additional samples from the limestone and the baked claystone just above the basalt proved to lack these fossils. Core 25 contained caved fragments and chips of various lithology including basalt throughout the core. An unwashed sample from the bottom of the core contained rare Cretaceous nannoplankton together with fairly common forms from the lower Eocene (e.g., *Discoaster diastypus*) and from the Oligocene/lower Miocene (e.g., *Discoaster* sp. of the *D. deflandrei* group, heavily overcalcified). However, a number of picked and cleaned claystone cavings ranging from reddish-brown to greenish-gray in color were barren of calcareous nannofossils or showed only rare specimens of *Watznaueria barnesae*, *Micula staurophora*, and *Cretarhabdus crenulatus* not sufficient for an age determination. Thus the oldest nannoplankton assemblage is that found in Core 21 belonging to the *T. gothicus* Zone, and indicating an age of approximately 76 m.y. B.P. It is underlain by at least 29 meters maximal 78 meters unfossiliferous sediments above the youngest basalt flow. Assuming a medium of approximately 40 meters unfossiliferous sediments between the first nannoplankton assemblage and the youngest basalt flow and an estimated sedimentation rate of 15 m/m.y. during the Late Cretaceous at this site, the minimum basement age is close to 79 m.y. B.P.

In Hole 315A the lowest nannoplankton assemblage was noted in Core 26 (911.0 to 920.5 m) where in the core catcher and Section 2 at 20-21 cm the uppermost part of the *Marthasterites furcatus* Zone was recovered with *M. furcatus* fairly common. In Sample 315A-26-1, 32-33 cm the first occurrence of *Tetralithus aculeus* was found (Table 4), indicating that the lowest nannoplankton assemblage has an age of approximately 80 m.y. B.P. Below Core 26 at least 70 meters maximal 82 meters of unfossiliferous sediments were recovered before the latest basalt flow was encountered in Core 30 (987.0 to 996.5 m). The sedimentation rate at this site seems to be similar to that at Site 165. Accordingly, some 5 m.y. can be added, and a minimum age of 85 m.y. B.P. for the youngest basalt seems realistic.

At Site 316 Core 30 (827.5 to 837.0.m) contained the lowest nannoplankton assemblage, which can be assigned to the *Tetralithus aculeus* Zone on the basis of a sample from the core catcher. As the first occurrences of *Tetralithus gothicus* were encountered just above the core catcher in Section 2 at 132-133 cm, it is the highest part of the *T. aculeus* Zone which can be considered as old as 77 m.y. B.P. However, in Site 316 basalt and the unfossiliferous sediments found at the earlier sites were not reached at the terminal depth of 837 meters, and the minimum age of 81-83 m.y. B.P. for the basement may be somewhat speculative although sedimentation rates and other data available were carefully considered (Schlanger et al, 1974), but the oldest nannoplankton assemblage encountered in this hole certainly is older than that found in Hole 165A.

The nannoplankton and deducted data from the three sites along the chain of the Line Islands do not seem to support the hot-spot theory inasmuch as the oldest basement was not found at the supposed Site 165 at the a more central position. Further on the supposed youngest basement of Site 316 probably is of the same age or may be even a little older than the basement of Site 165.

SECONDARY CALCITE GROWTH ON DISCOASTERS

Already noted in the course of the original descriptions of the first species of the genus *Discoaster* from Rotti, Indonesia, by Tan Sin Hok (1927) were specimens showing typical features of solution and secondary calcite growth, especially the alternating fusion of rays in six-rayed discoasters. This fusion of rays has been considered by several authors as characteristic of certain species (*Discoaster molengraaffi* Tan Sin Hok, 1927; Gardet, 1955; Stradner and Papp, 1961; *D. rotundus* cf. *molengraaffi* Manivit, 1959; *D. trinus* Stradner, 1961), but the condition may be found in any species of discoaster especially in six-rayed specimens as noted by Martini (1965) in a study based on Pacific deep-sea cores of Oligocene and Miocene age. With the material of the Deep Sea Drilling Project becoming available, calcareous nannoplankton assemblages with well-developed fusion of alternating rays were noted in various oceans and in various Tertiary strata, but were always associated with a low diversity in species due to solution of the more fragile forms in a given assemblage. Sturdy forms composed of relatively large calcite units, such as discoasters or species of the genera *Triquetrorhabdulus* and *Sphenolithus* together with only large coccoliths of the genera *Coccolithus, Reticulofenestra* and *Dictyococcites* are the only forms left in these solution-affected assemblages. Especially the discoasters seem to gain calcite from the solution of other species of the calcareous nannoplankton and other groups forming calcareous shells, and a step-by-step development from "normal" discoasters to such with fusion of alternating rays can be observed, finally leading to forms which are identical in their crystal development and although originated from entirely different species seem to represent an independent third species. The crystal development in relation to crystal faces was described in detail by Black (1972) and some results from a study on nannoplankton assemblages exposed to artificially simulated diagenetic effects were published by Adelseck et al. (1973), confirming the stages in the formation of fusion of alternating rays in discoasters.

A few stereoscan pictures, especially on Plate 12, are assembled to demonstrate the unusefulness of identifying species on the basis of alternating rays and the development from "normal" specimens to specimens showing the progressive fusion of alternating rays. Three specimens (Plate 7, Figure 7; Plate 11, Figures 1, 2) are identical in their crystal appearance and outline, but are from different stratigraphic levels and represent the final stage of crystallization of two different species. The specimen figured in Plate 11, Figure 1 is from a solution-affected assemblage of lower Eocene age (NP 12, *Marthasterites tribrachiatus* Zone) and originated from *Discoaster binodosus*, whereas specimens shown on Plate 11, Figure 2 and Plate 7, Figure 7 are from the middle Oligocene (NP 23, *Sphenolithus predistentus* Zone) and lower Miocene (NN 1, *Triquetrorhabdulus carinatus* Zone) and originated from *Discoaster deflandrei.* A solution-affected assemblage of lower Miocene age (NN 2, *Discoaster druggi* Zone) shown on Plate 11, Figure 12 is dominated by discoasters with secondary calcite growth and the sturdy distal shields of *Coccolithus pelagicus.* To demonstrate the progressive fusion of alternating rays two species from the lower Miocene (*Discoaster deflandrei* and *D. druggi*) are chosen showing relatively "normal" specimens in Plate 11, Figures 4 and 7, an intermediate stage with the beginning fusion of alternating rays and development of crystal faces on the rays in Plate 11, Figures 5 and 8, and the final stage of fusion with well-developed crystal faces and diminution of knots, bifurcations at the end of rays and other surface and outline features in specimens figured on Plate 11, Figures 6 and 9. These developments can be found in any other discoaster-species (compare Plate 11, Figure 3: *Discoaster exilis* with alternating rays fused together from the *Sphenolithus heteromorphus* Zone, NN 5, of the middle Miocene), not only six-rayed specimens are affected but also seven-rayed specimens show a tendency to develop a united crystal in fusing alternating rays and to suppress the seventh ray, as illustrated in Plate 11, Figure 11 for a seven-rayed specimen of *Discoaster deflandrei* from the lower Miocene *Triquetrorhabdulus carinatus* Zone (NN 1) of the Pacific Ocean.

Some of the new species of discoasters described in Hay et al. (1967) obviously are stages within the development to "discoaster-crystals" and can be found only in certain solution-affected assemblages, e.g., *Discoaster trinidadensis* seem to represent such a stage in the *Discoaster deflandrei*-crystal-lineage. These species need restudy in this respect. Meanwhile, in light of the above discussion, all discoaster species for which alternating rays fused together are among the diagnostic features for the species should be suppressed. These are *Discoaster molengraaffi* Tan Sin Hok (1927), *Discoaster geometricus* Brönniman and Stradner (1960), and *Discoaster trinus* Stradner (1971). In addition to material from Leg 33 samples from Leg 7 (Hole 66.0, lat 02°23.63'N, long 166°07.28'W, water depth 5293 m; Martini and Worsley, 1971); from the Scripps Institution Downwind-Expedition core DWHH 14 (lat 14°28'S, long 135°29'W, water depth 4400 m; Martini, 1965); and from Monsoon-Expedition core MSN 149 P (lat 09°23'N, long 145°15'W, water depth 5100 m; Martini, 1965) were used for this particular study and to make some of the stereoscan pictures.

NEW SPECIES AND SPECIES CONSIDERED

Among forms found in the Leg 33 material, some could not be attributed to known species with certainty as they were only found during scanning electron microscope studies and are from samples which are affected by dissolution and recrystallization or are represented by only one or two specimens. These include:

Transversopontis sp. (Plate 4, Figures 5, 6), middle Eocene, NP 16.
Cyclolithella sp. (Plate 5, Figures 1, 2), upper Eocene, NP 19/20.
Hayella sp. (Plate 5, Figure 3), upper Eocene, NP 19/20.
discoaster sp. (Plate 5, Figure 6), upper Eocene, NP 19/20.
Cyclococcolithus cf. *leptoporus* (Murray and Blackman) (Plate 7, Figure 12), lower Miocene, NN 1, (Plate 8, Figure 12), middle Miocene, NN 5.
Pontosphaera sp. (Plate 9, Figure 10), lower Pliocene, NN 12.
Oolithotus cf. *fragilis* (Lohmann) (Plate 9, Figure 10), lower Pliocene, NN 14.

Some species certainly are new and are described below. Type specimens are deposited in the "Naturmuseum und Forschungsinstitut Senckenberg," Frankfurt am Main, Germany, Catalogue Nos. SM.B 9712 to SM.B 9714.

Family MICRORHABDULACEAE Deflandre, 1963

Genus MICRORHABDULUS Deflandre, 1959

Microrhabdulus ? spiralis new species
(Plate 3, Figure 4; Plate 13, Figures 3-6)

Holotype: SM.B 9712, Plate 13, Figures 4-6.

Description: Short rods, truncated at both ends, with a relatively large central canal. Spiral arrangement of crystal units along rod. Under polarized light maximum birefringence when long axis in a position of 45° to crossed nicols.

Size: 7 to 12μ.

Remarks: Provisionally assigned to the Cretaceous genus *Microrhabdulus* Deflandre as it fits into the generic description, although in the Cretaceous representatives show a somewhat different arrangement of crystals and generally are much longer. Among approximately 100 specimens seen only one specimen seems to have a small basal plate. Broken stems of *Zygodiscus sigmoides* (*Z. simplex*, Bramlette and Sullivan, 1961, p. 151) show a slightly different spiral arrangement of calcite units and in most cases have the connecting rods to the basal plate still attached, which was never observed in the new species.

Type locality: Sample 317A-2-1, 30-31 cm, lower Eocene *Marthasterites tribrachiatus* Zone (NP 12).

Distribution: Few to abundant in Samples 317A-2-1, 10-11 cm to 317A-2-1, 60-61 cm and rare in Sample 317B-45, CC, Manihiki Plateau, Pacific Ocean, lower Eocene, *Marthasterites tribrachiatus* Zone (NP 12).

Family SPHENOLITHACEAE Vekshina, 1959

Genus SPHENOLITHUS Deflandre, 1952

Sphenolithus conspicuus new species
(Plate 3, Figures 1, 2; Plate 13, Figures 1-3)

Holotype: SM.B 9713, Plate 13, Figures 1-3.

Description: Basal part constructed of approximately 12 regularly placed calcite crystals, followed by some irregularly placed crystals arranged in what may be taken as two rows, from which a solid and prominent spine arises. The spine is clearly visible in normal light showing maximum relief when parallel to polarizer (Plate 13, Figure 1). In polarized light the spine has its maximum birefringence with the long axis in position of 45° to crossed nicols (Plate 13, Figure 2). In the position of the long axis parallel to crossed nicols only the basal part shows birefringence with a typical pair of tongue-like appearance of the upper part (Plate 13, Figure 3).

Size: 5 to 10μ.

Remarks: *Sphenolithus delphix* Bukry, 1973, has longer crystals in the basal part resulting in a different picture when viewed at a parallel position to crossed nicols (Plate 13, Figure 24) and occurs in the uppermost Oligocene and lower Miocene.

Type locality: Sample 317A-2-1, 30-31 cm, lower Eocene, *Marthasterites tribrachiatus* Zone (NP 12).

Distribution: Rare to common in Samples 317A-2-1, 10-11 cm to 317A-2-1, 60-61 cm, and 317B-45, CC, rare in Sample 316-9-1, 120-121 cm, Manihiki Plateau and Line Islands, Pacific Ocean. Lower Eocene, *Marthasterites tribrachiatus* Zone (NP 12) and *Discoaster binodosus* Zone (NP 11).

Sphenolithus intercalaris new species
(Plate 6, Figure 9; Plate 13, Figure 15, 26)

Holotype: SM.B 9714, Plate 6, Figure 9.

Description: Basal ring if present very small and reduced. The two spines are interlocked near their base by a knob-like structure (Plate 6, Figure 9), and taper to their upper end. In polarized light the knob-like structure is seen as an irregularity in the otherwise straight median line. Under polarized light this form shows maximum birefringence oriented with the long axis 45° to crossed nicols.

Size: 4 to 6μ.

Remarks: *S. intercalaris* is closely related to *S. predistentus*, but the latter lacks the knob-like structure and in general has a well-developed basal ring (Plate 6, Figure 11). The ranges of the two species show an overlap in the uppermost Eocpne/lowest Oligocene, and *S. predistentus* may have developed from *S. intercalaris*.

Type locality: Sample 317B-37, CC, middle/upper Eocene, combined *Discoaster saipanensis*/*Chiasmolithus oamaruensis* Zone (NP 17/18).

Distribution: Few to abundant in Samples 317B-35-6, 128-129 cm (NP 21) down to 317B-39-1, 30-31 cm (NP 16); in 317-3, CC, Manihiki Plateau; in Site 318 Core 16 (NP 21) to Core 20 (NP 16), Tuamotu Ridge; in Hole 315A lower part of Core 10 (NP 19/20), Line Islands; and in Site 44.0-Core 1 (NP 21) to Core 4 (NP 17/18), Horizon Ridge, all Pacific Ocean. Present also in the upper Eocene in Trinidad (Hospital Marl, Navet Formation, Sample TLL 238622) and in the Oceanic Formation of Barbados (Bath Cliff, Sample J.S.1076). Total known range from the middle Eocene *Discoaster tani nodifer* Zone (NP 16) to the lower Oligocene *Ericsonia subdisticha* Zone (NP 21).

Species considered in the Quaternary and Neogene are the same as listed in the Leg 7 nannoplankton chapter (Martini and Worsley) with the following additional species (figured on the plates):

Coccolithus abisectus Müller, 1970
Craspedolithus declivus Kamptner, 1963
Discoaster altus Müller, 1974
Gephyrocapsa aperta Kamptner, 1963
Pontosphaera discopora Schiller, 1925
Sphenolithus capricornutus Bukry and Percival, 1971
Sphenolithus delphix Bukry, 1973
Sphenolithus dissimilis Bukry and Percival, 1971
Scyphosphaera amphora Deflandre, 1942
Scyphosphaera kamptneri Müller, 1974
Scyphosphaera pulcherrima Deflandre, 1942
Syracosphaera ribosa (Kamptner) Borsetti and Cati, 1972
Umbilicosphaera mirabilis Lohmann, 1902.

In the Paleogene the following species were considered and are included in the fossil lists or are figured in the plates. Due to poor preservation in most samples, species of the genera *Coronocyclus*, *Cyclolithella*, and other "ring-like" species could not be determined with certainty and are not included in the fossil lists.

Bramletteius serraculoides Gartner, 1969
Campylosphaera dela (Bramlette and Sullivan) Hay and Mohler, 1967
Chiasmolithus bidens (Bramlette and Sullivan) Hay and Mohler, 1967
Chiasmolithus californicus (Sullivan) Hay and Mohler, 1967
Chiasmolithus consuetus (Bramlette and Sullivan) Hay and Mohler, 1967
Chiasmolithus danicus (Brotzen) Hay and Mohler, 1967
Chiasmolithus expansus (Bramlette and Sullivan) Gartner, 1970
Chiasmolithus gigas (Bramlette and Sullivan) Radomski, 1968
Chiasmolithus grandis (Bramlette and Riedel) Radomski, 1968
Chiasmolithus solitus (Bramlette and Sullivan) Locker, 1968
Chiasmolithus titus Gartner, 1970
Chiphragmalithus acanthodes Bramlette and Sullivan, 1961
Chiphragmalithus alatus (Martini) Martini, 1969
Chiphragmalithus cristatus (Martini, Bramlette, and Sullivan, 1961
Coccolithus abisectus Müller, 1970
Coccolithus eopelagicus (Bramlette and Riedel) Bramlette and Sullivan, 1961
Coccolithus pelagicus (Wallich) Schiller, 1930
Cruciplacolithus staurion (Bramlette and Sullivan) Gartner, 1971
Cruciplacolithus tenuis (Stradner) Hay and Mohler, 1967
Cyclococcolithus floridanus (Roth and Hay) Müller, 1970
Cyclococcolithus formosus Kamptner, 1963
Cyclococcolithus gammation (Bramlette and Sullivan) Sullivan, 1964
Dictyococcites dictyodus (Deflandre and Fert) Martini, 1969
Discoaster barbadiensis Tan Sin Hok, 1927
Discoaster binodosus Martini, 1958
Discoaster deflandrei Bramlette and Riedel, 1954
Discoaster diastypus Bramlette and Sullivan, 1961
Discoaster distinctus Martini, 1958
Discoaster gemmeus Stradner, 1959
Discoaster lodoensis Bramlette and Riedel, 1954
Discoaster mirus Deflandre, 1954
Discoaster multiradiatus Bramlette and Riedel, 1954
Discoaster saipanensis Bramlette and Riedel, 1954
Discoaster sublodoensis Bramlette and Sullivan, 1961
Discoaster tani Bramlette and Riedel, 1954
Discolithina sp.
Ellipsolithus macellus (Bramlette and Sullivan) Sullivan, 1964
Ericsonia cava (Hay and Mohler) Perch-Nielsen, 1969
Ericsonia fenestrata (Deflandre and Fert) Stradner, 1968
Ericsonia subdisticha (Roth and Hay) Roth, 1969
Fasciculithus involutus Bramlette and Sullivan, 1961
Fasciculithus tympaniformis Hay and Mohler, 1967
Helicosphaera heezeni (Bukry) Jafar and Martini, 1975
Helicosphaera lophota (Bramlette and Sullivan) Jafar and Martini, 1975

Helicosphaera seminulum (Bramlette and Sullivan) Jafar and Martini, 1975
Heliolithus cantabriae Perch-Nielsen, 1971
Heliolithus riedeli Bramlette and Sullivan, 1961
Heliolithus sp.
Lophodolithus nascens Bramlette and Sullivan, 1961
Lophodolithus rotundus Bukry and Percival, 1971
Markalius inversus (Deflandre) Bramlette and Martini, 1964
Marthasterites tribrachiatus (Bramlette and Riedel) Deflandre, 1959
Neochiastozygus concinnus (Martini) Perch-Nielsen, 1971
Pedinocyclus larvalis (Bukry and Bramlette) Loeblich and Tappan, 1973
Prinsius bisulcus (Stradner) Hay and Mohler, 1967
Reticulofenestra umbilica (Levin) Martini and Ritzkowski, 1968
Scyphosphaera expansa Bukry and Percival, 1971
Sphenolithus ciperoensis Bramlette and Wilcoxon, 1967
Sphenolithus dissimilis Bukry and Percival, 1971
Sphenolithus distentus (Martini) Bramlette and Wilcoxon, 1967
Sphenolithus furcatolithoides Locker, 1967
Sphenolithus obtusus Bukry, 1971
Sphenolithus orphanknolli Perch-Nielsen, 1971
Sphenolithus pacificus Martini, 1965
Sphenolithus predistentus Bramlette and Wilcoxon, 1967
Sphenolithus pseudoradians Bramlette and Wilcoxon, 1967
Sphenolithus radians Deflandre, 1954
Sphenolithus sp.
Thoracosphaera prolata Bukry and Bramlette, 1969
Thoracosphaera sp.
Toweius craticulus Hay and Mohler, 1967
Toweius eminens (Bramlette and Sullivan) Perch-Nielsen, 1971
Triquetrorhabdulus carinatus Martini, 1965
Triquetrorhabdulus inversus Bukry and Bramlette, 1969
Zygodiscus sigmoides Bramlette and Sullivan, 1961
Zygrhablithus bijugatus (Deflandre) Deflandre, 1959

In the Cretaceous the species diversity is heavily reduced by dissolution, therefore only a limited number occur in the fossil list of Hole 314A covering the Santonian to Maestrichtian interval. In the Barremian/Turonian interval preservation is too poor to give any decent fossil list and considerations are restricted to sturdy forms, which are more solution resistant. A few examples from the Albian are figured on Plate 1 and are included here.

Ahmuellerella octoradiata (Gorka) Reinhardt, 1966
Arkhangelskiella cymbiformis Vekshina, 1959
Broinsonia parca (Stradner) Bukry, 1969
Chiastozygus amphipons (Bramlette and Martini) Gartner, 1968
Cretarhabdus crenulatus Bramlette and Martini, 1964
Cribrosphaerella ehrenbergi Archangelsky, 1912
Cruciellipsis cuvillieri (Manivit) Thierstein, 1971
Cylindralithus gallicus (Stradner) Bramlette and Martini, 1964
Cylindralithus serratus Bramlette and Martini, 1964
Eiffellithus eximius (Stover) Perch-Nielsen, 1968
Eiffellithus turriseiffeli (Deflandre) Reinhardt, 1965
Gartnerago obliquum (Stradner) Reinhardt, 1970
Glaukolithus diplogrammus (Deflandre) Reinhardt, 1965
Lithastrinus floralis Stradner, 1962
Lithraphidites carniolensis Deflandre, 1963
Lithraphidites helicoideus (Deflandre) Deflandre, 1963
Lithraphidites quadratus Bramlette and Martini, 1964
Manivitella pemmatoidea (Deflandre) Thierstein, 1971
Markalius circumradiatus (Stover) Perch-Nielsen, 1968
Marthasterites furcatus Deflandre, 1959
Microrhabdulus decoratus Deflandre, 1959
Micula staurophora (Gardet) Stradner, 1963
Parhabdolithus embergeri (Noel) Stradner, 1963
Polycostella senaria Thierstein, 1971
Predicosphaera cretacea (Archangelsky) Gartner, 1968
Tranolithus sp.
Tetralithus aculeus (Stradner) Gartner, 1968
Tetralithus gothicus Deflandre, 1959
Tetralithus cf. *obscurus* Deflandre, 1959
Tetralithus trifidus (Stradner) Bukry, 1973
Watznaueria barnesae (Black) Perch-Nielsen, 1968
Watznaueria communis Reinhardt, 1966
Zygodiscus sp.

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PLATE 1

Cretaceous Calcareous Nannoplankton

Figure 1	cf. *Polycostella senaria* Thierstein, 1971. 6500 ×, proximal side. Sample 317A-9-2, 40-41 cm, lower/middle Albian.
Figure 2	*Watznaueria communis* Reinhardt, 1966. 6500 ×, distal side. Sample 317A-9-2, 40-41 cm, lower/middle Albian.
Figure 3	*Tranolithus* sp. 6500 ×, proximal side. Sample 317A-9-2, 40-41 cm, lower/middle Albian.
Figure 4	*Marthasterites furcatus* Deflandre, 1959. 6500 ×, overcalcified specimen. Sample 317-A-7-1, 55-56 cm, Santonian, *Marthasterites furcatus* Zone.
Figure 5	*Lithastrinus floralis* Stradner, 1962. 6500 ×, side view. Sample 317A-7-1, 55-56 cm, Santonian, *Marthasterites furcatus* Zone.
Figure 6	*Watznaueria barnesae* (Black) Perch-Nielsen, 1968. 6500 ×, proximal side. Sample 315A-25-3, 30-31 cm, lower Campanian, *Tetralithus aculeus* Zone.
Figure 7	*Watznaueria barnesae* (Black) Perch-Nielsen 1968. 6500 ×, distal side. Sample 315A-25-3, 30-31 cm, lower Campanian, *Tetralithus aculeus* Zone.
Figure 8	*Broinsonia parca* (Stradner) Bukry, 1969. 3250 ×, distal side. Sample 315A-25-3, 30-31 cm, lower Campanian, *Tetralithus aculeus* Zone.
Figure 9	*Predicosphaera cretacea* (Archangelsky) Gartner, 1968. 6500 ×, side view. Sample, 315A-25-3, 30-31 cm, lower Campanian, *Tetralithus aculeus* Zone
Figure 10	*Cylindralithus serratus* Bramlette and Martini, 1964. 6500 ×, incomplete specimen, basal view. Sample 316-26, CC, upper Campanian/lower Maestrichtian, *Tetralithus trifidus* Zone.
Figure 11	*Tetralithus trifidus* (Stradner) Bukry, 1973. 6500 ×, short-rayed form. Sample 315A-21-1, 110-111 cm, upper Campanian/lower Maestrichtian, *Tetralithus trifidus* Zone.
Figure 12	*Micula staurophora* (Gardet) Stradner, 1963. 6500 ×, overcalcified specimen. Sample 315A-21-1, 110-111 cm, upper Campanian/lower Maestrichtian, *Tetralithus trifidus* Zone.

PLATE 1

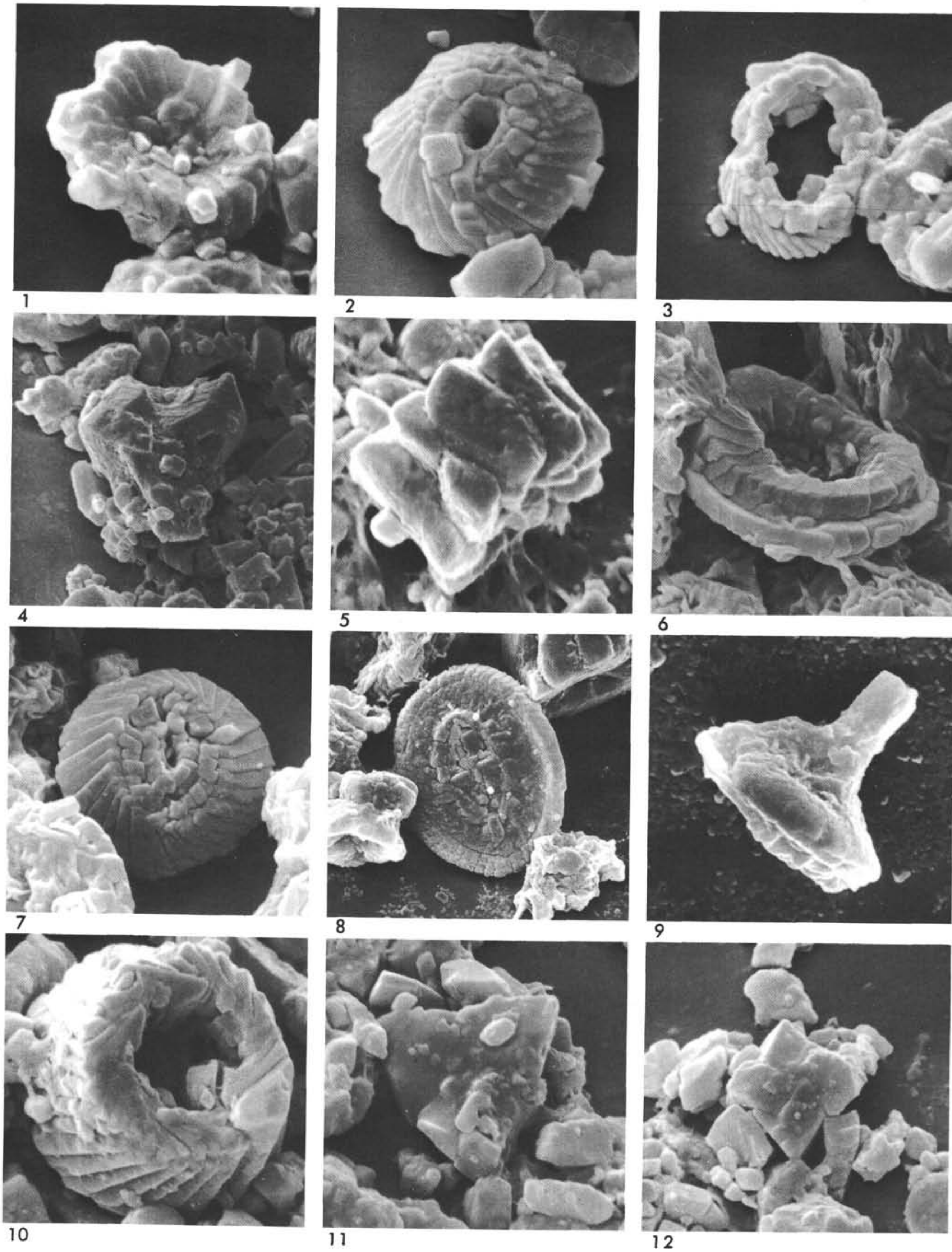


PLATE 2

Paleocene Calcareous Nannoplankton

Figure 1 *Ericsonia cava* (Hay and Mohler) Perch-Nielsen, 1969.
6500 ×, distal side.
Sample 316-17, CC, lower Paleocene, NP 3/4.

Figure 2 *Toweius craticulus* Hay and Mohler, 1967.
6500 ×, distal side.
Sample 316-17, CC, lower Paleocene, NP 3/4.

Figure 3 *Fasciculithus* sp. ?
6500 ×, top view.
Sample 316-15-1, 130-131 cm, upper Paleocene, NP 5.

Figure 4 *Ericsonia cava* (Hay and Mohler) Perch-Nielsen, 1969.
3250 ×, distal side.
Sample 316-15-1, 130-131 cm, upper Paleocene, NP 5.

Figure 5 *Fasciculithus tympaniformis* Hay and Mohler, 1967.
6500 ×, oblique view.
Sample 316-15-1, 130-131 cm, upper Paleocene, NP 5.

Figure 6 *Heliolithus* cf. *cantabriae* Perch-Nielsen, 1971.
6500 ×, side view.
Sample 316-11, CC, upper Paleocene, NP 9.

Figure 7 *Discoaster gemmeus* Stradner, 1959.
3250 ×.
Sample 316-11, CC, upper Paleocene, NP 9.

Figure 8 *Discoaster* cf. *diastypus* Bramlette and Sullivan, 1961.
3250 ×.
Sample 316-11, CC, upper Paleocene, NP 9.

Figure 9 *Discoaster* cf. *diastypus* Bramlette and Sullivan, 1961.
6500 ×.
Sample 316-11, CC, upper Paleocene, NP 9.

Figure 10 *Discoaster multiradiatus* Bramlette and Riedel, 1954.
3250 ×.
Sample 316-11, CC, upper Paleocene, NP 9.

Figure 11 *Ericsonia cava* (Hay and Mohler) Perch-Nielsen, 1969.
3250 ×, distal side.
Sample 316-11, CC, upper Paleocene, NP 9.

Figure 12 *Ericsonia cava* (Hay and Mohler) Perch-Nielsen, 1969.
3250 ×, proximal side.
Sample 316-11, CC, upper Paleocene, NP 9.

PLATE 2

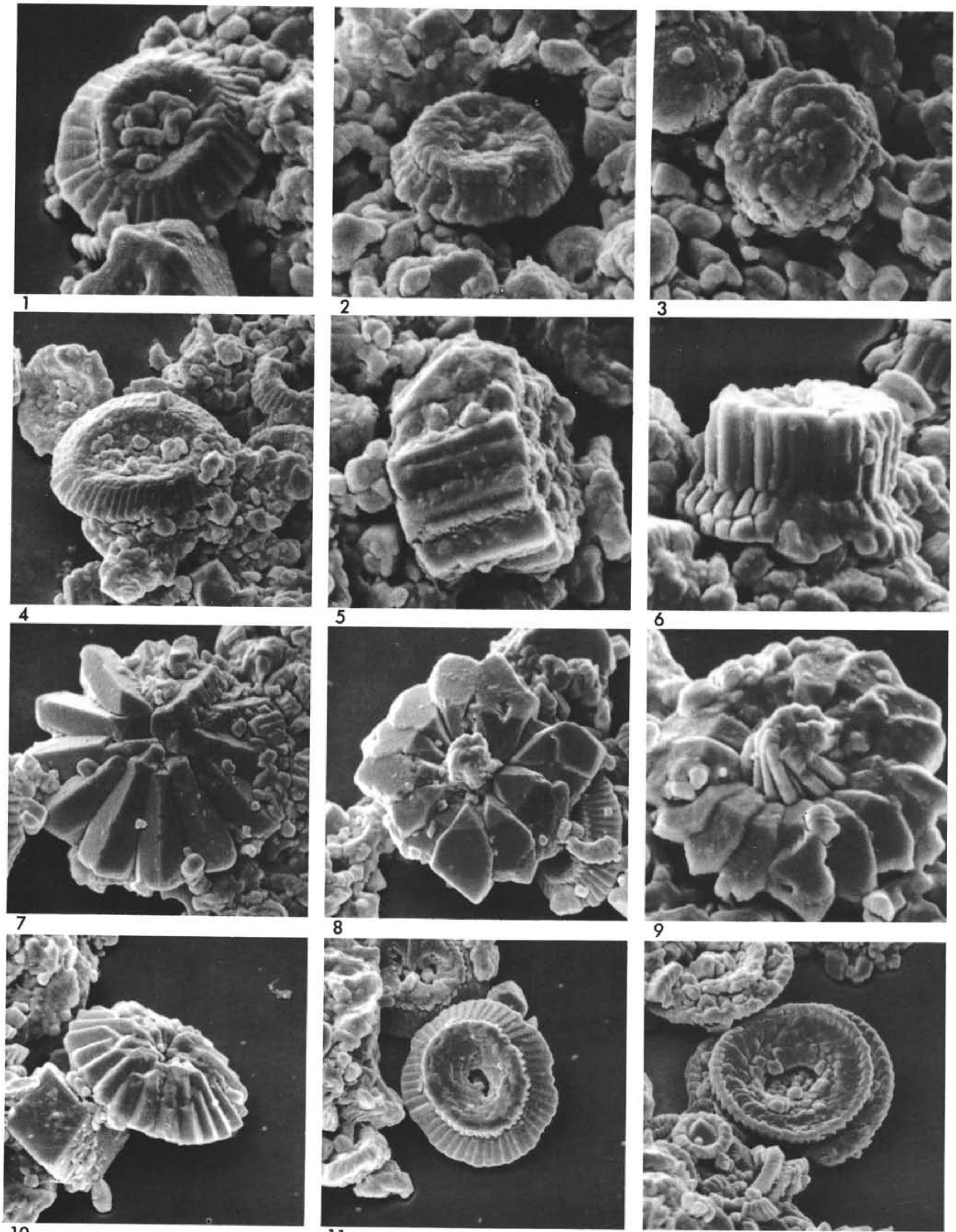


PLATE 3

Lower and Middle Eocene Calcareous Nannoplankton

Figure 1	*Sphenolithus conspicuus* new species. 6500 ×. Sample 317A-2-1, 30-31 cm, lower Eocene, NP 12.
Figure 2	*Sphenolithus* cf. *conspicuus* new species. 6500 ×. Sample 317A-2-1, 30-31 cm, lower Eocene, NP 12.
Figure 3	*Sphenolithus* sp. 6500 ×. Sample 317A-2-1, 30-31 cm, lower Eocene, NP 12.
Figure 4	*Microrhabdulus* cf. *spiralis* new species. 3250 ×. Sample 317A-2-1, 30-31 cm, lower Eocene, NP 12.
Figure 5	*Discoaster* cf. *lodoensis* Bramlette and Riedel, 1954. 3250 ×. Sample 317A-2-1, 30-31 cm, lower Eocene, NP 12.
Figure 6	*Discoaster* cf. *gemmeus* Stradner, 1959. 6500 ×. Sample 317A-2-1, 30-31 cm, lower Eocene, NP 12.
Figure 7	*Sphenolithus orphanknolli* Perch-Nielsen, 1971. 6500 ×. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 8	*Sphenolithus furcatolithoides* Locker, 1967. 6500 ×. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 9	*Sphenolithus furcatolithoides* Locker, 1967. 6500 ×. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 10	*Discoaster saipanenis* Bramlette and Riedel, 1954. 6500 ×. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 11	*Chiasmolithus grandis* (Bramlette and Riedel) Radomski, 1968. 3250 ×. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 12	*Thoracosphaera* sp. 1300 ×. Sample 317B-39, CC, middle Eocene, NP 16.

PLATE 3

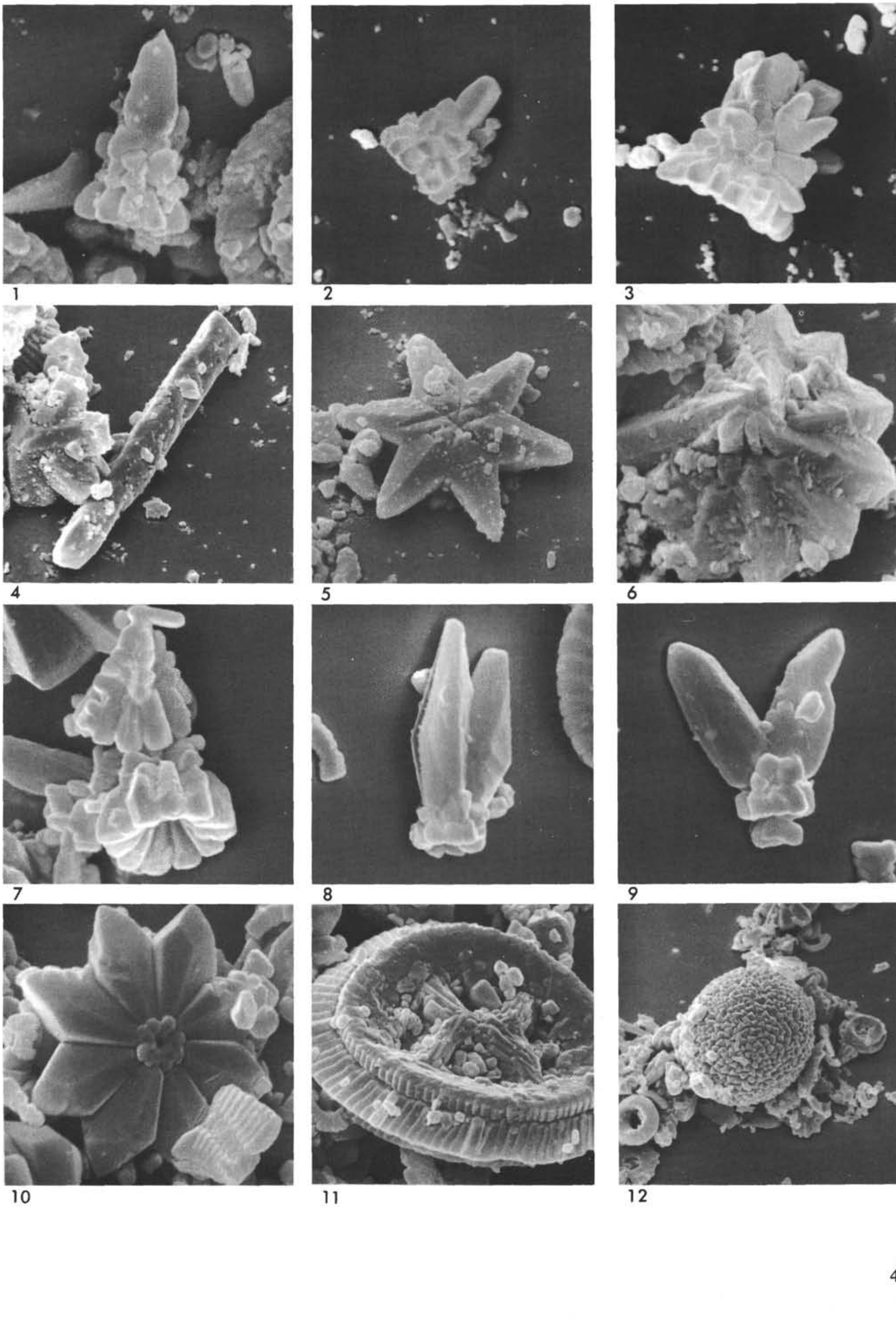


PLATE 4

Middle and Upper Eocene Calcareous Nannoplankton

Figure 1	*Helicosphaera heezeni* (Bukry) Jafar and Martini, 1975. 3250 ×, distal side. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 2	*Helicosphaera heezeni* (Bukry) Jafar and Martini, 1975. 3250 ×, proximal side. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 3	*Chiasmolithus titus* Gartner, 1970. 6500 ×, distal side. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 4	*Discoaster* cf. *gemmeus* Stradner, 1959. 6500 ×. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 5	*Transversopontis* sp. 6500 ×. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 6	*Transversopontis* sp. 6500 ×. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 7	*Pedinocyclus larvalis* (Bukry and Bramlette) Loeblich and Tappan, 1973. 6500 ×, proximal side. Sample 317B-38, CC, middle/upper Eocene, NP 17/18.
Figure 8	*Pedinocyclus larvalis* (Bukry and Bramlette) Loeblich and Tappan, 1973. 6500 ×, distal side. Sample 317B-38, CC, middle/upper Eocene, NP 17/18.
Figure 9	*Reticulofenestra umbilica* (Levin) Martini and Ritzkowski, 1968. 3250 ×, proximal side. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 10	*Reticulofenestra umbilica* (Levin) Martini and Ritzkowski, 1968. 3250 ×, distal side. Sample 317B-36, CC, upper Eocene, NP 19/20.
Figure 11	*Coccolithus eopelagicus* (Bramlette and Riedel) Bramlette and Sullivan, 1961. 3250 ×, proximal side. Sample 317B-36, CC, upper Eocene, NP 19/20.
Figure 12	*Coccolithus eopelagicus* (Bramlette and Riedel) Bramlette and Sullivan, 1961. 3250 ×, distal side. Sample 317B-36, CC, upper Eocene, NP 19/20.

PLATE 4

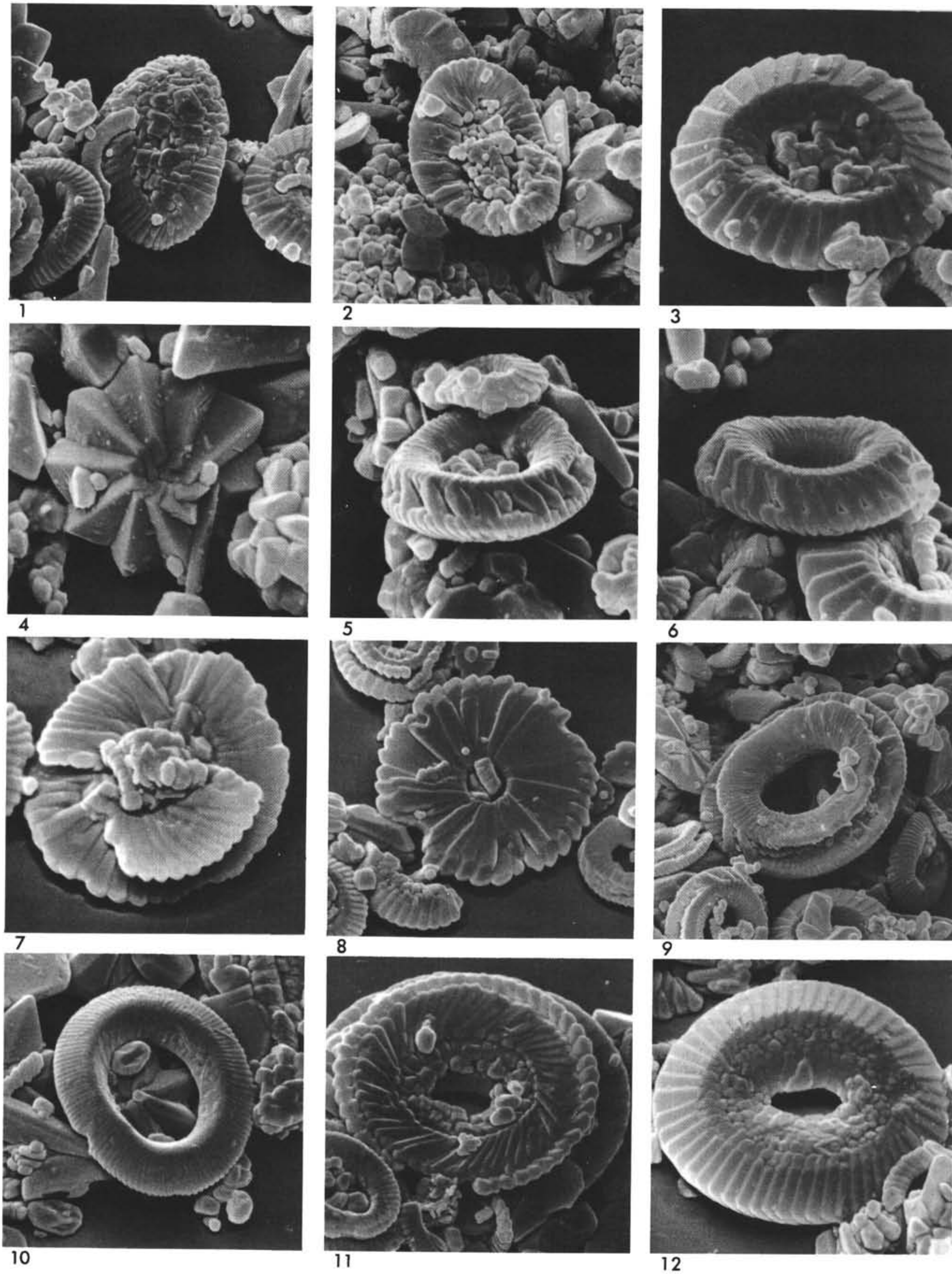


PLATE 5

Upper Eocene Calcareous Nannoplankton

Figure 1	*Cyclolithella* sp. 6500 ×, side view. Sample 317B-36, CC, upper Eocene, NP 19/20.
Figure 2	*Cyclolithella* sp. 6500 ×, oblique side view. Sample 317B-35, CC, upper Eocene, NP 19/20.
Figure 3	*Hayella* sp. 6500 ×. Sample 317B-35, CC, upper Eocene, NP 19/20.
Figure 4	*Discoaster barbadiensis* Tan Sin Hok, 1927. 3250 ×. Sample 317B-36, CC, upper Eocene, NP 19/20.
Figure 5	*Discoaster saipanensis* Bramlette and Riedel, 1954. 3250 ×. Sample 317B-36, CC, upper Eocene, NP 19/20.
Figure 6	*Discoaster* sp. 3200 ×. Sample 317B-35, CC, upper Eocene, NP 19/20.
Figure 7	*Discoaster tani* Bramlette and Riedel, 1954. 3250 ×. Sample 317B-36, CC, upper Eocene, NP 19/20.
Figure 8	*Discoaster tani* Bramlette and Riedel, 1954. 3250 ×. Sample 317B-35, CC, upper Eocene, NP 19/20.
Figure 9	*Sphenolithus* sp. cf. *S. moriformis* (Brönnimann and Stradner) Bramlette and Wilcoxon, 1967. 6500 ×. Sample 317B-35, CC, upper Eocene, NP 19/20.
Figure 10	*Dictyococcites dictyodus* (Deflandre and Fert) Martini, 1969. 3250 ×, distal side. Sample 317B-35, CC, upper Eocene, NP 19/20.
Figure 11	*Dictyococcites dictyodus* (Deflandre and Fert) Martini, 1969. 3250 ×, proximal side. Sample 317B-35, CC, upper Eocene, NP 19/20.
Figure 12	*Cyclococcolithus formosus* Kamptner, 1963. 6500 ×, distal side. Sample 317B-35, CC, upper Eocene, NP 19/20.

PLATE 5

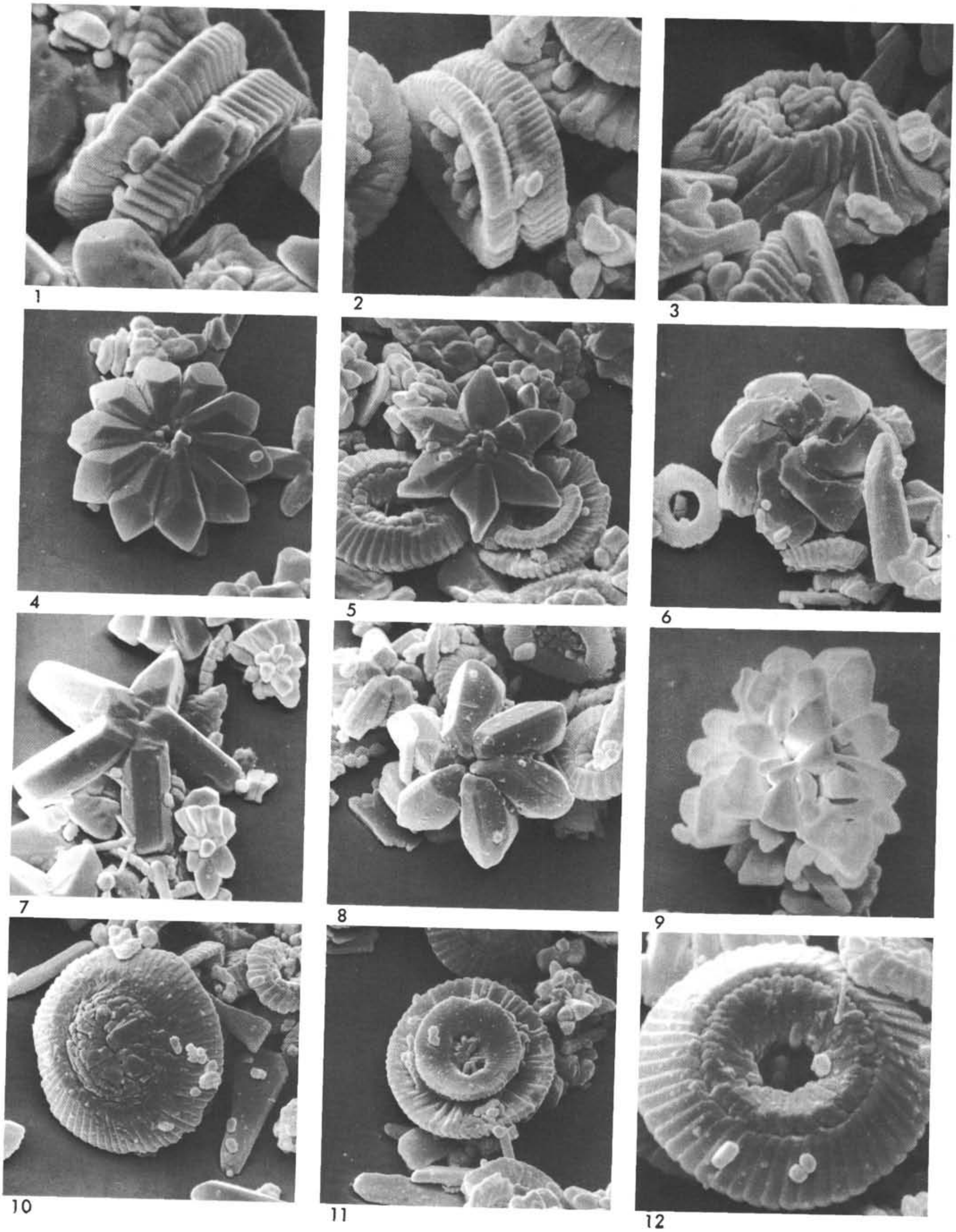


PLATE 6

Middle Eocene to Middle Oligocene Calcareous Nannoplankton

Figure 1	*Sphenolithus pseudoradians* Bramlette and Wilcoxon, 1967. 6500 ×. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 2	*Sphenolithus pseudoradians* Bramlette and Wilcoxon, 1967. 6500 ×. Sample 317B-38, CC, middle/upper Eocene, NP 17/18.
Figure 3	*Sphenolithus pseudoradians* Bramlette and Wilcoxon, 1967. 6500 ×. Sample 317B-35, CC, upper Eocene, NP 19/20.
Figure 4	*Sphenolithus orphanknolli* Perch-Nielsen, 1971. 6500 ×, basal part, side view. Sample 317B-39, CC, middle Eocene, NP 16.
Figure 5	*Sphenolithus orphanknolli* Perch-Nielsen, 1971. 6500 ×. Sample 317B-38, CC, middle/upper Eocene, NP 17/18.
Figure 6	*Sphenolithus* cf. *radians* Deflandre, 1954. 6500 ×. Sample 317B-38, CC, middle/upper Eocene, NP 17/18.
Figure 7	*Sphenolithus obtusus* Bukry, 1971. 6500 ×. Sample 317B-38, CC, middle/upper Eocene, NP 17/18.
Figure 8	*Sphenolithus obtusus* Bukry, 1971. 6500 ×. Sample 317B-38, CC, middle/upper Eocene, NP 17/18.
Figure 9	*Sphenolithus intercalaris* new species. 6500 ×. Holotype SM.B 9714. Sample 317B-37, CC, middle/upper Eocene, NP 17/18.
Figure 10	*Sphenolithus predistentus* Bramlette and Wilcoxon, 1967. 6500 ×. Sample 317B-32, CC, middle Oligocene, NP 23.
Figure 11	*Sphenolithus predistentus* Bramlette and Wilcoxon, 1967. 6500 ×. Sample 317B-32, CC, middle Oligocene, NP 23.
Figure 12	*Sphenolithus predistentus* Bramlette and Wilcoxon, 1967. 6500 × spinose form. Sample 317B-32, CC, middle Oligocene, NP 23.

PLATE 6

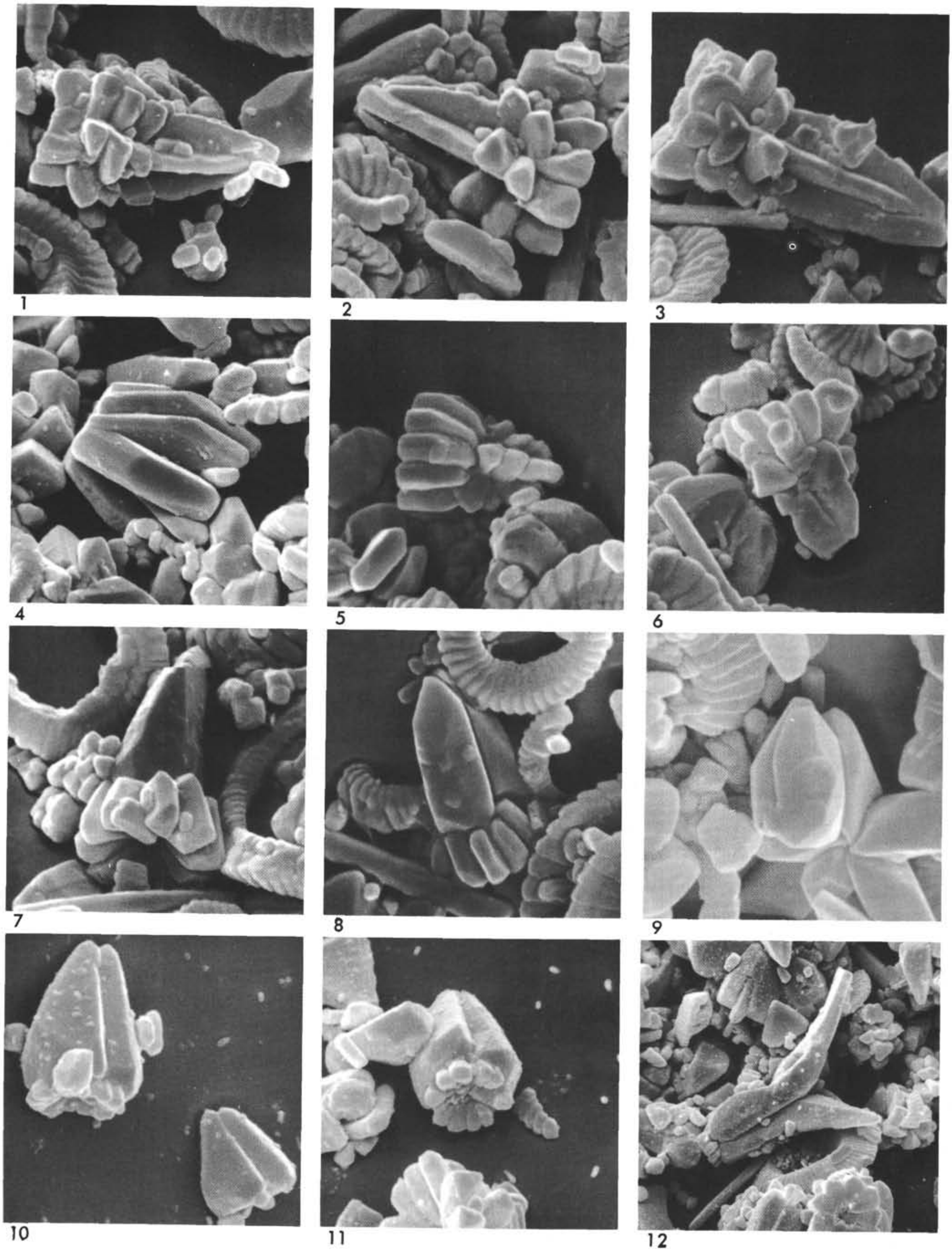


PLATE 7

Middle Oligocene and Lower Miocene Calcareous Nannoplankton

Figure 1	*Coccolithus eopelagicus* (Bramlette and Riedel) Bramlette and Sullivan, 1961. 3250 ×, proximal side. Sample 317B-32, CC, middle Oligocene, NP 23.
Figure 2	*Coccolithus eopelagicus* (Bramlette and Riedel) Bramlette and Sullivan, 1961. 3250 ×, proximal side. Sample 317B-32, CC, middle Oligocene, NP 23.
Figure 3	*Cyclococcolithus floridanus* (Roth and Hay) Müller, 1970. 6500 ×, proximal side. Sample 317B-32, CC, middle Oligocene, NP 23.
Figure 4	*Discoaster tani* Bramlette and Riedel, 1954. 3250 ×. Sample 317B-32, CC, middle Oligocene, NP 23.
Figure 5	*Sphenolithus pacificus* Martini, 1965. 6500 ×. Sample 317B-32, CC, middle Oligocene, NP 23.
Figure 6	*Sphenolithus pacificus* Martini, 1965. 6500 ×, basal view. Sample 317B-32, CC, middle Oligocene, NP 23.
Figure 7	*Discoaster* sp. ex *D. deflandrei*-group. 6500 ×, overcalcified specimen showing crystal faces and alternating rays fused together. Sample 318-11-1, 30-31 cm, lower Miocene, NN 1.
Figure 8	*Coccolithus abisectus* Müller, 1970. 3250 ×, proximal side. Sample 317B-25-6, 29-30 cm, lower Miocene, NN 1.
Figure 9	*Cyclococcolithus floridanus* (Roth and Hay) Müller, 1970. 3250 ×. Sample 318-11-1, 30-31 cm, lower Miocene, NN 1.
Figure 10	*Coccolithus eopelagicus* (Bramlette and Riedel) Bramlette and Sullivan, 1961. 6500 ×, distal side. Sample 318-11-1, 30-31 cm, lower Miocene, NN 1.
Figure 11	*Cyclococcolithus floridanus* (Roth and Hay) Müller, 1970. 3250 ×, proximal side. Sample 318-11-1, 30-31 cm, lower Miocene, NN 1.
Figure 12	*Cyclococcolithus* cf. *leptoporus* (Murray and Blackman) Kamptner, 1954. 6500 ×, distal side. Sample 318-11-1, 30-31 cm, lower Miocene, NN 1.

PLATE 7

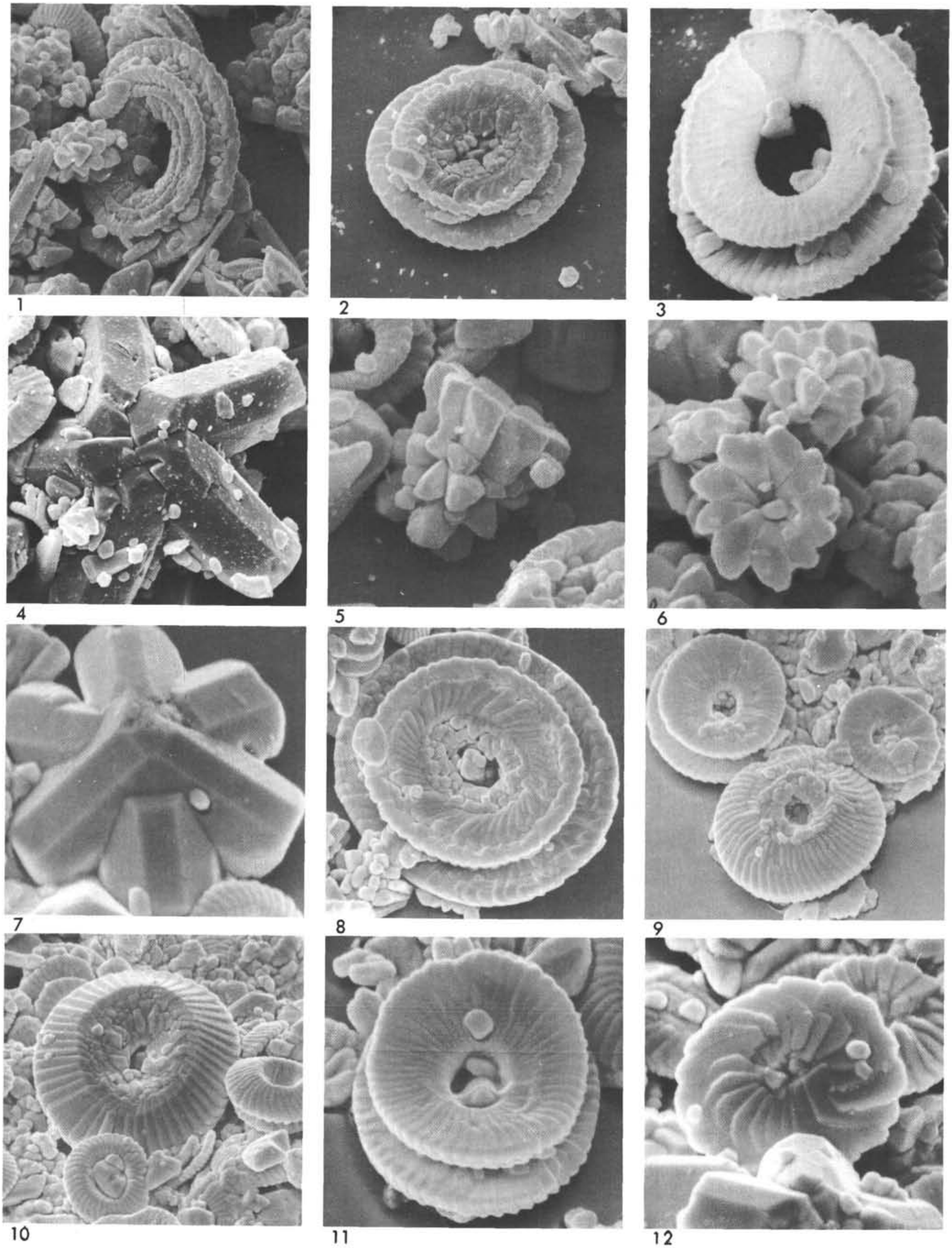


PLATE 8

Lower and Middle Miocene Calcareous Nannoplankton

Figure 1	*Sphenolithus* sp. 6500 ×. Sample 318-11-1, 30-31 cm, lower Miocene, NN 1.
Figure 2, 3	*Sphenolithus dissimilis* Bukry and Percival, 1971. 6500 ×. Sample 317B-25-6, 29-30 cm, lower Miocene, NN 1.
Figure 4	*Sphenolithus delphix* Bukry, 1973. 6500 ×. Sample 317B-25-6, 29-30 cm, lower Miocene, NN 1.
Figures 5, 6	*Sphenolithus delphix* Bukry, 1973. Sample 318-11-1, 30-31 cm, lower Miocene, NN 1. 5. 6500 ×. 6. 3250 ×.
Figures 7-9	*Sphenolithus capricornutus* Bukry and Percival, 1971. 6500 ×. Sample 318-11-1, 30-31 cm, lower Miocene, NN 1.
Figures 10, 11	*Sphenolithus heteromorphus* Deflandre, 1953. 6500 ×. Sample 317B-18, CC, middle Miocene, NN 5.
Figure 12	*Cyclococcolithus* cf. *leptoporus* (Murray and Blackman) Kamptner, 1954. 6500 ×, distal side. Sample 317B-18, CC, middle Miocene, NN 5.

PLATE 8

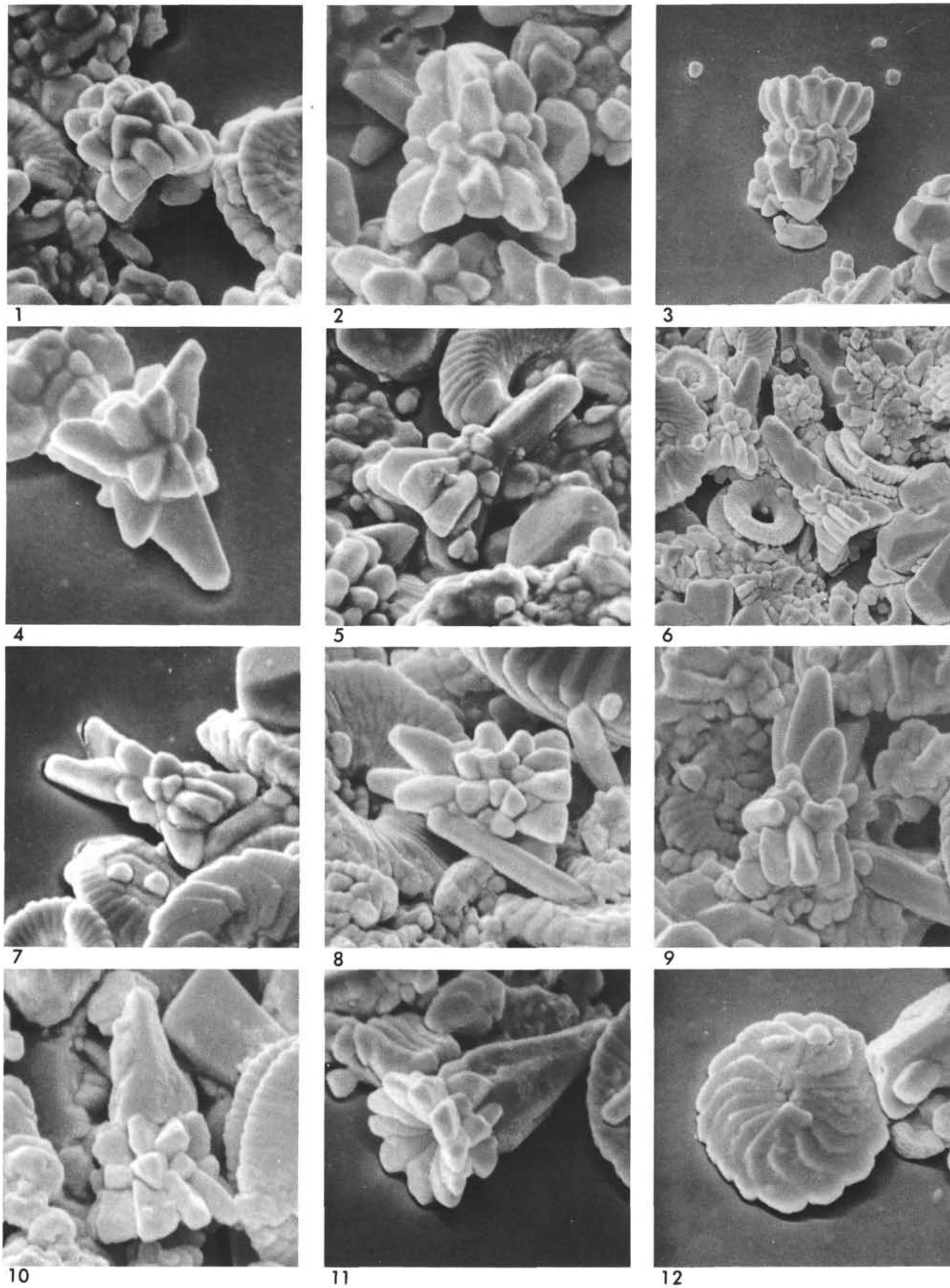


PLATE 9

Middle Miocene, Lower Pliocene, and
Quaternary Calcareous Nannoplankton

Figure 1 *Discoaster exilis* Martini and Bramlette, 1963.
3250 ×.
Sample 317B-18, CC, middle Miocene, NN 5.

Figure 2 *Sphenolithus abies* Deflandre, 1954.
6500 ×.
Sample 318-5, CC, lower Pliocene, NN 12.

Figure 3 *Pontosphaera* sp.
6500 ×.
Sample 318-5, CC, lower Pliocene, NN 12.

Figure 4 *Scyphosphaera pulcherrima* Deflandre, 1942.
3250 ×.
Sample 318-5, CC, lower Pliocene, NN 12.

Figure 5 *Scyphosphaera kamptneri* Müller, 1974.
3250 ×, base broken off.
Sample 318-5, CC, lower Pliocene, NN 12.

Figure 6 *Scyphosphaera amphora* Deflandre, 1942.
3250 ×.
Sample 318-5, CC, lower Pliocene, NN 12.

Figure 7 *Cyclococcolithus leptoporus* (Murray and Blackman) Kamptner, 1954 ex 1956.
6500 ×, proximal side.
Sample 318-4, CC, lower Pliocene, NN 14.

Figure 8 *Helicosphaera carteri* (Wallich) Kamptner, 1954.
3250 ×, proximal side.
Sample 318-4, CC, lower Pliocene, NN 14.

Figure 9 *Reticulofenestra pseudoumbilica* (Gartner) Gartner, 1969.
6500 ×, proximal side.
Sample 318-4, CC, lower Pliocene, NN 14.

Figure 10 *Oolithotus* cf. *fragilis* (Lohmann) Martini and Müller, 1972.
6500 ×.
Sample 318-4, CC, lower Pliocene, NN 14.

Figure 11 *Discoaster surculus* Martini and Bramlette, 1963.
3250 ×.
Sample 318-4, CC, lower Pliocene, NN 14.

Figure 12 *Pseudoemiliania lacunosa* (Kamptner) Gartner, 1969.
6500 ×, proximal side.
Sample 317-1-6, 100-101 cm, Quaternary, NN 19.

PLATE 9

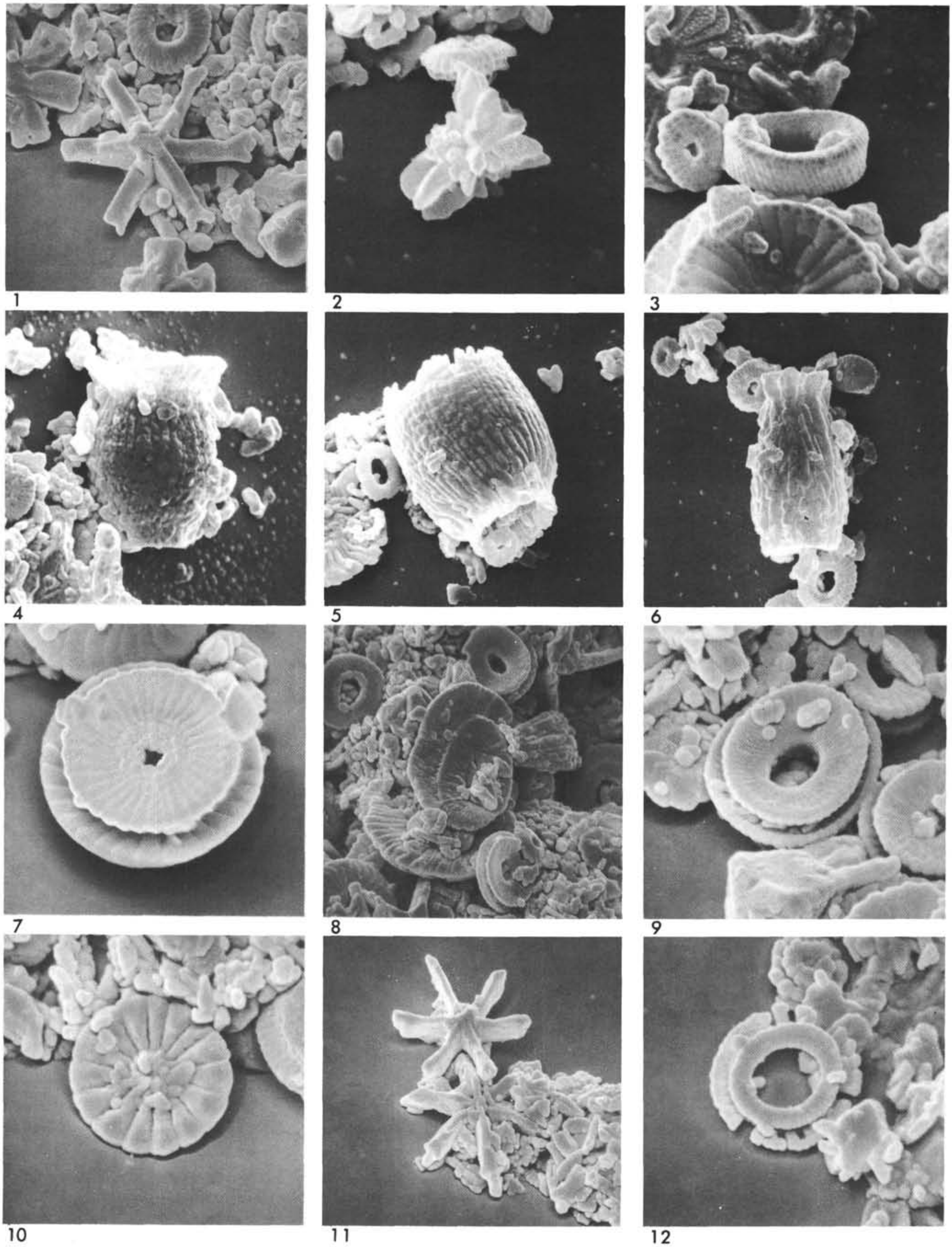
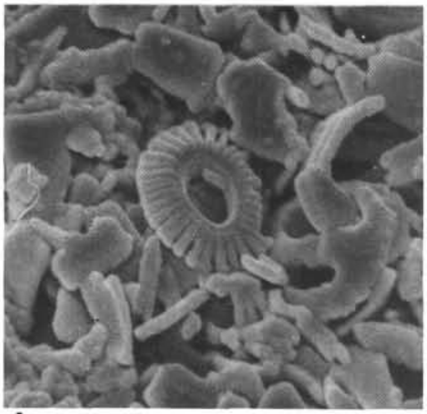


PLATE 10

Quaternary Calcareous Nannoplankton

Figures 1, 2	*Emiliania huxleyi* (Lohmann) Hay and Mohler, 1967. Sample 317-1-1, 5-6 cm, Quaternary, NN 21. 1. 6500 ×. 2. 13000 ×, distal side.
Figure 3	*Gephyrocapsa aperta* Kamptner, 1963. (= *Gephyrocapsa ericsonii* McIntyre and Bé, 1967) 13000 ×, distal side. Sample 317-1-1, 5-6 cm, Quaternary, NN 21.
Figure 4	*Gephyrocapsa oceanica* Kamptner, 1943. 6500 ×, distal side. Samples 316-1-4, 5-6 cm, Quaternary, NN 19.
Figure 5	*Hayaster perplexus* (Bramlette and Riedel) Bukry, 1973. 6500 ×, proximal side (?). Sample 317-1-1, 5-6 cm, Quaternary, NN 21.
Figure 6	*Umbilicosphaera mirabilis* Lohmann, 1902. 6500 ×, distal side. Sample 316-1, CC, Quaternary, NN 19.
Figures 7, 8	*Cyclococcolithus leptoporus* (Murray and Blackman) Kamptner, 1954 ex 1956. Sample 317-1-1, 5-6 cm, Quaternary, NN 21. 7. 6500 ×. 8. 13000 ×, with distal shield penetrated by two holes.
Figure 9	*Craspedolithus declivus* Kamptner, 1963. 3250 ×, distal side. Sample 317-1-1, 5-6 cm, Quaternary, NN 21.
Figure 10	*Syracosphaera ribosa* (Kamptner) Borsetti and Cati, 1972. 13000 ×, proximal side. Sample 317-1-1, 5-6 cm, Quaternary, NN 21.
Figure 11	*Pontosphaera discopora* Schiller, 1925. 6500 ×, proximal side. Sample 317-1-1, 5-6 cm, Quaternary, NN 21.
Figure 12	*Ceratolithus cristatus* Kamptner, 1954. 6500 ×. Sample 317-1-1, 5-6 cm, Quaternary, NN 21.

PLATE 10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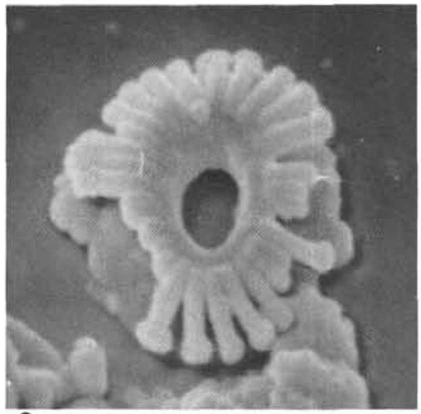
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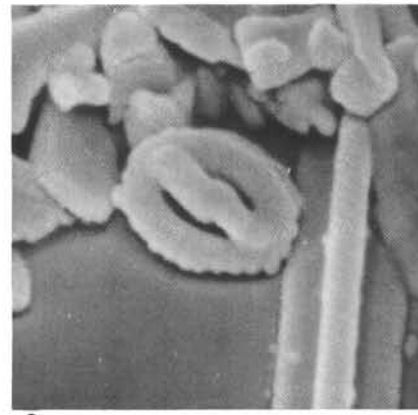
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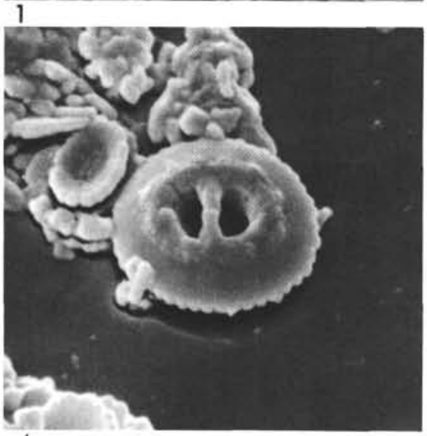
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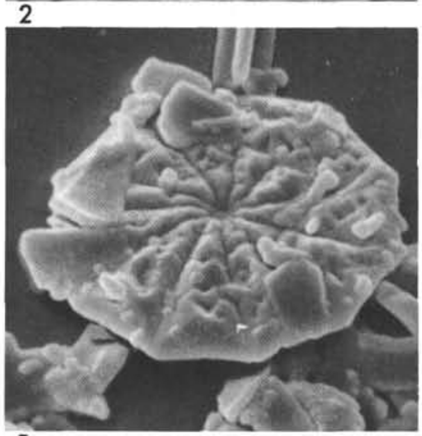
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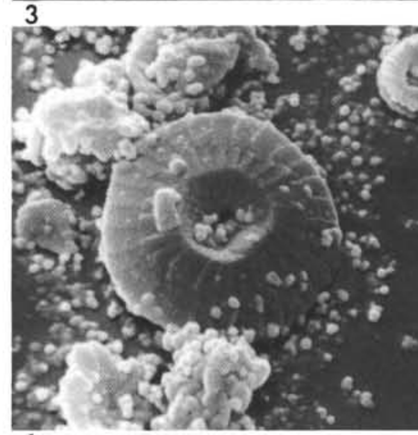
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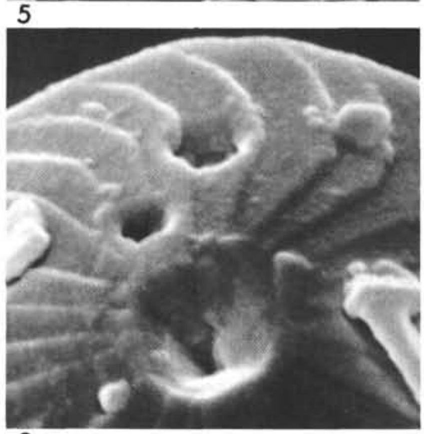
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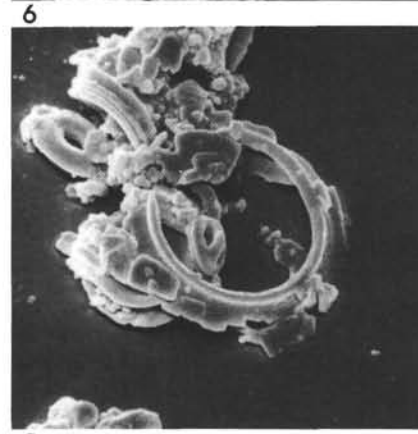
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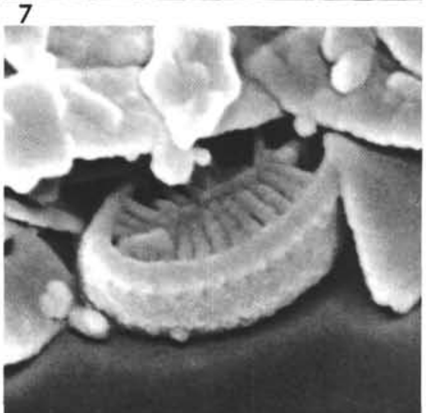
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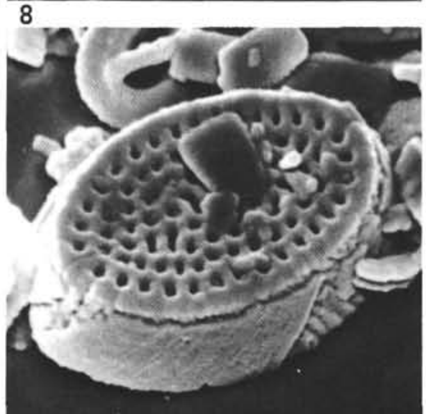
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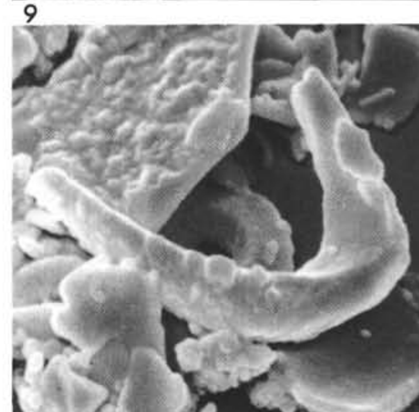
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PLATE 11

Eocene to Miocene overcalcified Discoasters

Figure 1	*Discoaster* sp. cf. *D. binodosus* Martini, 1958. 3250 ×, overcalcified specimen showing fusion of alternating rays and crystal faces. Sample 317A-2-1, 30-31 cm, lower Eocene, NP 12.
Figure 2	*Discoaster* sp. cf. *D. deflandrei* Bramlette and Riedel, 1954. 3250 ×, overcalcified specimen showing fusion of alternating rays and crystal faces. Sample 317B-32, CC, middle Oligocene, NP 23.
Figure 3	*Discoaster exilis* Martini and Bramlette, 1963. 5000 ×, slightly overcalcified specimen showing fusion of alternating rays. Sample 66.0-2-2, 140-141 cm, middle Miocene, NN 5.
Figures 4-6	*Discoaster deflandrei* Bramlette and Riedel, 1954. DWHH 14: 30-32 cm, lower Miocene, NN 2. 4. 5000 ×, slightly overcalcified specimen. 5. 3050 ×, overcalcified specimen showing fusion of alternating rays and crystal faces. 6. 6000 ×, heavily overcalcified specimen with fusion of alternating rays and crystal faces.
Figures 7-9	*Discoaster druggi* Bramlette and Wilcoxon, 1967. DWHH 14: 30-32 cm, lower Miocene, NN 2. 7. 3550 ×, slightly overcalcified specimen. 8. 2200 ×, moderately overcalcified specimen showing beginning fusion of alternating rays and crystal faces. 9. 3300 ×, heavily overcalcified specimen with fusion of alternating rays and crystal faces.
Figure 10	*Discoaster* sp. cf. *D. deflandrei* Bramlette and Riedel, 1954. 4100 ×, oblique view of overcalcified specimens showing crystal faces. DWHH 14: 30-32 cm, lower Miocene, NN 2.
Figure 11	*Discoaster deflandrei* Bramlette and Riedel, 1954. 4000 ×, overcalcified seven-rayed specimen showing tendency of fusion of alternating rays and suppression of the seventh ray. MSN 149 P: 325 cm, lower Miocene, NN 1.
Figure 12	Solution-affected nannoplankton assemblage, with only discoasters and sturdy *Coccolithus* sp. rims left. 1150 ×. DWHH 14: 30-32 cm, lower Miocene, NN 2.

PLATE 11

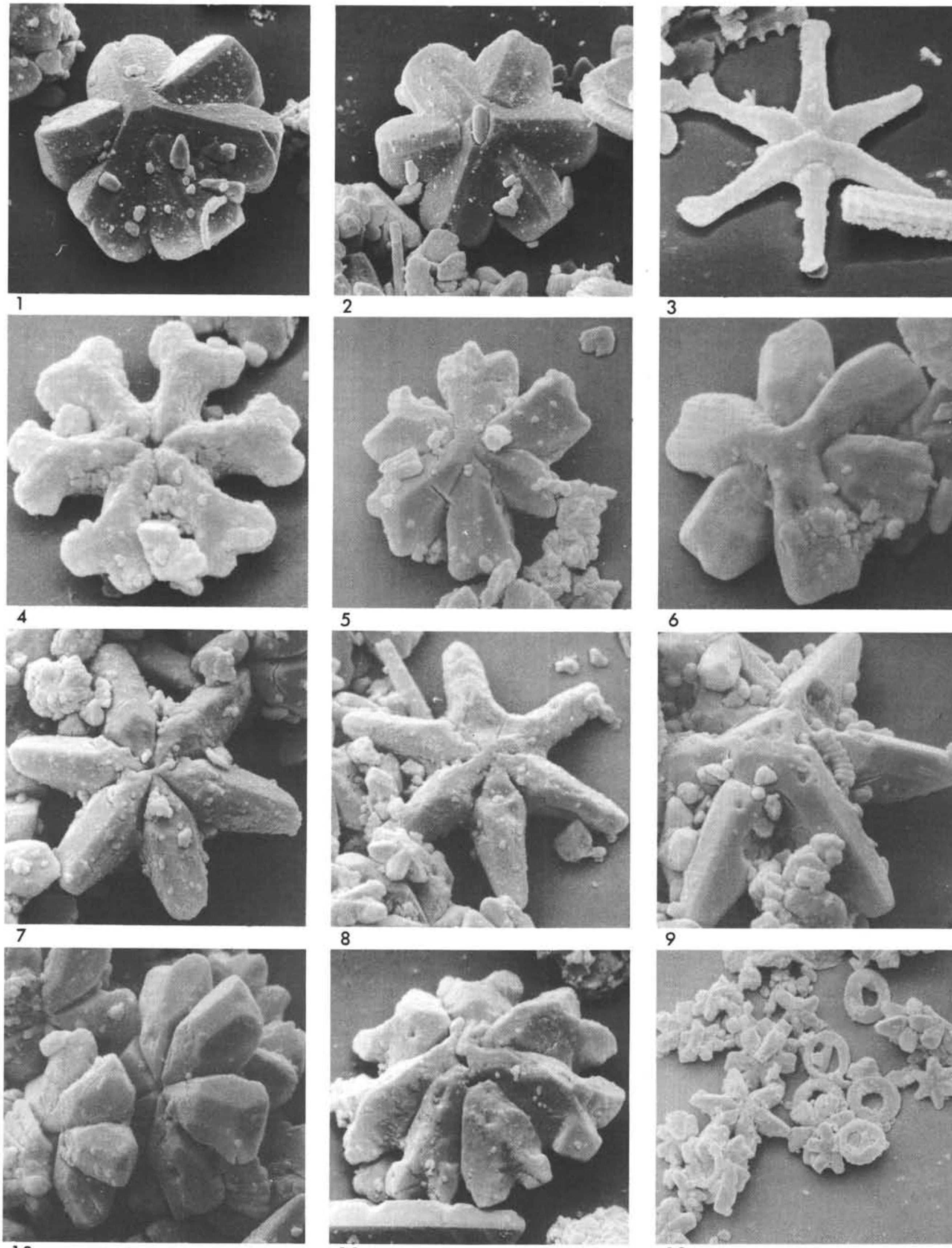


PLATE 12

All Specimens Approximately 2000×.

Figures 1, 2	*Tetralithus trifidus* (Stradner) Bukry, 1973. Sample 316-26, CC, upper Campanian/lower Maestrichtian, *Tetralithus trifidus* Zone. Short rayed form. 2. Crossed nicols.
Figures 3, 4	*Tetralithus gothicus* Deflandre, 1959. Sample 316-27, CC, middle Campanian, *Tetralithus gothicus* Zone. Short rayed form. 4. Crossed nicols.
Figures 5, 6	*Tetralithus aculeus* (Stradner) Gartner, 1968. Sample 316-27, CC, middle Campanian, *Tetralithus gothicus* Zone. 5. Semipolarized light with quartz red I plate. 6. Long axis 85° to crossed nicols.
Figures 7, 8	*Broinsonia parca* (Stradner) Bukry, 1969. Sample 316-27, CC, middle Campanian, *Tetralithus gothicus* Zone. 7. Semipolarized light with quartz red I plate. 8. Long axis 45° to crossed nicols.
Figures 9, 10	*Campylosphaera dela* (Bramlette and Sullivan) Hay and Mohler, 1967. Sample 317-A-2-1, 30-31 cm, lower Eocene, NP 12. 10. Long axis 0° to crossed nicols.
Figures 11, 12	*Ellipsolithus macellus* (Bramlette and Sullivan) Sullivan, 1964. Sample 317A-2-1, 30-31 cm, lower Eocene, NP 12. 12. Long axis 45° to crossed nicols.
Figures 13, 14	*Cyclococcolithus gammation* (Bramlette and Sullivan) Sullivan, 1964. Sample 317B-43, CC, middle Eocene, NP 14. 14. Crossed nicols.
Figures 15, 16	*Helicosphaera heezeni* (Bukry) Jafar and Martini, 1975. Sample 317B-38, CC, middle/upper Eocene, NP 17/18. 16. Long axis 30° to crossed nicols.
Figures 17, 18	*Discoaster altus* Müller, 1974. Sample 318-4, CC, lower Pliocene, NN 14. 17. Median focus. 18. High focus.
Figures 19, 20	*Ceratolithus tricorniculatus* Gartner, 1967. Sample 318-4-1, 30-31 cm, lower Pliocene, NN 14. 20. Long axis 90° to crossed nicols.

PLATE 12

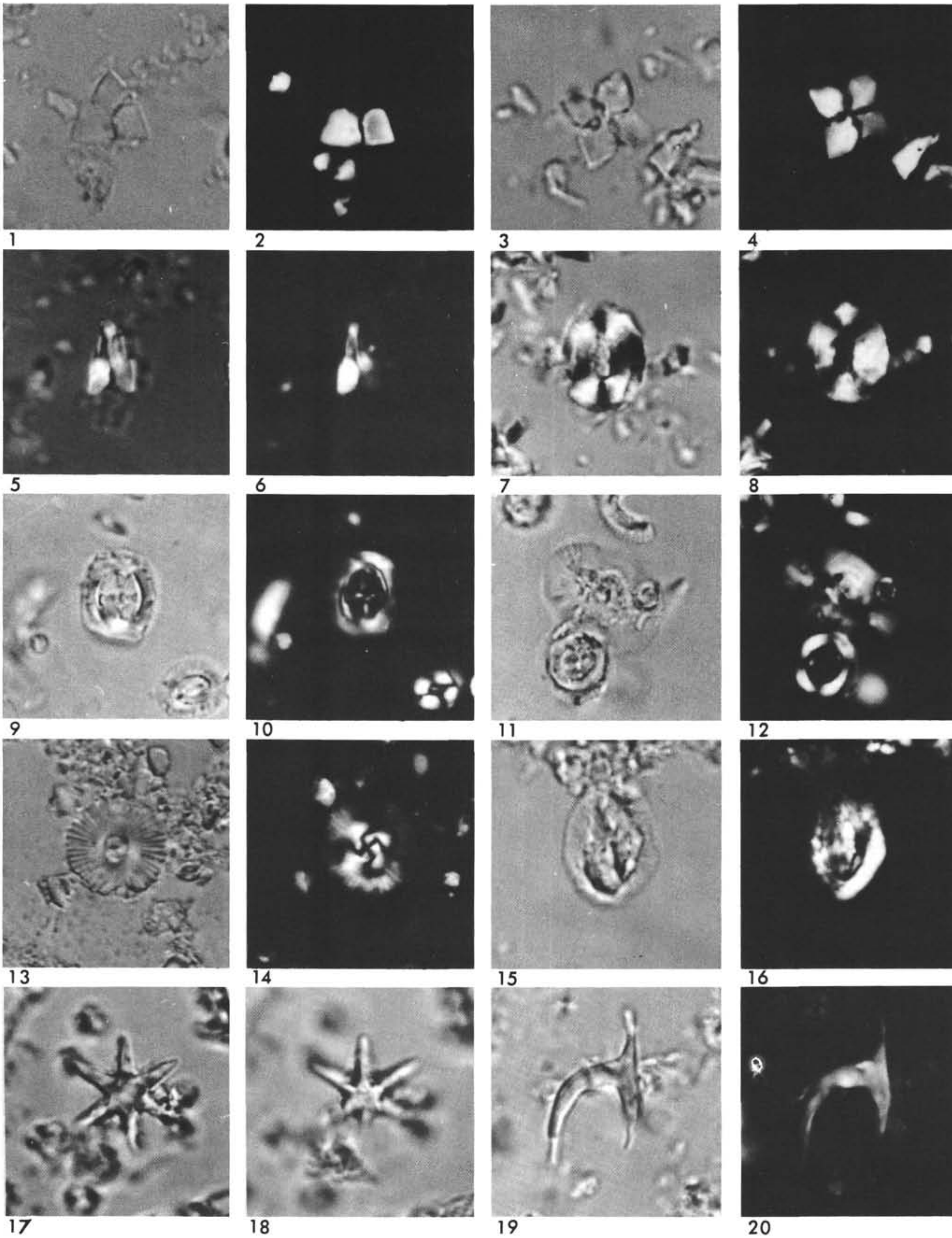
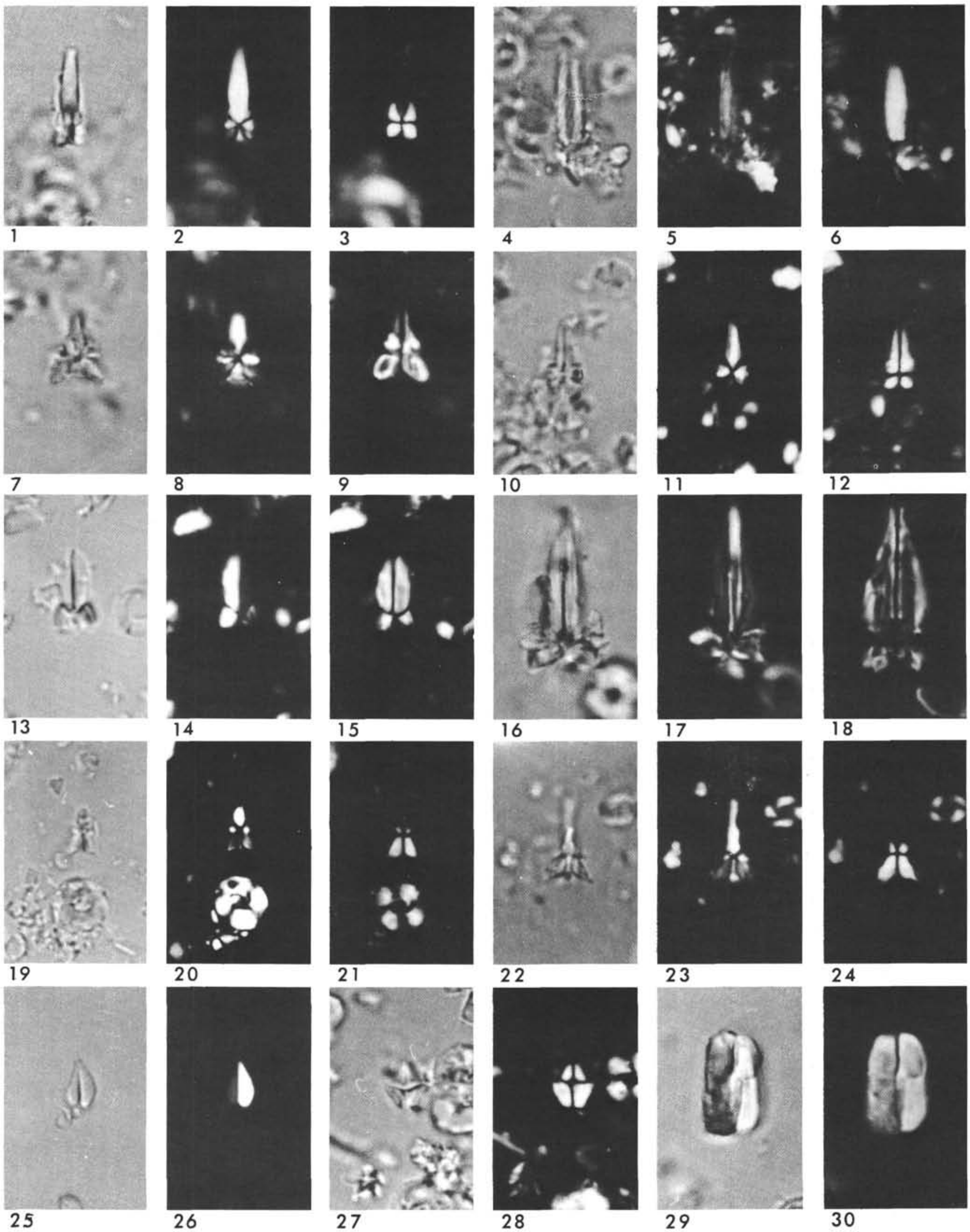


PLATE 13

All Specimens Approximately 2000×.

Figures 1-3	*Sphenolithus conspicuus* new species, Holotype SM.B 9713. Sample 317A-2-1, 30-31 cm, lower Eocene, NP 12. 2. Long axis 45° to crossed nicols. 3. Long axis 0° to crossed nicols.
Figures 4-6	*Microrhabdulus* ? *spiralis* new species, Holotype SM.B 9712. Sample 317A-2-1, 30-31 cm, lower Eocene, NP 12. 5. Long axis 0° to crossed nicols. 6. Long axis 45° to crossed nicols.
Figures 7-9	*Sphenolithus orphanknolli* Perch-Nielsen, 1971. Sample 317B-42, CC, middle Eocene, NP 14. 8. Long axis 45° to crossed nicols. 9. Long axis 0° to crossed nicols.
Figures 10-12	*Sphenolithus radians* Deflandre, 1952. Sample 317B-42, CC, middle Eocene, NP 14. 11. Long axis 45° to crossed nicols. 12. Long axis 0° to crossed nicols.
Figures 13-15	*Sphenolithus obtusus* Bukry, 1971. Sample 317B-38, CC, middle/upper Eocene, NP 17/18. 14. Long axis 30° to crossed nicols. 15. Long axis 0° to crossed nicols.
Figures 16-18	*Sphenolithus pseudoradians* Bramlette and Wilcoxon, 1967. Sample 317B-34-5, 30-31 cm, lower Oligocene, NP 22. 17. Long axis 45° to crossed nicols. 18. Long axis 0° to crossed nicols.
Figures 19-21	*Sphenolithus dissimilis* Bukry and Percival, 1971. Sample 318-10-1, 145-146 cm, lower Miocene, NN 2. 20. Long axis 45° to crossed nicols. 21. Long axis 0° to crossed nicols.
Figures 22-24	*Sphenolithus delphix* Bukry, 1973. Sample 318-10-1, 145-146 cm, lower Miocene, NN 2. 23. Long axis 45° to crossed nicols. 24. Long axis 0° to crossed nicols.
Figures 25, 26	*Sphenolithus intercalaris* new species. Sample 317B-38, CC, middle/upper Eocene, NP 17/18. 26. Long axis 45° to crossed nicols.
Figures 27, 28	Calcareous nannofossil of unknown affinities. Sample 318-10-1, 145-146 cm, lower Miocene, NN 2. 28. Long axis 0° to crossed nicols.
Figures 29, 30	*Zygrhablithus* sp. cf. *Z. bijugatus* (Deflandre) Deflandre, 1959. Sample 317A-2-1, 30-31 cm, lower Eocene, NP 12. 30. Long axis 0° to crossed nicols. Overcalcified specimen.

PLATE 13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