28. CALCAREOUS NANNOPLANKTON — LEG 26, DEEP SEA DRILLING PROJECT

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INTRODUCTION

During Leg 26, 11 Holes were drilled at nine sites in the southern part of the Indian Ocean. The locations of the sites are shown in Figure 1. At all sites calcareous nannofossils were recovered, ranging in age from the Lower Cretaceous to the Quaternary. A list of the zonal assignments and the ages of the cores based on investigation of their nannofossils is given in Figure 2. Due to a major unconformity, no Campanian to lower Eocene sediments were encountered. Two especially interesting, almost continuous sequences of mid-latitudinal nannofossil assemblages were found, one at Site 251, ranging from lower Miocene to Quaternary, and the other at Site 258, ranging from middle Albian to Santonian. An inventory of the stratigraphically useful Cenozoic nannoplankton species identified in the light microscope and a more complete list of the Cretaceous nannoplankton species are included in the range charts (Tables 1-8). Additional remarks on the preservation and taxonomy of some Cretaceous nannofossils are made.

The extent and correlation of nannofossil zones with foraminiferal zones and with the lithology of the sediments are discussed in this chapter and in the Site Reports and are shown in the lithologic and biostratigraphic summary sheets included with each Site Report (Chapters 3-11). All sediment samples checked for nannofossils are listed in the appropriate positions in the detailed core descriptions included in each Site Report by one or more letters indicating the abundance and preservation of the respective assemblage, as explained in Chapter 2 (Explanatory Notes).

The following nannofossil species are considered in this report (listed in alphabetical order of species epithets):

Cenozoic

Sphenolithus abies Deflandre and Fert, 1954
Dictyococcites abisectus (Müller, 1970) Bukry and Percival, 1971
Ceratolithus amplificus Bukry and Percival, 1971
Discoaster asymmetricus Gartner, 1969
Discoaster barbadiensis Tan Sin Hok, 1927
Sphenolithus belemnos Bramlette and Wilcoxon, 1967
Discoaster berggreni Bukry, 1971
Braarudosphaera bigelowi (Gran and Braarud, 1935) Deflandre, 1947
Zygrhablithus bijugatus (Deflandre and Fert, 1954) Deflandre, 1959
Discoaster bollii Martini and Bramlette, 1963
Discoaster brouweri Tan Sin Hok, 1927
Discoaster calcaris Gartner, 1967
Catinaster calyculus Martini and Bramlette, 1963
Gephyrocapsa caribbeanica Boudreaux and Hay, 1967(= *Gephyrocapsa* sp.)
Triquetrorhabdulus carinatus Martini, 1965
Discoaster challengeri Bramlette and Riedel, 1954
Sphenolithus ciperoensis Bramlette and Wilcoxon, 1967
Catinaster coalitus Martini and Bramlette, 1963
Helicopontosphaera compacta Bramlette and Wilcoxon, 1967
Ceratolithus cristatus Kamptner, 1954
Dictyococcites dictyodus (Deflandre and Fert, 1954) Martini, 1969
Sphenolithus distentus (Martini, 1965) Bramlette and Wilcoxon, 1967
Discoaster druggi Bramlette and Wilcoxon, 1967
Zygolithus dubius Deflandre and Fert, 1954
Discoaster exilis Martini and Bramlette, 1963
Cyclicargolithus floridanus (Roth and Hay, 1967) Bukry, 1971
Cyclococcolithina formosa (Kamptner, 1963) Wilcoxon, 1970
Discoaster formosus Martini and Worsley, 1971
Chiasmolithus grandis (Bramlette and Riedel, 1954) Gartner, 1970
Discoaster hamatus Martini and Bramlette, 1963
Sphenolithus heteromorphus Bramlette and Wilcoxon, 1967
Markalius inversus (Deflandre and Fert, 1954) Bramlette and Martini, 1964
Triquetrorhabdulus inversus Bukry and Bramlette, 1969
Helicopontosphaera kamptneri Hay and Mohler, 1967
Discoaster kugleri Martini and Bramlette, 1963
Pseudoemiliania lacunosa (Kamptner, 1963) Gartner, 1969
Cyclococcolithina leptopora (Murray and Blackman, 1898) Wilcoxon, 1970
Helicopontosphaera lophota (Bramlette and Sullivan, 1961) Bukry, 1971
Lanternithus minutus Stradner, 1962
Discoaster neohamatus Bukry and Bramlette, 1969
Discoaster nephados Hay, 1967
Chiasmolithus oamaruensis (Deflandre and Fert, 1954) Hay, Mohler & Wade, 1966
Gephyrocapsa oceanica Kamptner, 1943 (= *Gephyrocapsa* sp.)
Discoaster pentaradiatus Tan Sin Hok, 1927
Sphenolithus predistentus Bramlette and Wilcoxon, 1967
Ceratolithus primus Bukry and Percival, 1971
Sphenolithus pseudoradians Bramlette and Wilcoxon, 1967
Reticulofenestra pseudoumbilica (Gartner, 1967) Gartner, 1969
Discoaster pseudovariabilis Martini and Worsley, 1971
Discoaster quinqueramus Gartner, 1969
Sphenolithus radians Deflandre, 1952

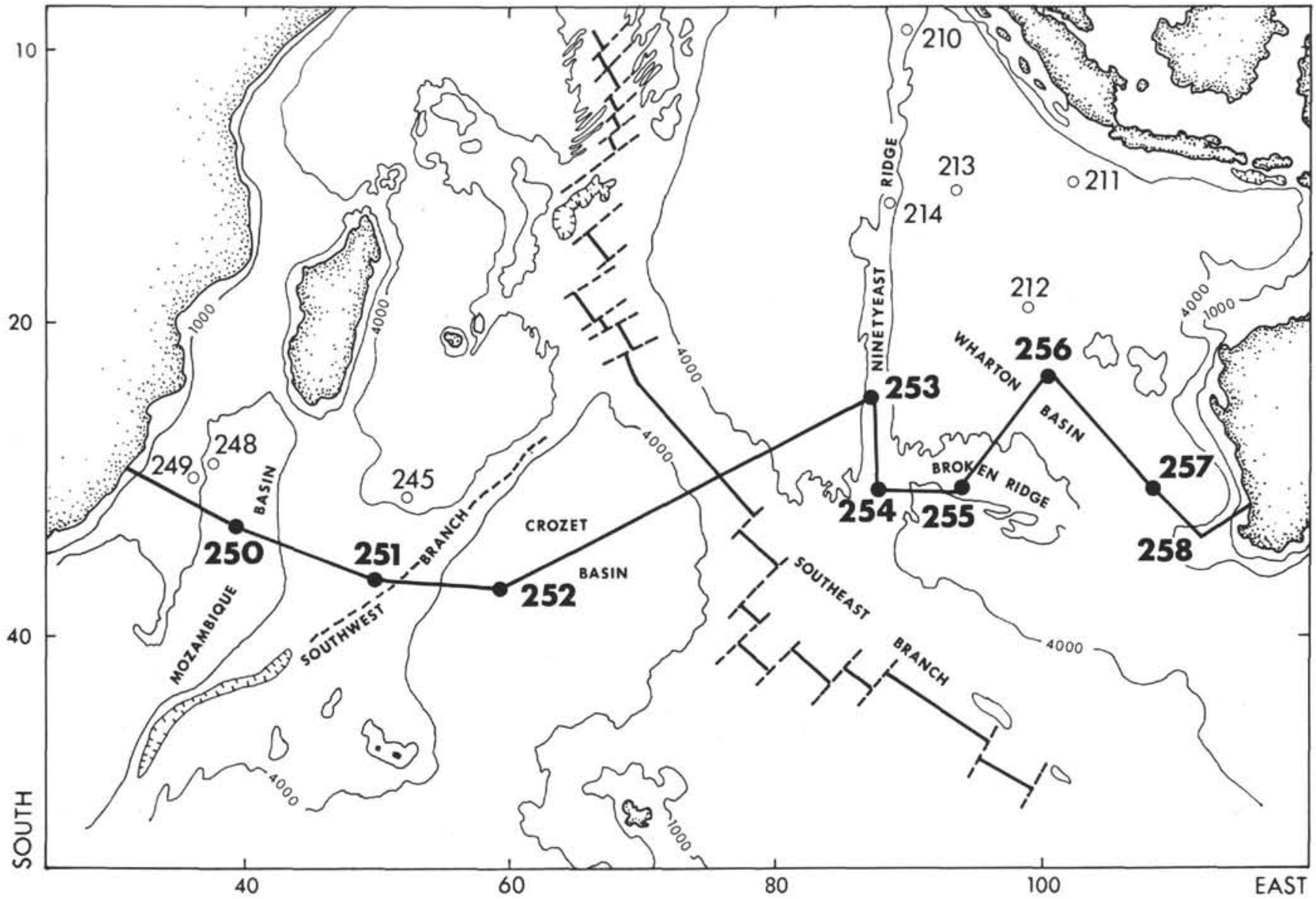


Figure 1. *Location of sites cored during Leg 26 of the Deep Sea Drilling Project.*

Helicopontosphaera recta (Haq, 1966) Martini, 1969
Isthmolithus recurvus Deflandre and Fert, 1954
Pemma rotundum Klumpp, 1953
Ceratolithus rugosus Bukry and Bramlette, 1968
Triquetrorhabdulus rugosus Bramlette and Wilcoxon, 1967
Discoaster saipanensis Bramlette and Riedel, 1954
Reticulofenestra samodurovi (Hay et al., 1966) Roth, 1970
Chiasmolithus solitus (Bramlette and Sullivan, 1961) Locker, 1968
Discoaster surculus Martini and Bramlette, 1963
Discoaster tamalis Kamptner, 1967
Ceratolithus tricorniculatus Gartner, 1967
Discoaster trinidadensis Hay, 1967
Reticulofenestra umbilica (Levin, 1966) Martini and Ritzkowski, 1968
Discoaster variabilis Martini and Bramlette, 1963
Gephyrocapsa sp.
Micrantholithus sp.
Scyphosphaera sp.

Mesozoic

Vagalapilla aachena Bukry, 1969
Corollithion achylosum (Stover, 1966) Thierstein, 1971
Lithraphidites alatus Thierstein, 1972
Podorhabdus albianus Black, 1967
Hayesites albiensis Manivit, 1971
Parhabdolithus angustus (Stradner, 1963) Stradner, Adamiker and Maresch, 1968
Parhabdolithus asper (Stradner, 1963) Manivit, 1971
Watznaueria barnesae (Black, 1959) Perch-Nielsen, 1968
Microrhabdulus belgicus Hay and Towe, 1963
Flabellites biforaminis Thierstein, 1973
Braarudosphaera bigelowi (Gran and Braarud, 1935) Deflandre, 1947
Watznaueria biporta Bukry, 1969
Watznaueria britannica (Stradner, 1963) Reinhardt, 1964
Lithraphidites carniolensis Deflandre, 1963
Lucianorhabdus cayeuxi Deflandre, 1959
Cruciellipsis chiasta (Worsley, 1971) Thierstein, 1972
Markalius circumradiatus (Stover, 1966) Perch-Nielsen, 1968
Watznaueria communis Reinhardt, 1964
Vagalapilla compacta Bukry, 1969
Cretarhabdus conicus Bramlette and Martini, 1964
Biscutum constans (Górka, 1957) Black, 1
Cylindralithus coronatus Bukry, 1969
Cretarhabdus coronadventis Reinhardt, 1966
Cretarhabdus crenulatus Bramlette and Martini, 1964, emend. Thierstein, 1971
Prediscosphaera cretacea (Arkhangelsky, 1912) Gartner, 1968
Chiastozygus cuneatus (Lyulyeva, 1967) Cepek and Hay

Age		Zone	Hole 250	Hole 250A	Hole 251	Hole 251A	Site 252	Site 253	Site 254	Site 255	Site 256	Site 257	Hole 258	Hole 258A
NEOGENE														
Quaternary		NN21 *Emiliania huxleyi*												
Quaternary		NN20 *Gephyrocapsa oceanica*	1-2		1-2		1		1				1-2	1
Quaternary		NN19 *Pseudoemiliania lacunosa*	2-3	1-3	2-6			1		1			2	2-4
Pliocene	Upper	NN18 *Discoaster brouweri*		4-5	6-8									
Pliocene	Upper	NN17 *D. pentaradiatus*						1						
Pliocene	Upper	NN16 *D. surculus*		5	10	1-2		2	2				3	5
Pliocene	Lower	NN15 *Reticulofenestra pseudoumbilica*				4		2						5-6
Pliocene	Lower	NN14 *Discoaster asymmetricus*		7		4		2	3	3				
Pliocene	Lower	NN13 *Ceratolithus rugosus*				5-7		2						
Miocene	Upper	NN12 *C. tricorniculatus*				7-10		3		3			4	6
Miocene	Upper	NN11 *Discoaster quinqueramus*		7-9		10-13		3-5	4				4	7-8
Miocene	Upper	NN10 *D. calcaris*				13-14								8
Miocene	Middle	NN9 *D. hamatus*				14-16		5-6	5-7					
Miocene	Middle	NN8 *Catinaster coalitus*				16-17			7-11					
Miocene	Middle	NN7 *Discoaster kugleri*				17-19								
Miocene	Middle	NN6 *D. exilis*				20-25								
Miocene	Middle	NN5 *Sphenolithus heteromorphus*				25-30		8	12-14	4				
Miocene	Lower	NN4 *Helicopontosphaera ampliaperta*		11-13										
Miocene	Lower	NN3 *Sphenolithus belemnos*						9	17-19	5				
Miocene	Lower	NN2 *Discoaster druggi*		16				9						
Miocene	Lower	NN1 *Triquetrorhabdulus inversus*		16				9						
CRETACEOUS AND PALEOGENE														
Oligocene	U.	NP25 *Sphenolithus ciperoensis*						10						
Oligocene	M.	NP24 *S. distentus*						10						
Oligocene	M.	NP23 *S. predistentus*						11-12						
Oligocene	L.	NP22 *Helicopontosphaera reticulata*												
Oligocene	L.	NP21 *Esicsonia subdisticha*						12						
Eocene	Upper	NP20 *Sphenolithus pseudoradians*						13-14						
Eocene	Upper	NP19 *Isthmolithus recurvus*												
Eocene	Upper	NP18 *Chiasmolithus oamaruensis*						14						
Eocene	Upper	NP17 *Discoaster saipanensis*						15-16						
Eocene	M.	NP16 *D. tani nodifer*						17-57						
Santonian														
Coniacian		*Marthasterites furcatus*		22-23						9-11			5-11	8-9
Coniacian		*Kampnerus magnificus*											11-13	
Turonian		*Micula staurophora*											13	
Cenomanian		*Gartnerago obliquum*											13-14	
Cenomanian		*Lithraphidites alatus*											14	
Albian	U.	*Eiffellithus turriseiffeli*									8-9		15-19	
Albian	M.	*Prediscosphaera cretacea*										7-9	20-23	

Figure 2. *Zonal and geologic age assignments of Leg 26 cores based on calcareous nannofossils.*

Microrhabdulus decoratus Deflandre, 1959
Podorhabdus decorus (Deflandre and Fert, 1954) Thierstein, 1972
Micula decussata Vekshina, 1959 (= *Micula staurophora* (Gardet, 1955))
Octopodorhabdus decussatus Manivit, 1959) Manivit, 1971
Zygodiscus diplogrammus (Deflandre and Fert, 1954) Gartner, 1968
Cribrosphaerella ehrenbergi (Arkhangelsky, 1912) Deflandre, 1952
Zygodiscus elegans Gartner, 1968, emend. Bukry, 1969
Parhabdolithus embergeri (Noël, 1958) Stradner, 1963
Broinsonia enormis (Shumenko, 1968) Manivit, 1971
Tranolithus exiguus Stover, 1966
Lithastrinus floralis Stradner, 1962
Scapholithus fossilis Deflandre and Fert, 1954
Marthasterites furcatus (Deflandre and Fert, 1954) Deflandre, 1959
Broinsonia furtiva Bukry, 1969
Lithastrinus grilli Stradner, 1962
Lithraphidites helicoideus (Deflandre, 1959) Deflandre, 1963
Stephanolithion laffittei Noël, 1970
Broinsonia lata (Noël, 1969) Noël, 1970
Chiastozygus litterarius (Górka, 1957) Manivit, 1971
Cretarhabdus loriei Gartner, 1968
Kamptnerius magnificus Deflandre, 1959
Cyclagelosphaera margereli Noël, 1965
Vagalapilla matalosa (Stover, 1966) Thierstein, 1973
Gartnerago nanum Thierstein, n. sp.
Gartnerago obliquum (Stradner, 1963) Reinhardt, 1970
Ahmuellerella octoradiata (Górka, 1957) Reinhardt, 1966
Tranolithus orionatus Stover, 1966
Broinsonia orthocancellata Bukry, 1969
Manivitella pemmatoidea (Deflandre ex Manivit, 1965) Thierstein, 1971
Cribrosphaerella primitiva Thierstein, n. sp.
Kamptnerius punctatus Stradner, 1963
Micula pyramida (Gardet, 1955) Thierstein, n. comb.
Tetralithus quadratus Stradner, 1961
Corollithion rhombicum (Stradner and Adamiker, 1966) Bukry, 1969
Discorhabdus rotatorius (Bukry, 1969) Thierstein, 1973
Gartnerago segmentatum (Stover, 1966) Thierstein, n. comb.
Broinsonia signata (Noël, 1969) Noël, 1970
Corollithion signum Stradner, 1963
Prediscosphaera spinosa (Bramlette and Martini, 1964) Gartner, 1968
Parhabdolithus splendens (Deflandre, 1953) Noël, 1969
Micula staurophora (Gardet, 1955) Stradner, 1963
Tegumentum stradneri Thierstein, 1972
Vagalapilla stradneri (Rood, Hay & Barnard, 1971) Thierstein, 1973
Gartnerago striatum (Stradner, 1963) Forchheimer, 1972
Cretarhabdus surirellus (Deflandre and Fert, 1954) Reinhardt, 1970
Eiffellithus turriseiffeli (Deflandre and Fert, 1954) Reinhardt, 1965
Watznaueria virginica Bukry, 1969

PRESERVATION

The preservation of the Mesozoic and Cenozoic nannoplankton assemblages recovered during Leg 26 is indicated in the core descriptions included in the site reports (Chapters 3-11) and on the range charts (Tables 1-8) in this chapter. Explanation of the symbols is found in Chapter 2 (Explanatory Notes). Only the dominant features (either overgrowth or etching) are given, although signs of both were sometimes found in the same assemblage. Discussions of the nannofossil preservation are included in the paleontology sections of the Site Reports (Chapters 3-11), as well as in this chapter under the discussion of the calcareous nannofossils at the drill sites. The preservation of the calcareous nannofossils from the Cretaceous sequence at Site 258 drilled on Naturaliste Plateau was studied in more detail.

Preservation of Cretaceous Nannofossils— Its Impact on Taxonomy and Biostratigraphy

At Site 258, on Naturaliste Plateau during Leg 26, an Upper Cretaceous sequence of pelagic oozes deposited in an austral paleoenvironment was recovered. The nannofossil assemblages in the upper Turonian through lower Santonian part of this sequence are mostly well preserved and show various stages of overgrowth and etching. After a stratigraphic study of the sequence in the light microscope, a few scattered samples were prepared for investigation in the scanning electron microscope (SEM), using the method described by Thierstein et al. (1972). The purpose of this SEM investigation was to confirm the identity of the species definitions as observed and used during the light microscopic investigation with the type illustrations (mostly electron microscope pictures) given by various authors (e.g., Black, 1967, 1972; Bukry, 1969; Forchheimer, 1972; Gartner, 1968; Noël, 1969, 1970; Stradner et al., 1968). The study of about 350 specimens from a few selected groups of species yielded valuable information concerning the identification of these species in the two microscopes. The SEM investigation confirmed the higher abundances of delicate and perforated "species" in well-preserved or slightly etched assemblages and of more robust and imperforated "species" in overgrown assemblages as observed by the light microscopic investigation. This finding did produce serious difficulties in determining species attribution for a large number of specimens as well as in their stratigraphic interpretation using the existing literature. For comparative studies a Turonian sample of a Lamont core (RC 8-56) from Naturaliste Plateau (Burckle et al., 1967), and a number of upper Cretaceous samples from Texas (partly topotype material of Bukry, 1969) and Crimea were prepared and studied under the light microscope. These studies revealed additional indications of a relationship between sample lithology, assemblage preservation, and "species" occurrences. The frequently diverging stratigraphic ranges of species given by various authors became much more comparable and allowed correlation with Site 258 after the ranges of two closely related species had been added.

Although these findings are tentative and not based on extensive statistical investigations, they strongly suggest minor revisions of the taxonomic concepts used recently for some Upper Cretaceous nannofossils. A large number of species descriptions seem to be based on morphological features subject to either infraspecific variation and/or various states of overgrowth or etching. Apparently overgrowth of certain coccoliths does not affect all their morphological features equally: In *Gartnerago obliquum* (Stradner) first the crystallites of the innermost cycle of the distal shield increase their size (see Plate 6, Figure 2; Plate 7, Figure 1), and subsequently the central area perforations gradually become closed by increasing overgrowth of the crystallites surrounding them (Plate 5, Figure 4; Plate 6, Figure 1). On the other hand, overgrowth of *Gartnerago striatum* (Stradner) does not affect the perforations in the central area (see remarks under *Gartnerago striatum* [Stradner] in the taxonomic section). Overgrowth of *Kamptnerius magnificus* Deflandre first affects its central area by closing its perforations and increasing the size of its transverse bars.

Only a restricted number of species involved are discussed in the taxonomic part of this paper and only a small selection of the available micrographs could be given as illustrations. Adaptations of the taxonomic concepts of *Gartnerago obliquum* (Stradner), *Kamptnerius magnificus* Deflandre, and *Micula staurophora* (Gardet) are proposed. Detailed investigations now in progress of the *Broinsonia enormis* (Shumenko)—*Broinsonia furtiva* (Bukry—*Broinsonia parca* (Stradner), *Tranolithus exiguus* Stover—*Tranolithus manifestus* Stover—*Tranolithus orionatus* Stover, *Eiffellithus trabeculatus* (Górka)—*Chiastozygus cuneatus* (Lyulyeva), and other groups might necessitate further revisions.

At present it is not yet possible to indicate to what extent these morphological variations are due to original polymorphism or to diagenetic alterations. *Kamptnerius magnificus* Deflandre is very likely an overgrown morphotype of *Kamptnerius punctatus* (Stradner) and *Kamptnerius pseudopunctatus* (Cepek), as suggested by a comparison of their stratigraphic distribution and the preservation of the respective assemblages given in the literature, as well as by a comparison of their ranges and inverse abundances at Site 258. *Gartnerago costatum costatum* (Gartner) and *Gartnerago costatum porolatum* Bukry, on the other hand, show primary morphological differentiation in their central area perforations. Nevertheless, they may be conspecific since a number of living coccospheres show comparable morphological variability of their coccoliths as shown by Borsetti and Cati (1972, pl. 4; pl. 9, fig. 1, 2), Clocchiatti (1971b), Gaarder (1970, p. 122, fig. 4, 7, 8), McIntyre and Bé (1967, p. 568, 569, 572, pl. 5, 6, 11), and Markali and Paasche (1955, pl. 2, 4). Until further evidence for the applicability of these morphotypes for stratigraphic or paleoecologic purposes becomes available, they should be considered monospecific which greatly improves their usability for stratigraphic correlation.

BIOSTRATIGRAPHY

Cenozoic Nannoplankton Zones

The standard nannoplankton zonation described by Martini (1970, 1971), Martini and Worsley (1970) is used in this report. Additional stratigraphic information by Bukry (1971a, 1971b, 1973) and Roth et al. (1971) was incorporated. The zonal sequence, the criteria for the recognition of zonal boundaries, and additional biostratigraphic events used are given in Figure 3. The stratigraphic distribution of the calcareous nannofossils found in the fossiliferous samples is shown in Tables 1-8. The number of Cenozoic species listed is restricted to the stratigraphically and ecologically most important. Due to strong overgrowth (Sites 253 and 255) or the ecologic restrictions (Sites 250, 253, 254, 255, and 258), a number of species, usually used as stratigraphic markers, could not be found or identified.

The lowermost *Sphenolithus abies* (including *S. neoabies*) are encountered in the basal middle Miocene (NN5 *Sphenolithus heteromorphus* Zone) at Sites 251 and +54, and they become extinct in the lower Pliocene (NN14 *Discoaster asymmetricus* Zone at Sites 250 and 254, and NN15 *Reticulofenestra pseudoumbilica* Zone at Sites 253 and 258). The uppermost *Dictyococcites abisectus* occurred in the middle Miocene (NN6 *Discoaster exilis* Zone) at Sites 251, 253(?), and 254. *Helicopontosphaera ampliaperta* and *Discoaster bollii* were not found in any of the lower Miocene assemblages of Leg 26. *Gephyrocapsa* sp., which for the purposes of this report include all *Gephyrocapsa* species with a cross bar have their lowermost occurrence below the extinction of long-rayed discoasters at Sites 251, 255, and 258. *Cyclicargolithus floridanus* made its last occurrence at different stratigraphic levels: NN5 *Sphenolithus heteromorphus* Zone at Site 254, NN6 *Discoaster exilis* Zone at Sites 251 and 253 (?), NN11 *Discoaster quinqueramus* Zone at Site 258.

The abundances of *Cyclicargolithus floridanus* and *Dictyococcites abisectus* were inverse at Sites 251 and 254. Their identification in the light microscope, based on the presence or absence of a high central collar (Bukry and Percival, 1971), seems to depend on the preservation of the assemblage. *Emiliania huxleyi* was not identified with certainty in the light microscope, the NN21 *Emiliania huxleyi* Zone may therefore be included in the NN20 *Gephyrocapsa oceanica* Zone in this report. The earliest *Helicopontosphaera kamptneri* were found in the lowermost Miocene (NN1 *Triquetrorhabdulus carinatus* Zone) at Site 250. *Pseudoemiliania lacunosa* made its first occurrence in the lower Pliocene (NN15 *Reticulofenestra pseudoumbilica* Zone) at Sites 251 and 253. The lowermost *Cyclococcolithina leptopora* are found in the lower Miocene (NN2 *Discoaster druggi* Zone) at Site 253. This species, as used in this report, includes *Cyclococcolithina macintyrei*. *Discoaster nephados* and *D. trinidadensis* were not used as stratigraphic markers since a number of other *Discoaster* species showed similar shapes when overgrown. The stratigraphic distribution of *Ceratolithus primus* (NN11 *Discoaster quinqueramus* Zone at Sites 251, 253, and 254; NN12 *Ceratolithus tricorniculatus* Zone and NN14 *Discoaster asymmetricus* Zone at Site 255) proved to be within the range of *Ceratolithus tricorniculatus*. The lowermost *Reticulofenestra pseudoumbilica* was found in the basal middle Miocene (NN5 *Sphenolithus heteromorphus* Zone at Site 251), its total range equals that of *Sphenolithus abies*. The stratigraphic ranges of *Dis-*

Zonal Boundaries	Zones	First Occurrence	Last Occurrence		Age
	NN21 *Emiliania huxleyi* NN20 *Gephyrocapsa oceanica*				Quaternary
last *Pseudoemiliania lacunosa*					
	NN19 *Pseudoemiliania lacunosa*		*Ceratolithus rugosus*		
last *Discoaster brouweri*					
	NN18 *Discoaster brouweri*	*Gephyrocapsa* sp.		Upper	Pliocene
last *D. pentaradiatus*					
	NN17 *D. pentaradiatus*			Upper	Pliocene
last *D. surculus*					
	NN16 *D. surculus*	*Ceratolithus cristatus*	*Discoaster asymmetricus* *D. tamalis*	Upper	Pliocene
last *Reticulofenestra pseudoumbilica*					
	NN15 *Reticulofenestra pseudoumbilica*	*Pseudoemiliania lacunosa*	*Sphenolithus abies*	Lower	Pliocene
last *Ceratolithus tricorniculatus*					
	NN14 *Discoaster asymetricus*	*Discoaster tamalis*		Lower	Pliocene
first *Discoaster asymmetricus*					
	NN13 *Ceratolithus rugosus*			Lower	Pliocene
first *Ceratolithus rugosus*					
	NN12 *C. tricorniculatus*		*Discoaster challengeri* *Triquetrorhabdulus rugosus* *Discoaster variabilis*	Upper	Miocene
last *Discoaster quinqueramus*					
	NN11 *Discoaster quinqueramus*	*Ceratolithus primus* *Discoaster surculus*	*Cyclicargolithus floridanus* *Discoaster calcaris* *D. pseudovariabilis*	Upper	Miocene
first *D. quinqueramus*					
	NN10 *D. calcaris*			Upper	Miocene
last *D. hamatus*					
	NN9 *D. hamatus*	*D. pentaradiatus* *D. calcaris*	*Catinaster calyculus* *C. coalitus*	Upper / Middle	Miocene
first *D. hamatus*					
	NN8 *Catinaster coalitus*	*Catinaster calyculus*	*Discoaster exilis* *D. kugleri*	Middle	Miocene
first *Catinaster coalitus*					
	NN7 *Discoaster kugleri*			Middle	Miocene
first *Discoaster kugleri*					
	NN6 *D. exilis*	*Discoaster brouweri* *D. challengeri* *Triquetrorhabdulus rugosus* *Discoaster pseudovariabilis*	*D. abisectus*	Middle	Miocene
last *Sphenolithus heteromorphus*					
	NN5 *Sphenolithus heteramorphus*	*Sphenolithus abies* *Reticulofenestra pseudoumbilica*	*D. druggi*	Middle	Miocene
last *Helicopontosphaera ampliaperta*					
	NN4 *Helicopontosphaera ampliaperta*	*Discoaster exilis*		Lower	Miocene
last *Sphenolithus belemnos*					
	NN3 *Sphenolithus belemnos*	*Sphenolithus heteromorphus*		Lower	Miocene
last *Triquetrorhabdulus carinatus*					
	NN2 *Discoaster druggi*	*Cyclococcolithina leptopora*		Lower	Miocene
first *Discoaster druggi*					
	NN1 *Triquetrorhabdulus carinatus*	*Discoaster trinidadensis* *Sphenolithus belemnos* *Helicopontosphaera kamptneri*	*D. dictyodus*	Lower	Miocene
last *Sphenolithus ciperoensis*					
	NP25 *Sphenolithus ciperoensis*			Upper	Oligocene
last *S. distentus*					
	NP24 *S. distentus*		*Chiasmolithus oamaruensis*	Upper / Middle	Oligocene
first *S. ciperoensis*					
	NP23 *S. predistentus*	*Discoaster abisectus*	*Sphenolithus predistentus* *S. pseudoradians* *Zygrhablithus bijugatus*	Middle	Oligocene
first *S. distentus*					
	NP22 *Helicopontosphaera reticulata*		*Isthmolithus recurvus* *Cyclococcolithina formosa*	Lower	Oligocene
last *Ericsonia ? subdisticha*					
	NP21 *Ericsonia ? subdisticha*			Lower	Oligocene
last *Discoaster saipanensis*					
	NP20 *Sphenolithus pseudoradians*	*Sphenolithus predistentus*	*Discoaster barbadiensis*	Upper	Eocene
first *Sphenolithus pseudoradians*					
	NP19 *Isthmolithus recurvus*			Upper	Eocene
first *Isthmolithus recurvus*					
	NP18 *Chiasmolithus oamaruensis*			Upper	Eocene
first *Chiasmolithus oamaruensis*					
	NP17 *Discoaster saipanensis*			Upper	Eocene
last *C. solitus*					
	NP16 *D. tani nodifer*	*Discoaster dictyodus* *D. saipanensis*		Middle	Eocene

Figure 3. *Cenozoic zones and zonal boundaries (from Martini, 1971) and additional stratigraphic events used for correlation in this report.*

coaster pseudovariabilis (NN6 *Discoaster exilis* Zone to NN11 *Discoaster quinqueramus* Zone at Site 251) and of *Triquetrorhabdulus rugosus* (NN6 *Discoaster exilis* Zone to NN11 *Discoaster quinqueramus* Zone at Site 253 and to NN12 *Ceratolithus tricorniculatus* Zone at Site 251) proved to be longer in the Indian Ocean than elsewhere.

Mesozoic Nannoplankton Zones

The correlation of the Albian nannoplankton assemblages at Sites 256, 257, and 258 is based on the zonation proposed by Thierstein (1971, 1973). The Upper Cretaceous (Cenomanian-Santonian) nannofossils at Site 258 could not be definitely assigned to one of the available, formally described zonations (Cepek and Hay, 1969; Manivit, 1971) for the following reasons: The sequence of the first occurrences of *Kamptnerius magnificus* and *Marthasterites furcatus* indicated in both publications is the reverse of that on the Naturaliste Plateau (Site 258). Secondly, a number of nannofossils formerly described and used as individual species seem to be morphotypes of one species, i.e., they show almost equal stratigraphic ranges, and their relative abundances are often inverse and depend on the lithology and the diagenesis which affected the sample (e.g., perforated and imperforated specimens of the genera *Broinsonia*, *Gartnerago*, and *Kamptnerius*, and *Micula pyramida*/*M. staurophora* and others).

On the other hand, no new zonal system is formally described since the foraminiferal biostratigraphic control of the sequence on Naturaliste Plateau is unsatisfactory, sedimentation at this site was not continuous, and correlation by detailed studies of further nannofossil assemblages of known age was not possible during the time available for preparing this report. In addition, the Cretaceous assemblages at Sites 250 and 255 are poorly preserved and their correlation is, therefore, rather tentative.

For these reasons, an informal zonal system is used here, incorporating results from Cepek and Hay (1969), Manivit (1971), Roth and Thierstein (1972), and Roth (1973) as well as from preliminary studies of upper Cretaceous samples from Texas and the Crimea by the author. The essential parts of the biostratigraphic scale employed are summarized in Figure 4 and more details are given in Table 8b.

Since both biogeographic distribution as well as preservation of upper Cretaceous nannoplankton are the main impediments to their stratigraphic usability, studies in these two directions are being continued.

Prediscosphaera cretacea Zone

Interval from the first occurrence of *Prediscosphaera cretacea* to the first occurrence of *Eiffellithus turriseiffeli*. The assemblages of this zone found at two Sites (257 and 258) closely resemble those described from Copt Point (Great Britain) by Thierstein (1973). They must be considered of austral character, since they contain *Cribrosphaerella primitiva*, which was found in the middle Albian of Copt Point too; and lack the tethyan *Nannoconus* sp., *Rucinolithus irregularis*, and *Parhabdolithus infinitus*.

Eiffellithus turriseiffeli Zone

Interval from the first occurrence of *Eiffellithus turriseiffeli* to the first occurrence of *Lithraphidites alatus*. Moderately etched assemblages of this zone were encountered at Site 256, Cores 8 and 9. At Site 258 this zone reaches the considerable thickness of 80-100 meters. Its upper limit is defined by the first occurrence of *L. alatus*, as proposed by Roth (1973).

Lithraphidites alatus Zone

Interval from the first occurrence of *Lithraphidites alatus* to the first occurrence of *Gartnerago obliquum*

Zonal Boundaries	Zones	Stratigraphic Events	Age
	Marthasterites furcatus	first *Tetralithus obscurus* first *Broinsonia furtiva*	Santonian Coniacian
first *Marthasterites furcatus*	*Kamptnerius magnificus*	first *Microrhabdulus decoratus* last *Gartnerago striatum*	Coniacian
first *Kamptnerius magnificus*	*Micula staurophora*		Turonian
first *Micula staurophora*	*Gartnerago obliquum*	first *Ahmuellerella octoradiata* last *Podorhabdus albianus* last *Lithraphidites alatus*	Turonian
first *Gartnerago obliquum*	*Lithraphidites alatus*		Cenomanian
first *Lithraphidites alatus*	*Eiffellithus turriseiffeli*	first *Corollithion signum*	U. Albian
first *Eiffellithus turriseiffeli*	*Prediscosphaera cretacea*	first *Prediscosphaera spinosa* first *Cretarhabdus coronadventis* first *Broinsonia signata* first *Cribrosphaerella primitiva*	M. Albian
first *Prediscosphaera cretacea*			

Figure 4. *Correlation of Cretaceous zones, zonal boundaries, and additional stratigraphic events used in this report.*

(perforated and imperforated). *Lithraphidites alatus*, although usually rare in occurrence, has proved to be a valuable marker for the Albian/Cenomanian boundary; its occurrence is known from the Alps, the Crimea, the Central and Western North Atlantic, the Pacific, and the Indian Ocean. Only Sample 258-14, CC contains an assemblage of this zone.

Gartnerago obliquum Zone

Interval from the first occurrence of *Gartnerago obliquum* (perforated and imperforated) to the first occurrence of *Micula staurophora*. The zone as used here includes the *Corollithion exiguum* Zone (middle Turonian) of Manivit (1971). The *Gartnerago obliquum* Zone is represented only by the assemblages in Samples 258-14-1, 85 cm and 258-13, CC. Sample 258-13-4, 9 cm contains the lowermost *Micula staurophora*, the first occurrence of which was found in the upper Turonian (Manivit, 1971). *Lithraphidites alatus* and *Podorhabdus albianus* have their last occurrence in Sample 258-14-1, 85 cm and *Ahmuellerella octoradiata* has its first occurrence in Sample 258-13, CC. The thickness (7.5-16 m) between Samples 258-14, CC (upper Cenomanian) and 258-13-4, 9 cm (upper Turonian) suggests an unconformity. A more refined subdivision of the relatively long interval represented by the *Gartnerago obliquum* Zone might be obtained elsewhere by using the last occurrences of *Lithraphidites alatus* and *Podorhabdus* albianus and the first occurrence of *Ahmuellerella octoradiata*.

Micula staurophora Zone

Interval from the first occurrence of *Micula staurophora* to the first occurrence of *Kamptnerius magnificus* (perforated and imperforated). The first occurrence of *Micula staurophora* has been used to define a zone by Manivit (1971). The fact that *M. pyramida* and *M. staurophora* probably represent morphotypes or preservational stages of the same species might explain the differences in stratigraphic distribution of the two species indicated and discussed by Manivit (1971, p. 41) and Roth (1973, p. 698). This zone is found in Sections 2, 3, and 4 of Core 13, Site 258.

Kamptnerius magnificus Zone

Interval from the first occurrence of *Kamptnerius magnificus* (perforated and imperforated) to the first occurrence of *Marthasterites furcatus*. The first occurrences of *Kamptnerius punctatus* and *K. magnificus* have been used as zonal boundaries of two subsequent zones by Cepek and Hay (1969) above their *Marthasterites furcatus* Zone. Manivit (1971) retained the *Kamptnerius magnificus* Zone above the *Marthasterites furcatus* Zone, but found *Kamptnerius punctatus* below the *Marthasterites furcatus* Zone. Cepek (1970) gives the age sequence of first occurrences as *Kamptnerius magnificus*, upper Turonian; *Marthasterites furcatus*, upper Coniacian; and *Kamptnerius pseudopunctatus*, upper Santonian. The inverse abundances of perforated and imperforated specimens of *Kamptnerius* and their almost simultaneous occurrences at Site 258 strongly suggests considering them monospecific, as proposed by Bramlette and Martini (1964). Assemblages of this zone have been found from Samples 258-13-2, 88 cm to Sample 258-11-3, 73 cm.

Marthasterites furcatus Zone

The base of this zone is defined by the first occurrence of *Marthasterites furcatus*. Its top has been defined by various means: the first occurrence of *Arkhangelskiella ethmopora* (see Cepek and Hay, 1969); the first occurrence of *Kamptnerius magnificus* (see Manivit, 1971); and the last occurrence of *Marthasterites furcatus* (see Roth, 1973). Within this zone (Samples 258-11-2, 7 cm to 258-5-1, 120 cm and Samples 258A-9-6, 39 cm to 258A-8-6, 133 cm) *Broinsonia furtiva*, *Lucianorhabdus cayeuxi*, and *Watznaueria virginica* have their first occurrence and *Micula staurophora* becomes abundant. The nannoplankton assemblages of the Santonian Gingin Chalk (Belford, 1960) in the Perth Basin differ from those at Site 258 by the presence of *Tetralithus obscurus* and *T. ovalis* and the absence of *Marthasterites furcatus*. Whether or not this is related to paleoecology or stratigraphy is difficult to evaluate.

CALCAREOUS NANNOPLANKTON AT THE DRILL SITES

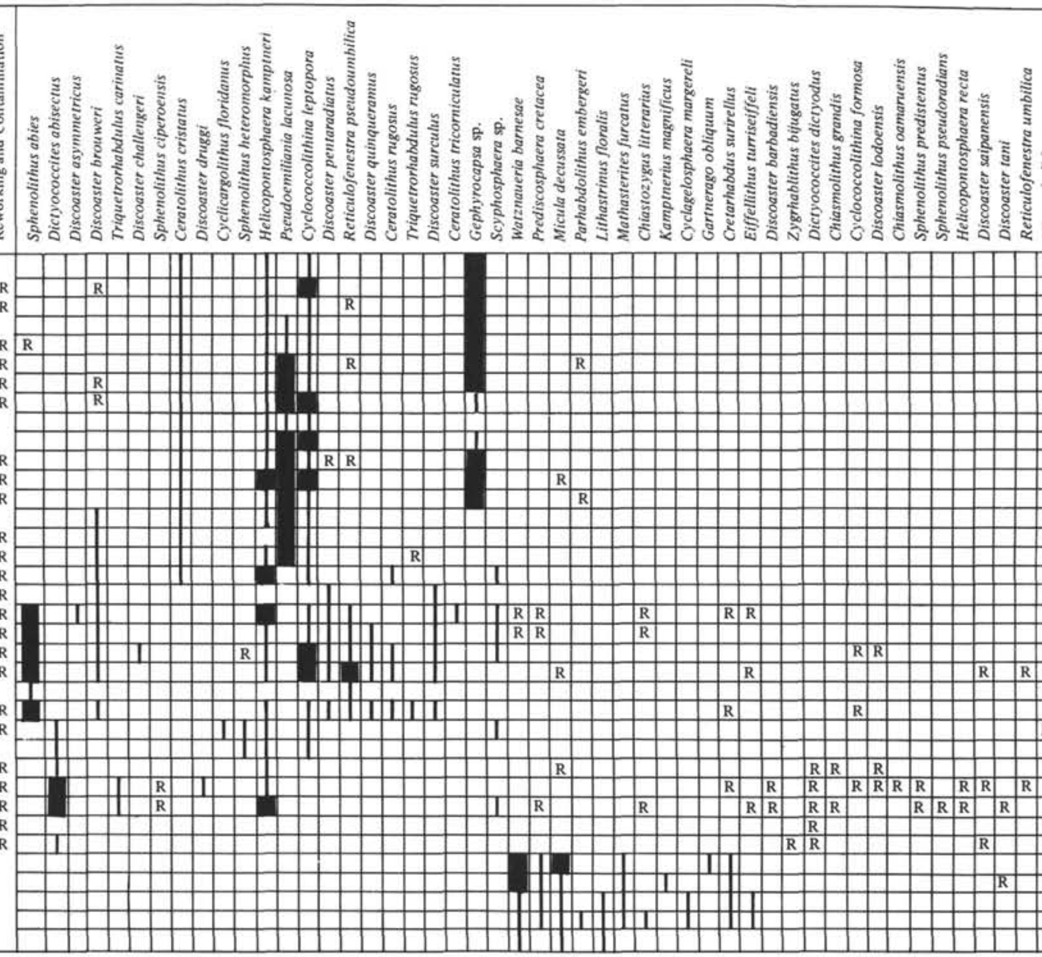
Stratigraphic interpretation of nannofossil assemblages at each site and their correlation with stratigraphic subdivision by means of planktonic foraminifera are discussed below. The preservation of the nannofossil assemblages and some tentative paleoecologic implications are given. Additional information on the distribution of nannoplankton species in the samples may be found in the detailed range charts (Tables 1-8). For extent of nannofossil zones, their correlation with foraminifera zones, and lithology of the cores, refer to the lithologic and biostratigraphic summary diagrams included in the Site reports (this volume).

SITE 250
(lat 33°27.74'S, long 39°22.15'E, depth 5119 m)

Stratigraphy: At this site Quaternary, Pliocene, Miocene, and Upper Cretaceous ages of the sediments could be determined by means of calcareous nannoplankton. The stratigraphic distribution of the calcareous nannoplankton in Holes 250 and 250A is shown in Table 1. The extent of the zones encountered and their correlation with the foraminiferal and radiolarian stratigraphy are summarized on the biostratigraphic and lithologic summary diagram included in Chapter 3, this volume. A total of 108 samples from the two holes was prepared but only 36 contained nannofossils. The age correlations by means of foraminifera and calcareous nannoplankton are in good agreement, except for Core 18, where exclusively middle to upper Eocene nannofossils and lower to middle Miocene (with reworked Paleogene) foraminifera were found. Although the abundance and preservation of the Cretaceous nannofossil assemblages are not favorable, they can be correlated with the Coniacian assemblages on the Naturaliste Plateau (Site 258) in the eastern

TABLE 1
Distribution of Calcareous Nannofossils at Site 250[a]

Age	Zone	Sample (Interval in cm)	Abundance[b]	Preservation[c]	Reworking and Contamination[d]
Quaternary	NN20 *Gephyrocapsa oceanica*	250-1-1, 110	A	PE	
		250-1-4, 110	A	ME	R
		250-2-1, 117	A	ME	R
	NN19 *Pseudoemiliania lacunosa*	250-2-4, 116	A	ME	
		250-2, CC	A	ME	R
		250-3-1, 110	A	GE	R
		250-3-3, 110	A	ME	R
		250-3, CC	A	ME	R
		250A-1-1, 125	A	PE	
		250A-1, CC	A	ME	
		250A-3-2, 110	C	ME	R
		250A-3-5, 110	A	ME	R
		250A-3, CC	C	ME	R
Pliocene U.	NN18 *Discoaster brouweri*	250A-4-1, 107	C	ME	
		250A-4, CC	A	ME	R
		250A-5-3, 102	C	ME	R
		250A-5-5, 110	C	MO	R
	NN16 *D. surculus*	250A-5, CC	F	PO	R
Pliocene L.	NN14 *D. asymmetricus*	250A-7-1, 28	A	G	R
Miocene U.	NN11 *D. quinqueramus*	250A-7-5, 93	A	G	R
		250A-8-3, 89	A	ME	R
		250A-8-5, 40	A	ME	R
		250A-8-5, 110	R	PE	
		250A-9, CC	A	ME	R
Miocene L.	NN3-NN5 *Sphenolithus belemnos-S. heteromorphus*	250A-11-1, 2	C	ME	R
		250A-13-1, 10	R	PE	
		250A-15-4, 146	F	PE	R
	NN2 *Discoaster druggi*	250A-16-2, 148	A	GE	R
	NN1 *Triquetrorhabdulus carinatus*	250A-16-3, 2	A	GE	R
		250A-17-1, 92	R	PE	R
		250A-18, CC	R	PE	R
Coniacian-Santonian	*Marthasterites furcatus*	250A-22-3, 128	C	PE	
		250A-22-4, 14	C	PE	
		250A-22, CC	F	PE	
		250A-23-1, 22	F	PE	
		250A-23-1, 33	R	PE	



[a]Distribution Chart: ■ = common to abundant; | = rare to few; R = reworked.

[b]Abundance: A = abundant; C = common; F = few; R = rare.

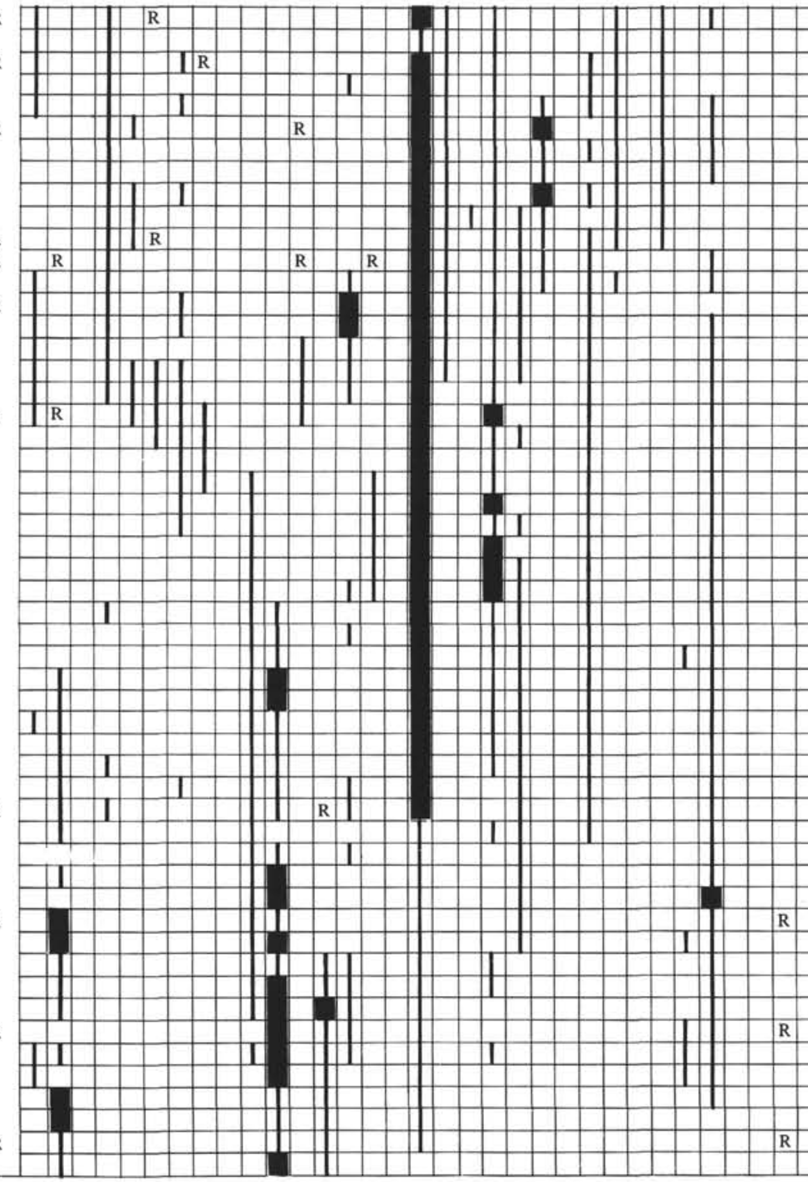
[c]Preservation: G = good; E = etched; M = moderate, O = overgrown, P = poor.

[d]Reworking and Contamination: R = reworked; C = contaminated.

TABLE 2
Distribution of Calcareous Nannofossils at Site 251[a]

Age	Zone	Sample (Interval in cm)	Abundance[b]	Preservation[c]	Reworking and Contamination[d]	Sphenolithus abies	Dictyococcites abisectus	Discoaster asymmetricus	Discoaster brouweri	Discoaster calcaris	Catinaster calyculus	Discoaster challengeri	Catinaster coalitus	Ceratolithus cristatus	Discoaster exilis	Cyclicargolithus floridanus	Discoaster hamatus	Sphenolithus heteromorphus	Helicopontosphaera kamptneri	Discoaster kugleri	Pseudoemiliania lacunosa	Cyclococcolithina leptopora	Discoaster pentaradiatus	Ceratolithus primus	Reticulofenestra pseudoumbilica	Discoaster pseudovariabilis	Discoaster quinqueramus	Ceratolithus rugosus	Triquetrorhabdulus rugosus	Discoaster surculus	Discoaster tamalis	Ceratolithus tricorniculatus	Discoaster trinidadensis	Discoaster variabilis	Gephyrocapsa sp.	Scyphosphaera sp.	Dictyococcites dictyodus	Reticulofenestra umbilica
Quaternary	NN20 *Gephyrocapsa oceanica*	251-1-1, 132	A	G																																		
		251-1, CC	A	G																																		
		251-2-?, 111	A	G																																		
		251-2-5, 110	A	G																																		
	NN19 *Pseudoemiliania lacunosa*	251-2, CC	A	G	R																																	
		251-3-2, 110	A	G																																		
		251-3, CC	A	G																																		
		251-4-2, 110	A	GE																																		
		251-4-5, 110	A	G																																		
		251-4, CC	A	GE																																		
		251-5-2, 110	A	G	R																																	
		251-5-5, 110	A	G	R																																	
		251-5, CC	A	G																																		
		251-6-2, 110	A	GE																																		
		251-6-5, 110	A	GE																																		
U. Pliocene	NN18 *Discoaster brouweri*	251-6, CC	A	GE																							R			R								
		251-7-1, 110	A	GE																																		
		251-7-2, 110	A	GE	R																																	
		251-7-6, 110	A	GE	R																																	
		251-7, CC	A	GE	R		R																															
		251-8-2, 110	A	G																																		
		251-8-5, 110	A	G	R																																	
		251-8, CC	A	G	R																																R	
	NN16 *D. surculus*	251-10-2, 110	A	G	R																																R	
		251-10-5, 110	A	G	R																																	
		251-10,CC	A	G	R																																	
		251A-1-1, 110	A	G																																		
		251A-1-5, 110	A	G																																		
		251A-1, CC	A	G																																		
		251A-2-2, 110	A	G																																		
		251A-2-5, 110	A	G																																		
		251A-2, CC	A	GE																																		
L. Pliocene	NN15 *Reticulofenestra pseudoumbilica*	251A-4-2, 110	A	GE	R		R																															
		251A-4-5, 110	A	GE	R																																R	
	NN14 *Discoaster asymmetricus*	251A-4, CC	A	GE	R		R																															
	NN13 *Ceratolithus rugosus*	251A-5-2, 110	A	G																																		
		251A-5-5, 110	A	G																																		
		251A-5, CC	A	G																																		
		251A-6-2, 110	A	GE	R		R																															R
		251A-6-5, 110	A	G																																		
		251A-6, CC	A	GE																																		
		251A-7-2, 110	A	G																																		
		251A-7-5, 110	A	G	R																								R									
		251A-7, CC	A	GE																																		
		251A-9-2, 110	A	GE																																		

Age		Zone	Sample	Abundance	Preservation	Reworking
U.	Miocene	NN12 *C. tricorniculatus*	251A-9-5, 110	A	GE	R
			251A-9, CC	A	GE	
			251A-10-2, 110	A	GE	R
			251A-10-5, 110	A	GE	
		NN11 *Discoaster quinqueramus*	251A-10, CC	A	GE	
			251A-11-1, 110	A	GE	R
			251A-11-3, 105	A	GE	
			251A-11, CC	A	GE	
			251A-12-1, 88	A	GE	
			251A-12-3, 110	A	G	
			251A-12, CC	A	G	R
			251A-13-2, 131	A	G	R
			251A-13-4, 111	A	G	
		NN10 *D. calcaris*	251A-13, CC	A	G	R
			251A-14-1, 104	A	G	
		NN9 *D. hamatus*	251A-14, CC	A	G	
			251A-15-2, 110	A	G	
M.			251A-15, CC	A	G	
			251A-16-2, 110	A	G	R
		NN8 *Catinaster coalitus*	251A-16-4, 110	A	GE	
			251A-16, CC	A	G	
			251A-17-2, 120	A	G	
		NN7 *Discoaster kugleri*	251A-17, CC	A	GE	
			251A-18-1, 105	A	G	
			251A-18, CC	A	GE	
			251A-19-1, 125	A	GE	
			251A-19, CC	A	GE	
		NN6 *D. exilis*	251A-20-2, 105	A	GE	
			251A-20-4, 100	A	GE	
			251A-20, CC	A	GE	
			251A-21-1, 60	A	GE	
			251A-21-3, 110	A	GE	
			251A-21, CC	A	GE	
			251A-22-1, 110	A	GE	
			251A-22-3, 110	A	GE	
			251A-22, CC	A	GE	
			251A-23-2, 110	C	M	R
			251A-23, CC	C	M	
			251A-24-1, 110	C	M	
			251A-24-3, 110	C	M	
			251A-24, CC	C	M	
			251A-25-2, 110	C	M	R
			251A-25-4, 105	C	M	
		NN5 *Sphenolithus heteromorphus*	251A-25, CC	C	M	
			251A-26-2, 70	C	M	
			251A-26-4, 56	C	M	
			251A-26, CC	C	M	R
			251A-27-1, 131	C	MO	
			251A-27-2, 110	C	MO	
			251A-27, CC	C	MO	
			251A-28-1, 4	C	MO	
			251A-28-1, 25	C	MO	R
			251A-30-1, 60	C	MO	



[a]Distribution Chart: ■ = common to abundant; | = rare to few; R = reworked.

[b]Abundance: A = abundant; C = common; F = few; R = rare.

[c]Preservation: G = good; E = etched; M = moderate; O = overgrown; P = poor.

[d]Reworking and Contamination: R = reworked; C = contaminated.

Indian Ocean. Reworked middle to upper Eocene nannofossils are found in Hole 250, Cores 2 and 3 and in Hole 250A, Cores 3-5, 7-9, 11, 15, 16, and 18. Reworked Upper Cretaceous nannoplankton are encountered in Hole 250, Core 3 and in Hole 250A, Cores 3, 5, 7-9, 15, and 16.

Preservation: Two samples in the lower part of Core 5 (Hole 250A) showed overgrowth. All other nannofossil assemblages are slightly to strongly etched.

Paleoecology: Any paleoecologic interpretation of the Cretaceous assemblages is prevented by their scarcity and poor preservation. Paucity of fossiliferous layers and great variability in preservation indicate a depositional depth around the calcium carbonate compensation depth throughout the Neogene. Influx of transported deposits must be assumed from the reworked nearshore Eocene and the Cretaceous nannofossils. The relative abundance of discoasters, sphenoliths, and scyphospheras indicates a temperate environment during the Neogene.

SITE 251
(lat 36°30.26′S, long 49°29.08′E, depth 3489 m)

Stratigraphy: Site 251 is of particular biostratigraphic interest, since it has revealed an almost complete and uninterrupted mid-latitudinal Neogene sequence of uniform lithology ranging in age from the upper part of the lower Miocene to Recent. Only the lowermost part of the section shows a change in lithology which is accompanied by sparse, poorly preserved microfossils. Unfortunately, the value of the site as a standard is considerably restricted by strong and selective dissolution effects of the foraminiferal assemblages especially in the Miocene part of the section. Table 2 shows the occurrences of some stratigraphically valuable species in the 98 fossiliferous samples and their zonal assignment. At this site the sediments from 0 to 175 meters and from 375 to 500 meters have been cored continuously leaving an intermediate interval of 200 meters thickness with intermittent coring at about every 30 meters. Nevertheless, the recovered material represents an almost continuous sequence of the nannofossil zones used in this report. The thickness and the correlation of the nannoplankton zones with the foraminiferal zones are shown on the biostratigraphic and lithologic summary diagram included in the Site Report. A difference of 10 meters thickness showed up when tracing the Pliocene/Quaternary boundary by means of nannoplankton and foraminifera. The core catcher of Core 7 (Hole 251) contains the lowermost occurring *Gephyrocapsa* sp., but in each of the four samples from this core, rare *Discoaster brouweri* have been found. The samples have therefore been attributed to the Pliocene. In a few scattered samples reworked Paleogene nannofossils (*Reticulofenestra umbilica, Dictyococcites dictyodus*) have been encountered.

Preservation: The nannofossils within the upper 420 meters (Hole 251, Cores 1-10; Hole 251A, Cores 1-22) are abundant and well preserved to slightly etched. The samples from depths of 420 to 470 meters contain common, moderately preserved assemblages with signs of overgrowth in the lowermost 15 meters (Cores 27, 28). One sample (251A-29-2, 100 cm) shows some heavily overgrown discoasters among thick, rounded calcite particles; the other two samples from this core are barren. A pocket of nannoplankton ooze in the vesicular basalt of Core 31 contained common, moderately overgrown nannofossils.

Paleoecology: The preservation of the nannofossils at this site suggests a consistent depositional depth around the lysocline since the middle Miocene. Site 251 is considered to be situated on the flank of a slowly spreading ridge, it therefore has been deepening since the formation of the crust beneath it (Sclater et al., 1971). The preservation of the nannofossils thus suggests a continuous deepening of the lysocline through the Neogene. Transitional paleotemperatures throughout the Neogene are documented by the scarcity of *Sphenolithus abies* and of discoasters.

SITE 252
(lat 37°02.44′S, long 59°14.33′E, depth 5032 m)

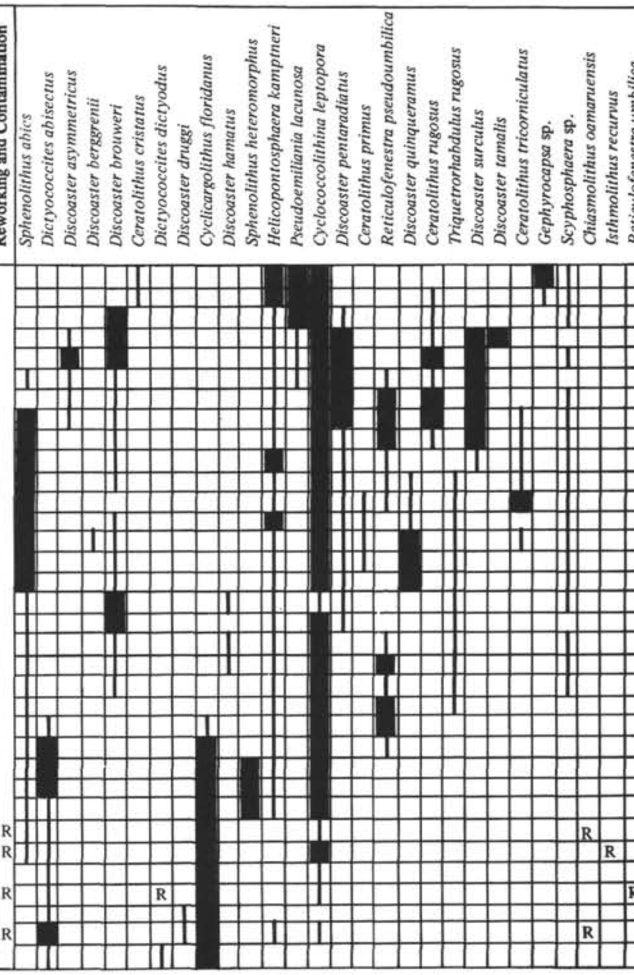
The sediments at Site 252 are devoid of calcareous nannoplankton except for a marly patch on a manganese nodule in Core Catcher 1, which contained a few etched *Gephyrocapsa* sp., *Coccolithus pelagicus,* and *Ceratolithus cristatus.*

SITE 253
(lat 24°52.65′S, long 87°21.97′E, depth 1962 m)

Stratigraphy: At Site 253, 153 meters of foraminifera-rich nanno ooze of Quaternary to upper Eocene age overlies 405 meters of volcanic ash containing scarce nannofossils, few small benthonic and very rare planktonic foraminifera, rare to common radiolarians and diatoms, and some other invertebrate fossils, such as larger foraminifera, bryozoans, crinoid fragments, and molluscs. Within the calcareous ooze, 9 meters belong to the Quaternary, 9 meters to the Pliocene, 66 meters to the Miocene, 30 meters to the Oligocene, and 35 meters to the uppermost middle and upper Eocene. The sedimentation is continuous throughout this sequence, except for a small hiatus in the upper part of the upper Eocene. The lower Oligocene is much reduced in thickness. Due to heavy overgrowth, several marker species could not be recognized, e.g., *Discoaster exilis, D. kugleri, Helicopontosphaera recta, H. reticulata,* and *Triquetrorhabdulus carinatus.* Many other species could only be identified tentatively and/or in small numbers, e.g., *Discoaster barbadiensis, D. brouweri, D. druggi, D. hamatus, D. saipanensis, Helicopontosphaera compacta, Reticulofenestra pseudoumbilica,* and *Triquetrorhabdulus inversus.* Nevertheless, members of the families Coccolithaceae, Sphenolithaceae, Ceratolithaceae, and some others allowed biostratigraphic interpretation of most of the samples. All nannofossil assemblages of the volcanic ash sequence (Cores 18 through 57) are considered to be of late-middle Eocene age (NP16 *Discoaster tani nodifer* Zone of Martini, [1971], or *Discoaster saipanensis* Subzone of Bukry, [1973]). Although abundance and preservation of the assemblages are not good, co-occurrence of *Chiasmolithus solitus, Discoaster saipanensis, Reticulofenestra samodurovi,* and *Dictyococcites bisectus,* and absence of *Rhabdosphaera gladius, Chiphragmalithus alatus, Discoaster lodoensis,* and

TABLE 3a
Neogene Distribution of Calcareous Nannofossils at Site 253[a]

Age	Zone	Sample (Interval in cm)	Abundance[b]	Preservation[c]	Reworking and Contamination[d]
Quaternary	NN19 *Pseudoemiliania lacunosa*	253-1-2, 105	A	G	
		253-1-5, 14	A	G	
U. Pliocene	NN17 *Discoaster pentaradiatus*	253-1, CC	A	GO	
	NN16 *D. surculus*	253-2-1, 45	A	GO	
		253-2-2, 110	A	GO	
L. Pliocene	NN15 *Reticulofenestra pseudoumbilica*	253-2-3, 65	A	GO	
		253-2-4, 65	A	MO	
	NN14 *Discoaster asymmetricus*	253-2-5, 110	A	MO	
	NN13 *Ceratolithus rugosus*	253-2, CC	A	MO	
U. Miocene	NN12 *C. tricorniculatus*	253-3-2, 110	A	MO	
	NN11 *Discoaster quinqueramus*	253-3-5, 110	A	MO	
		253-3, CC	A	MO	
		253-4-2, 109	A	MO	
		253-4-5, 110	A	MO	
		253-4, CC	A	MO	
		253-5-2, 110	A	MO	
	NN9 *D. hamatus*	253-5-5, 110	A	MO	
		253-5, CC	A	MO	
		253-6-2, 97	A	MO	
M. Miocene		253-6-5, 90	A	MO	
		253-6, CC	A	MO	
		253-7-2, 131	A	MO	
		253-7-5, 114	A	MO	
		253-7, CC	A	MO	
	NN5 *Sphenolithus heteromorphus*	253-8-3, 78	A	MO	
		253-8-5, 110	A	MO	
		253-8, CC	A	MO	
L. Miocene	NN3 *S. belemnos*	253-9-1, 113	A	MO	R
		253-9-2, 68	A	MO	R
		253-9-3, 137	A	MO	
		253-9-4, 96	A	MO	R
	NN2 *Discoaster druggi*	253-9-5, 144	A	MO	
		253-9-6, 83	A	MO	R
	NN1 *Triquetrorhabdulus carinatus*	253-9, CC	A	MO	



[a]Distribution Chart: ■ = common to abundant; | = rare to few; R = reworked
[b]Abundance: A = abundant; C = common; F = few.
[c]Preservation: G = good; E = etched; M = moderate; O = overgrown; P = poor
[d]Reworking and Contamination: R = reworked; C = contaminated

Chiasmolithus gigas suggest this correlation. Following the time correlations by Perch-Nielsen (1972) and Bukry (1973), the 400-meter-thick volcanic-ash sequence has been deposited about 43 m.y. ago within less than 2 m.y. The boundary between the middle and upper Eocene is marked by the extinction of *Chiasmolithus solitus* and by the transition of the small *Reticulofenestra samodurovi* to the large *R. umbilica*. This boundary coincides with a change in lithology and a fast deepening of the site, obvious from the changes in composition and abundance of the nannofossil assemblages. Late Eocene assemblages are found up to Core 13. Cores 12 to 10 contain a nearly complete Oligocene. Cores 9 and 8 are of lower Miocene age. Core 8 (upper part) belongs to the basal middle Miocene. It was not possible to correlate the nannofossils of Cores 7 and 6 (basal part) because the short-ranging middle Miocene marker species *Discoaster kugleri, D. hamatus, Catinaster coalitus*, and *C. calyculus* could not be identified. Cores 6 through 1 contain an almost continuous sequence of upper Miocene through Quaternary assemblages. Scarce reworked upper Eocene species have been found in Core 9.

Preservation: All pre-Quaternary nannofossil assemblages showed strong overgrowth, which often made their recognition difficult. In the volcanic ash sequence the overgrowth apparently was preceded by partial dissolution. *Isthmolithus recurvus, Triquetrorhabdulus inversus, T. rugosus*, and most recognized discoasters were considerably altered. Other species, such as *Helicopontosphaera recta, H. reticulata, Sphenolithus belemnos, Discoaster bollii, D. calcaris, D. challengeri, D. exilis, D. formosus, D. kugleri, D. neohamatus, D. pseudovariabilis, D. trinidadensis, Catinaster calyculus, C. coalitus*, and *Triquetrorhabdulus carinatus*, could not be identified at all.

Paleoecology: The relative scarcity of discoasters in the middle Eocene ash sequence and the presence of *Zygolithus dubius, Micrantholithus* sp., *Braarudosphaera bigelowi, B. discula, Pemma rotundum*, and *Zygrhablithus bijugatus* indicate a nearshore or shallow-water environment. An increase in abundance of *Discoaster saipanensis* and the disappearance of the genera *Braarudosphaera, Micrantholithus*, and *Pemma* indicate a continuous deepening of the site through the upper

TABLE 3b
Paleogene Distribution of Calcareous Nannofossils at Site 253[a]

Age	Zone	Sample (Interval in cm)	Abundance[b]	Preservation[c]	Reworking and Contamination[d]	*Dictyococcites abisectus*	*Discoaster barbadiensis*	*Braarudosphaera bigelowi*	*Zygrhablithus bijugatus*	*Sphenolithus ciperoensis*	*Helicopontosphaera compacta*	*Dictyococcites dictyodus*	*Sphenolithus distentus*	*Zygolithus dubius*	*Cyclicargolithus floridanus*	*Cyclococcolithina formosa*	*Chiasmolithus grandis*	*Markalius inversus*	*Triquetrorhabdulus inversus*	*Helicopontosphaera lophota*	*Lanternithus minutus*	*Chiasmolithus oamaruensis*	*Sphenolithus predistentus*	*Sphenolithus pseudoradians*	*Sphenolithus radians*	*Isthmolithus recurvus*	*Pemma rotundum*	*Discoaster saipanensis*	*Reticulofenestra samodurovi*	*Chiasmolithus solitus*	*Reticulofenestra umbilica*	*Micrantholithus* sp.
U.	NP25 *Sphenolithus ciperoensis*	253-10-2, 23	A	MO		■				I		I			I																	
	NP24 *S. distentus*	253-10-5, 115	A	MO		■				I		I	I																			
		253-10, CC	A	MO		■				I		■										I									I	
	NP23 *S. predistentus*	253-11-2, 50	A	MO		■						■	I									I	I									
		253-11-5, 65	A	MO							I	■	I									I	I								I	
M. Oligocene		253-11, CC	A	MO	R							■			I							■	I	I				R			I	
		253-12-2, 130	A	MO		I						■	I									I	I	I							I	
		253-12-5, 122	A	MO					I			■	I								I	■	I	I							■	
L.	NP21 *Ericsonia ? subdisticha*	253-12, CC	A	MO					■			■				■					I		I			I					■	
	NP20 *Sphenolithus pseudoradians*	253-13-2, 110	A	MO					I		I	■				■					I					■		I			■	
		253-13-5, 110	A	MO			I		I			■				■										■		■			■	
		253-13, CC	A	MO			I		I			■				■							I			■		■			■	
		253-14-2, 73	A	MO			I		I			■				I						I	I	I		I		I			■	
		253-14-5, 130	A	MO			I		I			■				■		I				I	I	I		I		I			■	
U.	NP18 *Chiasmalithus oamaruensis*	253-14, CC	A	MO			I		■			■				■			I			■									■	
	NP17 *Discoaster saipanensis*	253-15, CC	A	MO					■			■				■	■		I									■			■	
		253-16-3, 41	A	MO			I		■			■				■	■	I	I									■			■	
		253-16-5, 25	A	MO			I		■			■				■	■		I									I			■	
Eocene		253-16, CC	A	MO			I		■			■				■	I		I						I			I			■	
	NP16 *D. tani nodifer*	253-17-3, 80	C	PO										I	I		I												I	I		
		253-17, CC	R	PO																									I	I		I
		253-18-3, 104	F	MO			I					I																	I	I		
		253-18, CC	C	MO			I		I							I	I	I									I		■	I		I
		253-19, CC	F	PO					I			I		I														I		I		
		253-20, CC	C	MO			I	I	I					I		I	I		I									I	I	I		I
		253-21, CC	R	PO					I																				I	I		
		253-25, CC	F	PO			I		I					I															I	I		
		253-29, CC	C	PO					I			I		I	I	I													I	I		I
M.		253-30, CC	F	MO					I			I				I													I	I		
		253-36, CC	R	PE												I													I			
		253-37, CC	R	MO																									I			
		253-43, CC	R	PO																									I	I		I
		253-44, CC	F	PO					I			I		I																I		
		253-46, CC	C	MO					I			I		I		I												I		I		I
		253-47, CC	F	MO					I			I			I															I		I
		253-51-2, 25	C	MO			I		I			I		I		I	I												I	I		I
		253-51, CC	C	MO			I		I			I		I	I	I				I					I				I	I		I
		253-55, CC	C	MO				I	I			I		I		I									I					I		I
		253-56, CC	C	MO					I			I		I	I	I	I												I	I		I
		253-57, CC	R	MO								I		I																I		

[a]Distribution Chart: ■ = common to abundant; I = rare to few; R = reworked
[b]Abundance: A = abundant; C = common; F = few
[c]Preservation: G = good; E = etched; M = moderate; O = overgrown; P = poor
[d]Reworking and Contamination: R = reworked; C = contaminated.

Eocene and the Oligocene. The Paleogene assemblages suggest transitional to subtropical paleoconditions (*Discoaster saipanensis, D. barbadiensis, Isthmolithus recurvus, Zygolithus dubius*), while those of the Miocene and Pliocene are subtropical to tropical paleoconditions (discoasters, sphenoliths, scyphospheres).

SITE 254
(lat 30°58.15′S, long 87°53.72′E, depth 1253 m)

Stratigraphy: A possibly continuous sequence of lower Miocene to Quaternary nannoplankton assemblages was encountered in the uppermost 170 meters of calcareous oozes (Cores 1-20) at this site. Cores 24 through 33 were barren of nannofossils. Since all pre-Quaternary assemblages showed signs of strong overgrowth, zonal assignment could be based only on a very restricted number of species and therefore remained tentative. The highly liquified nature of the cores and the foram-sand lithology might have resulted in the mixing of sediment within the core barrel. Reworked middle to upper Eocene coccoliths were found in Cores 18 through 20. Core Catcher 16 and Core 12 (middle Miocene) are contaminated with upper Miocene to Pliocene nannofossils.

Preservation: All pre-Quaternary assemblages are overgrown.

Paleoecology: Rare *Braarudosphaera bigelowi* are found in Cores 17 through 20 indicating a nearshore or shallow-water environment in the lower Miocene. The ecologic conditions during the middle and upper Miocene and the Pliocene were subtropical to tropical, as at Site 253.

SITE 255
(lat 31°07.87′S, long 93°43.72′E, depth 1144 m)

Stratigraphy: Common to few, strongly overgrown nannofossils of Santonian (Cores 9-11), middle Eocene (Core 7), Miocene (Cores 3-5), Pliocene (Core 3), and Quaternary age (Core 2) were found. The three poorly preserved upper Cretaceous nannofossil assemblages are correlated with those of the Santonian on the Naturaliste Plateau (Site 258) and seem to be slightly older

TABLE 4
Distribution of Calcareous Nannofossils at Site 254[a]

Age	Zone	Sample (Interval in cm)	Abundance[b]	Preservation[c]	Reworking and Contamination[d]	Sphenolithus abies	Dictyococcites abisectus	Ceratolithus amplificus	Discoaster asymmetricus	Sphenolithus belemnos	Discoaster brouweri	Discoaster druggi	Cyclicargolithus floridanus	Discoaster formosus	Sphenolithus heteromorphus	Helicopontosphaera kamptneri	Pseudoemiliania lacunosa	Cyclococcolithina leptopora	Discoaster neohamatus	Discoaster nephados	Discoaster pentaradiatus	Ceratolithus primus	Reticulofenestra pseudoumbilica	Discoaster quinqueramus	Triquetrorhabdulus rugosus	Discoaster surculus	Discoaster tamalis	Ceratolithus tricorniculatus	Discoaster trinidadensis	Discoaster variabilis	Gephyrocapsa sp.	Scyphosphaera sp.	Braarudosphaera bigelowi	Dictyococcites dictyodus	Chiasmolithus oamaruensis	Chiasmolithus solitus	Reticulofenestra umbilica
Quaternary	NN19 *Pseudoemiliania lacunosa*	254-1-2, 110	A	G																																	
		254-2-2, 85	A	GO	R																				R					R							
U. Pliocene	NN16 *Discoaster surculus*	254-2-5, 110	A	GO																																	
		254-2, CC	A	GO	R																				R												
		254-3-2, 110	A	GO	R																			R													
L.	NN14 *D. asymmetricus*	254-3-5, 110	A	GO																																	
		254-3, CC	A	GO	R																			R													
		254-4-2, 110	A	GO																																	
	NN11 *D. quinqueramus*	254-4-5, 110	A	GO	R																				R												
U.		254-4, CC	A	MO																																	
		254-5-2, 110	A	MO																																	
		254-5-5, 110	C	MO																																	
		254-5, CC	C	MO																																	
	NN9 *D. hamatus*	254-6-2, 110	C	MO																																	
		254-6-5, 110	A	MO																																	
		254-6, CC	A	MO																																	
		254-7-2, 110	A	MO																																	
		254-7-5, 110	A	MO																																	
		254-7, CC	A	MO																																	
		254-8-2, 110	A	MO																																	
		254-8-5, 110	A	MO	R		R																														
		254-8, CC	A	MO																																	
		254-9-2, 110	A	MO																																	
M. Miocene	NN6 *D. exilis*	254-9, CC	A	MO																																	
	NN9 *D. hamatus*	254-10-2, 110	A	MO																																	
		254-10-5, 110	A	MO																																	
		254-10, CC	A	MO																																	
		254-11-2, 110	A	MO																																	
		254-11-5, 110	A	MO																																	
		254-11, CC	A	MO																																	
		254-12-1, 112	A	MO	C			C													C							C									
		254-12-2, 98	A	MO	C				C												C						C	C									
		254-12-3, 67	A	MO	C			C	C												C							C									
	NN5 *Sphenolithus heteromorphus*	254-12, CC	A	MO																																	
		254-14, CC	A	MO																																	
		254-15, CC	A	MO																																	
		254-16, CC	A	MO	C												C				C		C			C											
		254-17-1, 137	A	MO																																	
		254-17, CC	A	MO																																	
		254-18-2, 63	A	MO																																	
		254-18-3, 110	A	MO																																	
	NN1–NN3 *Triquertrorhabdulus carinatus–Sphenolithus belemnos*	254-18-5, 135	A	MO	R																															R	
L.		254-18, CC	A	MO	R																																
		254-19-2, 110	A	MO	R																													R			
		254-19-5, 110	A	MO																																	
		254-19-6, 110	A	MO																																	
		254-19, CC	A	MO																																	
		254-20-1, 4	A	MO	R																													R	R	R	R
		254-20, CC	C	MO	R																													R		R	

[a]Distribution Chart: ■ = common to abundant; | = rare to few; R = reworked.
[b]Abundance: A = abundant; C = common; F = few; R = rare.
[c]Preservation: G = good; E = etched; M = moderate; O = overgrown; P = poor.
[d]Reworking and Contamination: R = reworked; C = contaminated

than the nannofossils of the Gingin Chalk (Santonian) in the Perth Basin. The assemblage in Sample 7, CC consists of about 50% Santonian and 50% lower to middle Eocene species. As at Sites 251 and 258, a stratigraphic overlap of *Discoaster* sp. and *Gephyrocapsa* sp. (Sample 255-3-1, 35 cm) is observed, and again the foraminifera indicate an upper Pliocene age for this overlap.

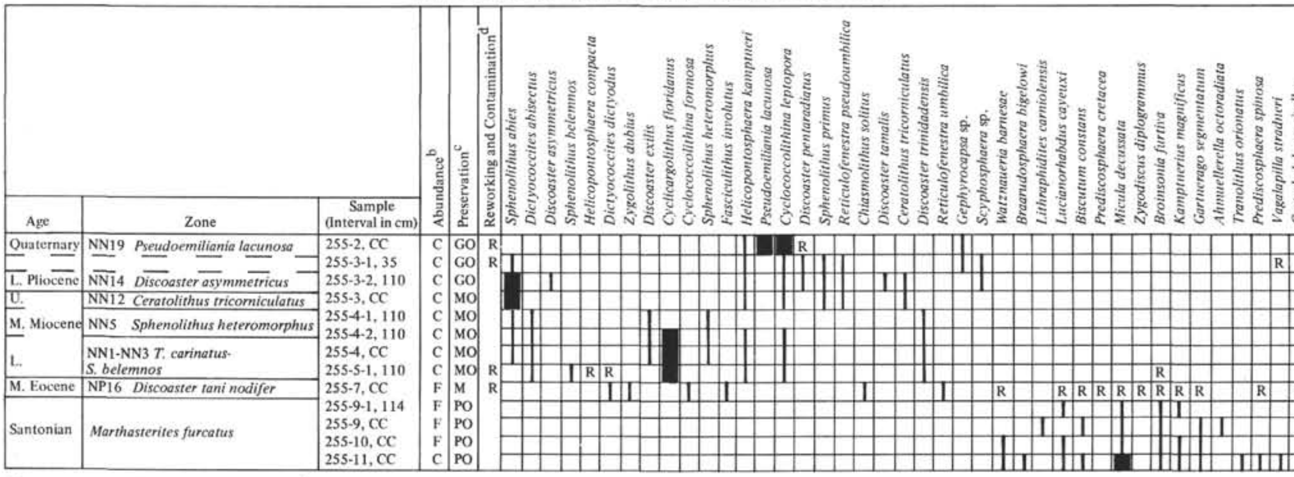
Preservation: The extent of overgrowth of the nannofossils increases with the age of the sediment.

Paleoecology: The Santonian and the Miocene assemblages are characteristic of transitional environments.

SITE 256
(lat 23°27.35'S, long 100°46.46'E, depth 5361 m)

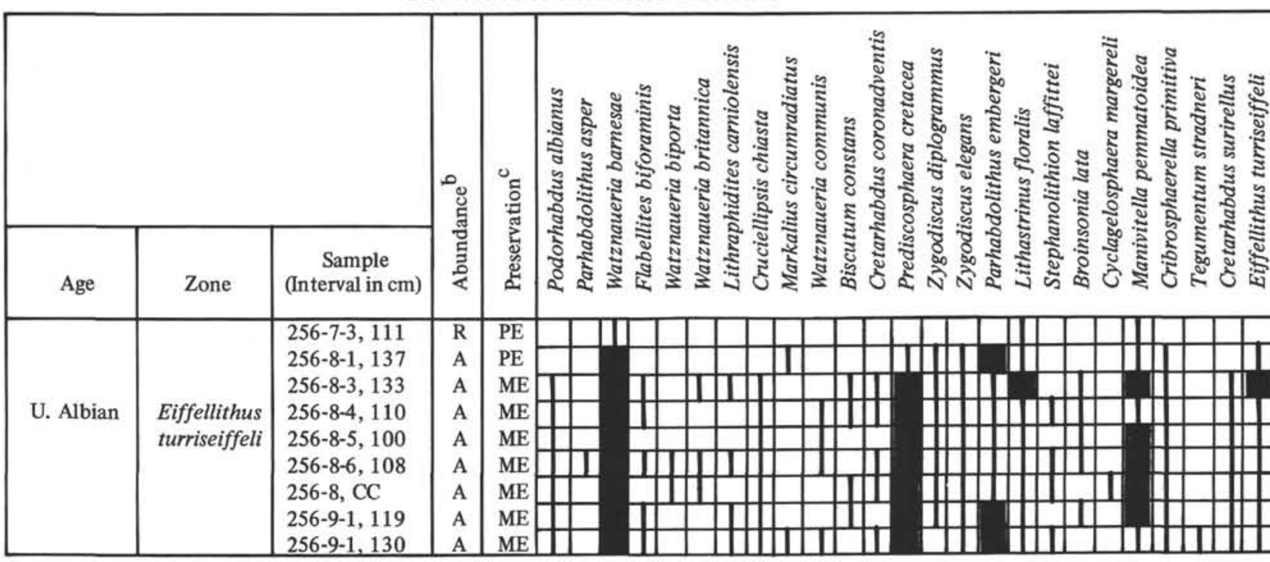
Stratigraphy: The 18 samples prepared from Cores 1 through 6 were barren of nannofossils. Sample 256-7-3, 111 cm showed very rare, strongly etched Cretaceous species. Several samples from Cores 8 and 9 contained abundant, moderately etched nannoplankton assemblages of the *Eiffellithus turriseiffeli* Zone (upper Albian, 100-103 m.y.B.P.). The lowermost fossiliferous sample, still belonging to this zone, has been found in Sample 256-9-1, 130 cm, a few centimeters above the basalt, for

TABLE 5
Distribution of Calcareous Nannofossils at Site 255[a]



[a]Distribution Chart: ■ common to abundant; | = rare to few; R = reworked.
[b]Abundance: A = abundant; C = common; F = few.
[c]Preservation: G = good; E = etched; M = moderate; O = overgrown; P = poor.
[d]Reworking and Contamination: R = reworked; C = contaminated

TABLE 6
Distribution of Calcareous Nannofossils at Site 256[a]



[a]Distribution Chart: ■ = common to abundant; | = rare to few.
[b]Abundance: A = abundant; C = common; F = few; R = rare.
[c]Preservation: G = good; M = moderate; P = poor; E = etched; O = overgrown.

which an absolute age of 102 m.y. has been determined (see Reynolds et al., this volume, Chapter 17).

Preservation: All nannofossils at this site show moderate to strong signs of dissolution.

Paleoecology: The upper Albian assemblages most closely resemble those described from Copt Point (Great Britain) by Thierstein (1973). They must be considered to be of temperate, austral character since they contain *Cribrosphaerella primitiva* which was found at Copt Point, and lack the tethyan nannoconids, *Rucinolithus irregularis* and *Parhabdolithus infinitus*.

SITE 257
(lat 30°59.16′S, long 108°20.99′E, depth 5278 m)

Stratigraphy: Calcareous nannofossils were found only in Cores 7, 8, and 9 and are all of middle Albian age (*Prediscosphaera cretacea* Zone).

Preservation: A continuous decrease of solution effects is observed from Sections 1-6 of Core 7. Samples 257-7, CC and 257-8-1, 139 cm contain only slightly etched assemblages. An increase of etching is observed in Samples 257-8-2, 9 cm through 257-9-2, 37 cm. The

TABLE 7
Distribution of Calcareous Nannofossils at Site 257[a]

Age	Zone	Sample (Interval in cm)	Abundance[b]	Preservation[c]	*Corollithion achylosum*	*Podorhabdus albianus*	*Hayesites albiensis*	*Parhabdolithus angustus*	*Parhabdolithus asper*	*Watznaueria barnesae*	*Watznaueria britannica*	*Lithraphidites carniolensis*	*Cruciellipsis chiasta*	*Markalius circumradiatus*	*Watznaueria communis*	*Vagalapilla compacta*	*Cretarhabdul conicus*	*Biscutum constans*	*Cretarhabdus coronadventis*	*Cretarhabdus crenulatus*	*Prediscosphaera cretacea*	*Podorhabdus decorus*	*Octopodorhabdus decussatus*	*Zygodiscus diplogrammus*	*Zygodiscus elegans*	*Parhabdolithus embergeri*	*Tranolithus exiguus*	*Lithastrinus floralis*	*Tranolithus gabalus*	*Stephanolithion laffittei*	*Cretarhabdus loriei*	*Cyclagelosphaera margereli*	*Vagalapilla matalosa*	*Manivitella pemmatoidea*	*Cribrosphaerella primitiva*	*Broinsonia signata*	*Prediscosphaera spinosa*	*Parhabdolithus splendens*	*Tegumentum stradneri*	*Vagalapilla stradneri*	*Cretarhabdus surirellus*
		257-7-1, 120	A	ME		│				■	│		│		│			│	│		│			│		│		│		│	│	│		│	│		│		│		
		257-7-2, 124	A	ME		│				■	│				│			│	│		│			│		│		│		│	│	│		│	│		│		│		
		257-7-3, 113	A	ME	│	│				■		│			│	│		│	│	│	│	│	│	│		│	│	│	│	│	│			│	■		│	│	■		│
		257-7-4, 115	A	ME		│				■	│				│	│		│	│		│			│		│	│	│		│	│	│		│	│		│		│		│
M. Albian	*Prediscosphaera cretacea*	257-7-5, 136	A	ME		│			│	■	│		│					│	│		│			│				│		│	│			│	│		│		│		
		257-7-6, 110	C	ME		│			│	■	│			│	│	│		│	│		│					│		│		│	│	│		│	│		│		│		│
		257-7, CC	A	GE						■	│			│	│			│	│		│			│		│		│		│	│	│			│				│		
		257-8-1, 139	A	GE			│	│	│	■	│	│			│	│	│	■	│		■			■	│			■		│		│	│	│	│	│	│	│	│	│	│
		257-8-2, 9	A	ME			│	│		■		│			│	│		■			■			■	│	│		│		│		│	│	│	│			│	│		│
		257-8, CC	C	PE						■											│			│		│		│			│			│							
		257-9-1, 123	C	PE			│			■	│				│									│	│			│		│		│		│	│				│		
		257-9-2, 37	A	ME			│			■	│				│	│		│	│		│			│		│		│		│	│	│	│	│	│				│	│	

[a]Distribution Chart: ■ = common to abundant; │ = rare to few.

[b]Abundance: A = abundant; C = common; F = few; R = rare.

[c]Preservation: G = good; M = moderate; P = poor; E = etched; O = overgrown.

samples from the lower part of Core 9 and those from Core 10 are barren. A shipboard study of 20 smear slides from red, brown, gray, and pale-green pebbles and the grayish-brown matrix of the drilling breccias in Core 8, Sections 2 and 6 showed no difference in age between pebbles and matrix, but a decreasing abundance of coccoliths, due to etching, from pale green to gray to brown to red-brown-colored pebbles.

Paleoecology: The middle Albian assemblages are similar to those from the Gault Section at Copt Point, Folkestone, Great Britain. They represent an austral, temperate to cool water paleoenvironment.

SITE 258
(lat 33°47.69'S, long 112°28.42'E, depth 2793 m)

Stratigraphy: In the two holes of Site 258, 114 meters of upper Miocene to Recent, overlying 411 meters of middle Albian to Santonian sediments were penetrated. The Cretaceous sequence consists of: 83 meters of middle Albian or older, 92 meters of middle Albian, and 85 meters of upper Albian detrital clays, all below 8 meters of Cenomanian, 18 meters of Turonian, 104 meters of Coniacian, and 24 meters of Santonian calcite (micarb) chalks with silicified limestone beds. This sequence includes: moderately to slightly etched nannofossils belonging to the middle Albian *Prediscosphaera cretacea* Zone (Hole 258, Cores 22-19) and to the upper Albian *Eiffellithus turriseiffeli* Zone (Hole 258, Cores 18-13); slightly etched nannofossil assemblages belonging to the Cenomanian *Lithraphidites alatus* Zone (Hole 258, Core 14) and the Cenomanian to Turonian *Gartnerago obliquum* Zone (Hole 258, Cores 14 and 13); moderately etched and overgrown assemblages belonging to the Turonian *Micula staurophora* Zone (Hole 258, Core 13) and the Turonian to Coniacian *Kamptnerius magnificus* Zone (Hole 258, Cores 13-11); and slightly etched to slightly overgrown assemblages belonging to the Coniacian to Santonian *Marthasterites furcatus* Zone (Hole 258, Cores 11-5; Hole 258A, Cores 9 and 8). The zonation, correlation, and preservation of the nannofossils from this Cretaceous sequence are discussed in more detail in separate paragraphs. A minor unconformity was encountered between the Cenomanian and the Turonian. The Santonian/Miocene unconformity was found in Section 258A-8-6. The age of the sediments in Cores 6 through 8 is based upon nannofossil samples taken from pebbles and is considered to be upper Miocene. Although many Pliocene foraminifera were encountered, these foraminiferal samples often had to be taken from liquified parts of the cores, which were apparently contaminated with material from higher in the hole. As at Sites 251 and 255 an overlap of the uppermost *Discoaster* sp. and the lowermost *Gephyrocapsa* sp. is observed. Again the foraminifera are considered to be of Pliocene age; in fact, the Pliocene/Quaternary boundary as determined by foraminifera lies 17 meters above the extinction of discoasters. In most of the Neogene samples reworked upper Cretaceous and upper Eocene nannofossils have been found.

Preservation: Most of the Neogene nannofossils are well preserved. Some signs of overgrowth are observed in the lower Pliocene and upper Miocene samples. The Cretaceous assemblages from the Turonian to Santonian chalk sequence are slightly etched to moderately overgrown. Downward increasing dissolution effects are observed in the Cenomanian to middle Albian clays. The lowermost strongly etched nannofossils are found in Core 23.

Paleoecology: The preservation of the nannofossils in the Cretaceous sequence indicates a continuous shallowing of this site from middle Albian through Santonian time. The species compositions point to a tranisitional to cool environment, although a tethyan species

TABLE 8a
Post-Paleogene Distribution of Calcareous Nannofossils at Site 258[a]

Age	Zone	Sample (Interval in cm)	Abundance[b]	Preservation[c]	Reworking and Contamination[d]	*Sphenolithus abies*	*Dictyococcites abisectus*	*Discoaster asymmetricus*	*Discoaster brouweri*	*Discoaster challengeri*	*Ceratolithus cristatus*	*Cyclicargolithus floridanus*	*Discoaster hamatus*	*Helicopontosphaera kamptneri*	*Pseudoemiliania lacunosa*	*Cyclococcolithina leptopora*	*Discoaster nephados*	*Discoaster pentaradiatus*	*Reticulofenestra pseudoumbilica*	*Discoaster pseudovariabilis*	*Discoaster quinqueramus*	*Ceratolithus rugosus*	*Discoaster surculus*	*Discoaster tamalis*	*Ceratolithus tricorniculatus*	*Discoaster trinidadensis*	*Discoaster variabilis*	*Gephyrocapsa* sp.	*Scyphosphaera* sp.	*Discoaster barbadiensis*	*Braarudosphaera bigelowi*	*Zygrhablithus bijugatus*	*Dictyococcites dictyodus*	*Zygolithus dubius*	*Cyclococcolithina formosa*	*Chiasmolithus grandis*	*Chiasmolithus oamaruensis*	*Isthmolithus recurvus*	*Discoaster saipanensis*	*Reticulofenestra umbilica*	Cretaceous species
Quaternary	NN20 *Gephyrocapsa oceanica*	258A-1-1, 17	A	G							│			■		■												■													
		258A-1-1, 76	C	G	R	R			R					■		│			R		R							│	│				R	R			R			R	R
		258A-1, CC	A	G	R						│			■		■												■												R	
		258-1-1, 40	A	G	R									■	R	■												■	│											R	
		258-1-3, 62	A	G	R	R								■		■												■													
		258-1-5, 113	A	G										■		■												■													
		258-1, CC	A	G	R									■	R	■												■													
		258-2-1, 140	A	G	R									■	R	■												■													
	NN19 *Pseudoemiliania lacunosa*	258-2-3, 50	A	G										■	■	■												■	│												
		258-2, CC	A	G										■	■	■												■													
		258A-2-2, 2	A	G	R									■	■	■						R						■	│											R	
		258A-2, CC	A	G	R									■	■	■												■	│			R								R	
		258A-3-2, 101	A	G										■	■	■												■	│												
		258A-3-3, 48	A	G	R									■	■	■												■					R								
		258A-3-4, 40	A	G	R									■	■	■												■													
		258A-3-5, 124	A	G	R									■	■	■												■					R								
		258A-3-6, 111	A	G	R	R			R					■	■	■												■					R								
		258A-3, CC	C	G	R									│	■	■												■	│												
		258A-4-1, 126	A	G	R									■	■	■												■				R	R								
		258A-4-2, 93	A	G										■	■	■												■													
		258A-4-3, 8	A	G	R				R					■	■	■		R					R	R				■	│												
		258A-4, CC	A	G	R									■	■	■												■	│						R						R
U. Pliocene	NN16 *Discoaster surculus*	258-3-1, 12	A	GO					│					■	■	■		│					│						■												
		258-3-3, 110	A	G				│	│					■	■	■		│					■	│					│												
		258-3-5, 60	A	G				│	│					■	│	■		■					■	│					│												
		258-3, CC	A	G				│	│					■	│	■						│	│	│					│												
		258A-5-1, 44	A	G					│					■	■	■		│				│	■						│												
		258A-5-2, 116	A	G					│					■	■	■		│					■	│					│												
		258A-5-3, 3	A	G				│	│					■	│	■		│				│	■	│					│												
		258A-5-4, 53	A	G				│	│					■	│	■		│				│	■	│					│												
		258A-5-5, 78	A	G				│	│					■	│	■		│				│	■	│					│												
		258A-5-6, 110	A	G	R			│	│					■	│	■		│				│	■	│			R		│												R
L.	NN13–NN15 *Ceratolithus rugosus*–*Reticulofenestra pseudoumbilica*	258A-5, CC	A	GO	R			│	│					■		■			│			│	■	│									R								
U. Miocene	NN12 *Ceratolithus tricorniculatus*	258A-6-3, 124	A	MO	R	■			│					■		■		│	│			│	│						│										R	R	
		258A-6-4, 89	A	MO		■								│		■			│				│		│	│			│												
		258A-6-5, 67	A	GO	R	■			│	│				■		■		│	■				│		│				│									R			
		258A-6-6, 110	C	MO	R	■			│					│		■			│				│		│				│												R
		258A-6, CC	A	GO	R	■			│					■		■		│	│						│				│		R										
		258-4-1, 110	C	MO	R	│				│				■		■		│	│							│			│												
	NN11 *Discoaster quinqueramus*	258-4, CC	A	G	R	■			│	│				■		■		│	│	│	│		│		│	│			│				R								R
		258A-7-3, 52	C	GO	R	■						│		│		│		│	│							│			│		R									R	
		258A-7-5, 77	C	GO	R	│						│		│		│										│							R		R					R	R
		258A-7, CC	C	GO	R	│	│		│			│				■										│			│				R				R				R
		258A-8-1, 102	A	G	CR			C	│				R	■	C	■		│	│		│	C	C				R														
	NN10–NN11 *D. calcaris*–*D. quinqueramus*	258A-8-3, 55	C	M	R	■	│			│		│		■		■		│	│						│	│			│			R	R		R				R	R	R
		258A-8-4, 51	C	M	R	■	│					│		■		■		│								│			│				R		R					R	
		258A-8-5, 120	C	MO	R	■						│		■		■	│									│			│	R			R		R	R	R	R		R	R
		258A-8-6, 127	A	GO	R	■			│			│		■		■	│	│							│	│		│	│				R							R	R

[a]Distribution Chart: ■ = common to abundant; | = rare to few; R = reworked.

[b]Abundance: A = abundant; C = common; F = few; R = rare.

[c]Preservation: G = good; E = etched; M = moderate; O = overgrown; P = poor.

[d]Reworking and Contamination: R = reworked; C = contaminated.

(*Lithraphidites alatus*) has been found in Core 14 (Cenomanian). The depositional depth at Site 258 during the Santonian was greater than that of the Gingin Chalk in the Perth Basin, based upon the absence of *Tetralithus obscurus, T. ovalis,* and the scarcity of *Lucianorhabdus cayeuxi.* All three are restricted to nearshore or shallow-water paleoenvironment and are abundant in the Gingin Chalk. The Neogene assemblages indicate temperate paleotemperatures.

TAXONOMY

All Cenozoic nannoplankton species used in this report are listed in the Introduction and have been described and illustrated in the literature. Reference to their original descriptions may be found in Loeblich and Tappan (1966, 1968, 1969, 1970a, 1970b, 1971).

A preliminary investigation of the Upper Cretaceous nannofossil assemblages from Site 258 yielded some new findings concerning the relationship between the taxonomy used in recent publications and the preservation of nannofossils. A certain biogenetic variation in coccolith ornamentation (e.g., perforations in *Gartnerago costatum costatum* [Gartner, 1968] Bukry, 1969, and *Gartnerago costatum porolatum*

Bukry) may be observed in the electron microscope in well-preserved assemblages; however, the absence of perforations in closely related specimens, attributed to genetic differences in the past, is actually due to overgrowth of crystallites. The inverse abundances of some of these related "species" at Site 258, together with their almost identical stratigraphic ranges and the limited resolution of light microscope (LM) techniques (most extensively used for stratigraphic purposes), suggested a revision of the taxonomic concepts within the genera *Gartnerago, Kamptnerius,* and *Micula.* Further investigations may confirm that conspecific morphotypes exist also in the genera *Broinsonia, Chiastozygus, Eiffellithus,* and *Tranolithus.* In addition, two new Cretaceous species are described, and some remarks concerning synonymies and new combinations are given below.

The SEM photographic negatives and the LM slides with the types are deposited at the Naturhistorisches Museum Basel (Switzerland). They are identified by the author's negative numbers (listed here in parentheses) and by the Basel Museum type collection numbers (A974-A981).

Genus BROINSONIA Bukry, 1969

Type species: *Broinsonia dentata* Bukry, 1969.

Remarks: This genus has been included by its author in the family Arkhangelskiellaceae Gartner, 1968, which is characterized, among other criteria, by the absence of a central process on its coccoliths. A few specimens have been found in Coniacian assemblages at Site 258 which show shield structures characteristic for *Broinsonia* Bukry, 1969, together with a central process (Plate 10, Figures 10, 11, 13, and 14). In this report these specimens are attributed tentatively to *Broinsonia furtiva* Bukry, 1969.

Broinsonia enormis (Shumenko, 1968) Manivit, 1971
(Plate 10, Figures 1-6; Plate 11, Figures 9-16)

1968 *Arkhangelskiella enormis* Shumenko, p. 33, pl. 1, fig. 3.
1969 *Broinsonia bevieri* Bukry, p. 21, pl. 1, fig. 8-10.
1969 *Aspidolithus angustus* Noël, p. 196, pl. 1, fig. 1, 2.
1971 *Broinsonia enormis* (Shumenko, 1968) Manivit, p. 105, pl. 1, fig. 18-20.
1972 *Broinsonia bevieri* Bukry, 1969—Roth and Thierstein, p. 480, pl. 14, fig. 14-17, 22-29.

Remarks: This imperforate species of *Broinsonia* has been found mainly in samples with overgrown nannofossils (see Table 8b). As shown on Plate 10, Figures 5-7, some specimens grade into *Broinsonia furtiva* Bukry 1969 and some into *Broinsonia parca* (Stradner) (Plate 11, Figures 13-16).

Known range: upper Albian-lower Campanian.

?Broinsonia furtiva Bukry, 1969
(Plate 10, Figures 7-14, Plate 11, Figures 1-8)

1969 *Broinsonia furtiva* Bukry, p. 22, pl. 2, fig. 7, 8.

Remarks: The original description of this species is based on three specimens from the Austin Chalk (Santonian). Two of the electronmicrographs from Site 258 (Plate 10, Figures 8, 9) show a good overall similarity with the types, except for the absence of transverse structures within the perforations. The specimens encountered at Site 258 definitely show the shield construction of *Broinsonia* Bukry. The central process seen in a few specimens (Plate 10, Figures 10, 11, 13, 14), however, disagrees with the definition of this genus. Nevertheless, these perforated specimens have tentatively been attributed to *Broinsonia furtiva* Bukry. It is difficult to differentiate some specimens from *Broinsonia enormis* (Shumenko) Manivit (see Plate 10, Figures 5-7) and from *Broinsonia parca* (Stradner) Bukry (see Plate 11, Figures 13-16). In the LM *Broinsonia furtiva* Bukry was distinguished from *Broinsonia enormis* (Shumenko) by the presence of perforations and by its prominent crossbars in the central area. *Broinsonia furtiva* Bukry shows a distinct first appearance in the middle Coniacian (Sample 258-10-1, 119 cm) and has been found in all younger Late Cretaceous samples in a consistent abundance, as well as in the Gingin Chalk of the Perth Basin (Santonian), and in samples from the Coniacian of Texas.

Known range: Coniacian-Santonian.

Genus CRIBROSPHAERELLA Deflandre, 1952

Type species: *Cribrosphaera ehrenbergi* Arkhangelsky, 1912.

Cribrosphaerella primitiva Thierstein, n. sp.
(Plate 1, Figures 1-3)

Diagnosis: The distal shield of this oval coccolith consists of 15-20 radially arranged elements, with irregular sutures between them. The elements incline slightly clockwise at their outer margin. The smaller proximal shield is constructed of 15-21 radial plates. The two shields are connected by at least one cycle of small elements, bordering the central area. Four crystal plates arranged in a zig-zag line along the long axis fill the oval central area.

Remarks: In slightly dissolved samples each plate in the central area shows a circular deepening on the distal side. *Cribrosphaerella primitiva* n. sp. differs from all other species of the genus by its consistent number of four central plates and from *Cribrosphaerella pelta* Gartner by having only one cycle of elements in each shield. In the LM the appearance of the shield of this species is close to that of species *Prediscosphaera.* The four offset elements in the central area differentiate *Cribrosphaerella primitiva* from any other species.

Maximum diameter: 5-9μ.

Holotype: (1122/5) A978.

Paratypes: (1122/1) A980, (1122/3) A979, (1021/11) A981.

Type locality: Sample 258-5-3, 115 cm.

Distribution: eastern Indian Ocean, Copt Point (Great Britain).

Known range: middle Albian-Santonian.

Genus GARTNERAGO Bukry, 1969

Type species: *Arkhangelskiella concava* Gartner, 1968 (=*Discolithus segmentatus* Stover, 1966 = ?*Arkhangelskiella obliqua* Stradner, 1963).

Remarks: A large number of species have been described which show all the basic shield construction of *Gartnerago.* For some of these species, differentiation has been based on differences in ultrastructure (cf. Noël, 1969, p. 200) of the central area that cannot be identified in the LM. The only differentiations that can be recognized with that tool are the following: (1) central area closed (without perforations) = *Discolithus segmentatus* Stover type; (2) central area with one row of perforations along each side of the axial sutures = *Arkhangelskiella obliqua* Stradner type; and (3) central area with more than one row of perforations along each side of the axial sutures = *Arkhangelskiella striata* Stradner type. The systematic concept adopted in this paper tries to use these three criteria in order to make the genus *Gartnerago* available again for routine stratigraphic investigations done with the LM. The stratigraphic ranges and reciprocal relative abundances of *Gartnerago segmentatum* (Stover) and *Gartnerago obliquum* (Stradner) suggest that they are conspecific morphotypes; however, their occurrences have been listed separately in Tables 1, 5, and 8b.

Gartnerago nanum Thierstein, n.sp.
(Plate 2, Figures 1-13)

Diagnosis: The proximal side shows four cycles of elements, three of them building up the shield and one filling the peripheral parts of the central area. The outermost cycle consists of 40-50 imbricated and counterclockwise-inclined elements. The two middle cycles are built of about 45 small blocky elements, the inner of the two with counterclockwise inclination. The innermost cycle consists of irregularly shaped elongated elements, showing the inverse inclination characteristic for the genus *Gartnerago* Bukry. The small subrhomboidal central opening is spanned by an axial cross and shows a few perforations in each quadrant. On the distal side a wide inner cycle of irregularly shaped sinistrally imbricated elements surrounds the perforated and crossbar-bearing central area. The outermost cycle consists of counterclockwise-inclined small elements.

Remarks: *Gartnerago nanum* Thierstein differs in the LM from *Gartnerago striatum* (Stradner) by its smaller central area filled with a distinct small cross. The broad inner cycle of inversely inclined elements on the proximal side, as well as the extinction pattern under crossed nicols, differentiate this species from *Broinsonia ?ethmoquadrata* Bukry and designate its attribution to the genus *Gartnerago* Bukry. Nevertheless, a striking similarity is seen in the peripheral parts of the shield of *Gartnerago nanum* n.sp. with *Broinsonia ?ethmoquadrata* Bukry and *Broinsonia ?staytonae* Bukry. Since *Gartnerago nanum* n.sp. has been encountered in the upper Albian already, it might represent a phylogenetic link between *Broinsonia* Bukry and *Gartnerago* Bukry.

Maximum diameter: 6.8-10.2μ.

Holotype: (1027/7) A974.

Paratypes: (1027/5) A975, (1027/9) A976, (1031/1) A977.

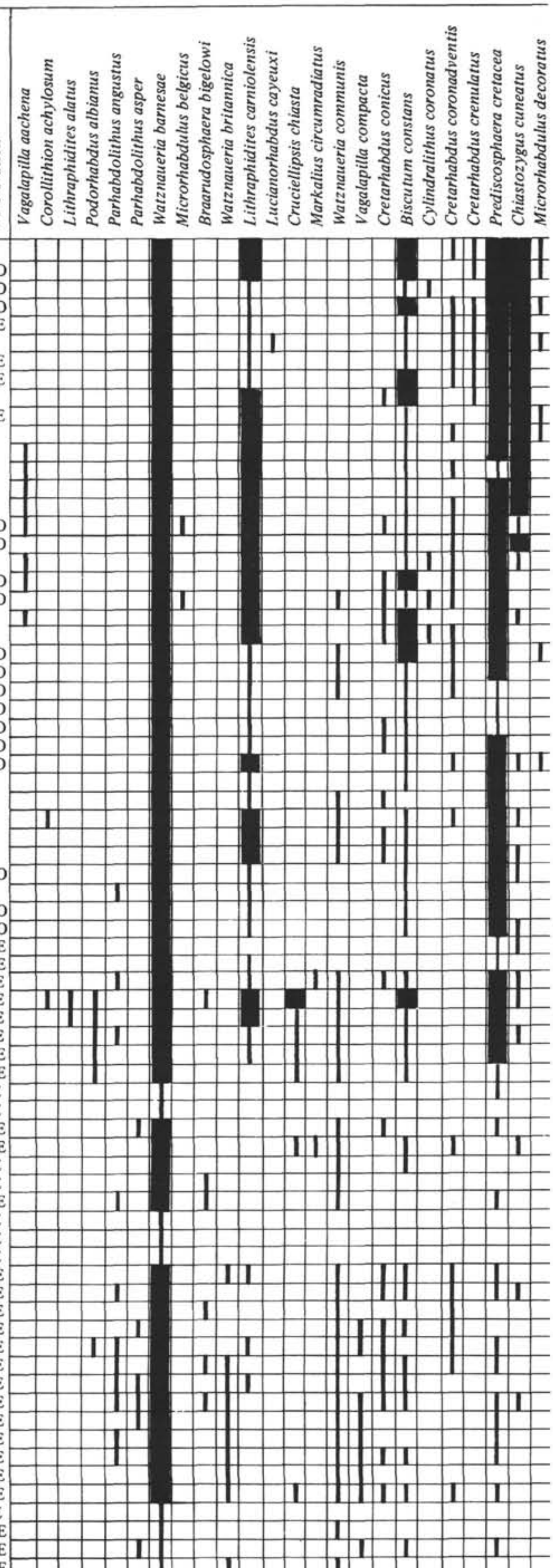
Type locality: Sample 258-14-1, 85 cm.

Distribution: eastern Indian Ocean, Crimea.

Known range: upper Albian-upper Cenomanian.

TABLE 8b
Cretaceous Distribution of Calcareous Nannofossils at Site 258[a]

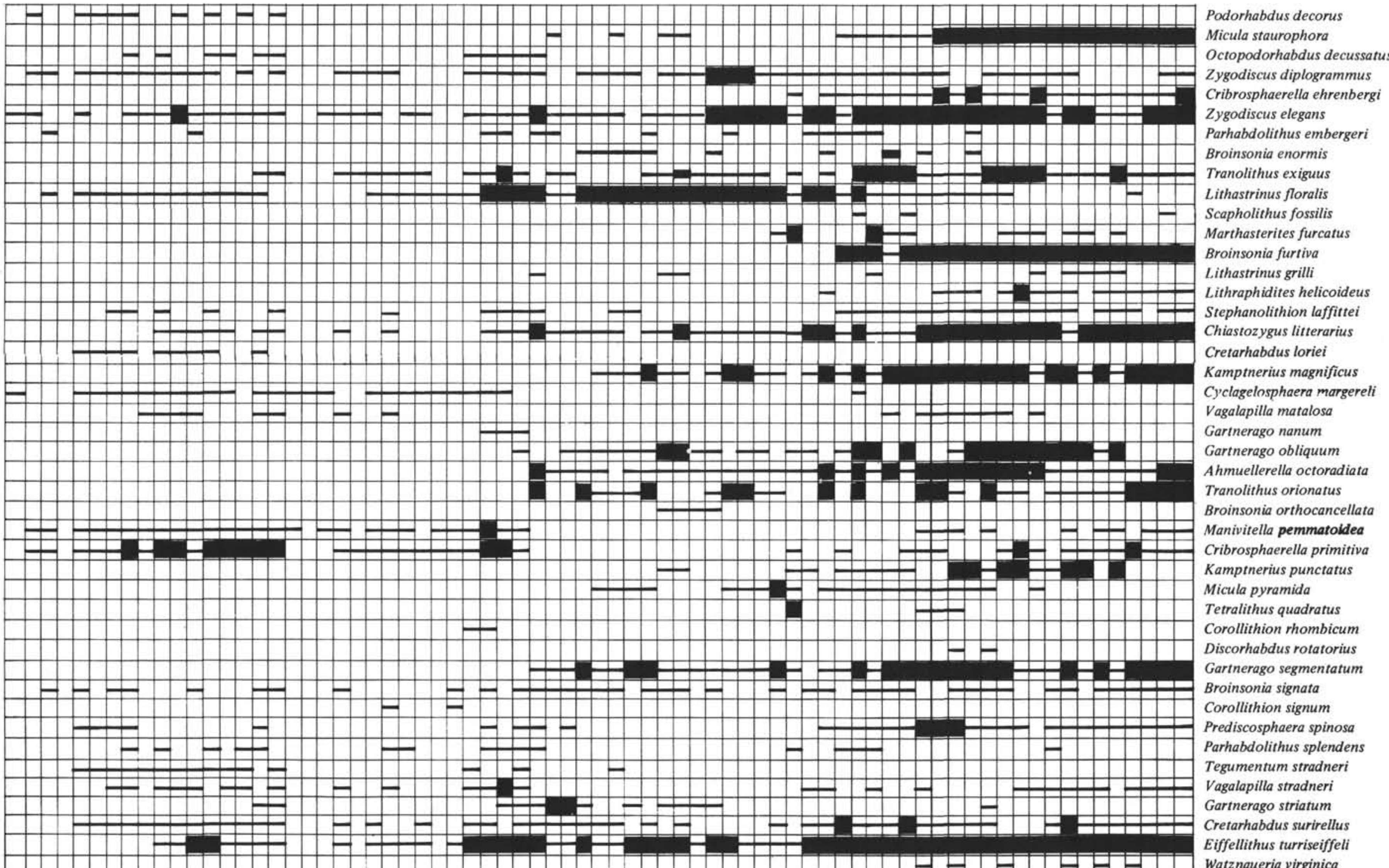
Stage	Zone	Sample (Interval in cm)	Abundance[b]	Preservation[c]
Santonian	*Marthasterites furcatus*	258A-8-6, 133	A	G
		258A-8, CC	A	GO
		258A-9-1, 140	A	GO
		258A-9-2, 53	A	GO
		258A-9-3, 144	A	GE
		258A-9-4, 52	A	G
		258A-9-5, 139	A	GE
		258A-9-6, 39	A	GE
		258A-9, CC	A	G
		258-5-1, 120	A	GE
		258-5-3, 115	A	G
		258-5, CC	A	G
Coniacian		258-6-2, 110	A	G
		258-6-4, 110	A	G
		258-6, CC	A	G
		258-7-2, 110	A	GO
		258-7-3, 110	A	GO
		258-7, CC	A	G
		258-8, CC	A	GO
		258-9-1, 71	A	GO
		258-9-1, 94	A	G
		258-10-1, 119	A	G
		258-10-2, 45	A	GO
		258-10, CC	A	GO
		258-11-1, 105	C	GO
		258-11-2, 7	A	GO
	Kamptnerius magnificus	258-11-3, 73	A	GO
		258-11, CC	A	GO
		258-12-1, 79	A	GO
		258-12-2, 100	A	M
Turonian		258-12-3, 35	C	M
		258-12-4, 139	A	M
		258-12-5, 64	A	M
		258-12-6, 123	A	M
		258-12, CC	A	MO
		258-13-1, 140	A	M
		258-13-2, 88	A	MO
	Micula decussata	258-13-2, 128	A	MO
		258-13-3, 144	C	ME
		258-13-4, 9	C	ME
	Gartnerago obliquum	258-13, CC	A	GE
Cenomanian		258-14-1, 85	A	GE
	Lithraphidites alatus	258-14, CC	A	GE
U. Albian	*Eiffelithus turiseiffeli*	258-15-1, 137	A	GE
		258-15-2, 124	A	ME
		258-15-3, 42	C	ME
		258-15-4, 20	C	PE
		258-15-5, 110	F	PE
		258-15-6, 11	A	ME
		258-15, CC	A	ME
		258-16-2, 110	C	PE
		258-16-5, 68	C	PE
		258-16, CC	C	ME
		258-17-2, 110	F	PE
		258-17-3, 110	F	PE
		258-17-4, 103	R	PE
		258-17-5, 102	A	GE
		258-17, CC	A	GE
		258-18-1, 110	A	GE
		258-18-2, 108	A	GE
		258-18-3, 140	A	GE
		258-18-4, 141	C	GE
		258-18, CC	C	GE
		258-19, CC	C	GE
M. Albian	*Prediscosphaera cretacea*	258-20-1, 137	C	GE
		258-20, CC	C	GE
		258-21-1, 110	C	GE
		258-21-3, 110	C	GE
		258-21, CC	C	GE
		258-22-1, 110	R	PE
		258-22-3, 95	F	ME
		258-22, CC	F	ME
		258-23, CC	F	ME



[a]Distribution Chart: ■ = common to abundant; | = rare to few

[b]Abundance: A = abundant; C = common; F = few; R = rare.

[c]Preservation: G = good; E = etched; M = moderate; O = overgrowns; P = poor.


Podorhabdus decorus
Micula staurophora
Octopodorhabdus decussatus
Zygodiscus diplogrammus
Cribrosphaerella ehrenbergi
Zygodiscus elegans
Parhabdolithus embergeri
Broinsonia enormis
Tranolithus exiguus
Lithastrinus floralis
Scapholithus fossilis
Marthasterites furcatus
Broinsonia furtiva
Lithastrinus grilli
Lithraphidites helicoideus
Stephanolithion laffittei
Chiastozygus litterarius
Cretarhabdus loriei
Kamptnerius magnificus
Cyclagelosphaera margereli
Vagalapilla matalosa
Gartnerago nanum
Gartnerago obliquum
Ahmuellerella octoradiata
Tranolithus orionatus
Broinsonia orthocancellata
Manivitella pemmatoidea
Cribrosphaerella primitiva
Kamptnerius punctatus
Micula pyramida
Tetralithus quadratus
Corollithion rhombicum
Discorhabdus rotatorius
Gartnerago segmentatum
Broinsonia signata
Corollithion signum
Prediscosphaera spinosa
Parhabdolithus splendens
Tegumentum stradneri
Vagalapilla stradneri
Gartnerago striatum
Cretarhabdus surirellus
Eiffellithus turriseiffeli
Watznaueria virginica

Gartnerago obliquum (Stradner, 1963) Reinhardt, 1970
(Plate 5, Figures 3-9; Plate 6, Figure 2;
Plate 7, Figures 1-5, 7-10)

1963 *Arkhangelskiella obliqua* Stradner, p. 176, pl. 1, fig. 2, 2a.
1968 *Arkhangelskiella costata* Gartner, p. 37, pl. 8, fig. 1-3; pl. 11, fig. 1; pl. 28, fig. 2.
1969 *Gartnerago costatum costatum* (Gartner, 1968) Bukry, p. 24, pl. 4, fig. 7-9.
1969 *Gartnerago costatum porolatum* (Gartner, 1968) Bukry, p. 24, pl. 4, fig. 10-12.
1970 *Gartnerago obliquum* (Stradner, 1963) Reinhardt, p. 66.
1972 *Gartnerago obliquum* (Stradner, 1963) Forchheimer, p. 28, pl. 4, fig. 5, 6.
1972 *Gartnerago costatum* (Gartner, 1968) Forchheimer, p. 27, pl. 4, fig. 2, 4.
1972 *Gartnerago porolatum* (Bukry, 1969) Forchheimer, p. 28, pl. 3, fig. 2, 4.

Remarks: Perforated morphotypes of *Gartnerago obliquum* (Stradner) are differentiated from *Gartnerago striatum* (Stradner) by having only two rows of perforations along the axes of the ellipse. At Site 258 perforated specimens of the *Gartnerago costatum costatum* (Gartner) type and imperforated specimens of the *Gartnerago segmentatum* (Stover) type have been found, usually together with intermediate specimens which could not be attributed to either of these two morphotypes with certainty (see Plate 5, Figure 4 and Plate 7, Figures 7-10). The abundances of the two morphotypes are clearly reciprocal and closely related to the preservation of the nannofossil assemblages in the respective samples (Table 8b). In the etched assemblage of Sample 258-12-4, 139 cm, for example, no imperforated specimens could be found in the scanning electron microscope, whereas the strongly overgrown assemblage of Sample 258-8, CC contained no perforated specimens. The maximum range of perforated *Gartnerago obliquum* (Stradner) extends from the late Cenomanian (Stradner, 1963; Reinhardt, 1967; Thierstein, this paper) to the Campanian (Stover, 1966; Reinhardt, 1967; Gartner, 1968; Bukry, 1969; Manivit, 1971) and that of imperforated *Gartnerago segmentatum* (Stover) from the late Cenomanian/early Turonian (Caratini, 1963; Stover, 1966; Thierstein, this paper) to the Campanian (Stover, 1966; Gartner, 1968; Bukry, 1969; Noël, 1969, 1970). Since there are no significant differences in the stratigraphic ranges of *Gartnerago obliquum* (Stradner) and *Gartnerago segmentatum* (Stover), since intermediate specimens occur rather frequently, and since it is impossible to differentiate any subspecies in the LM, it is proposed to include all these specimens in *Gartnerago obliquum* (Stradner). Their summarized abundance greatly facilitates their use as a valuable marker species.

Known range: upper Cenomanian-Campanian.

Gartnerago segmentatum (Stover, 1966) n. comb.
(Plate 5, Figures 1, 2; Plate 6, Figures 1, 3-10;
Plate 7, Figure 6.)

?1963 *Discolithus decoratus* Caratini, pl. 1, fig. 7-9 (invalid ICBN, art. 34).
?1963 *Discolithus ornamentus* Caratini, p. 18, pl. 1, fig. 7-9 (invalid ICBN, art. 34).
?1965 *Ahmuellerella oblata* Reinhardt, p. 31, pl. 1, fig. 2 (invalid ICBN, art. 38).
1966 *Discolithus segmentatus* Stover, p. 143, pl. 3, fig. 3-6.
1968 *Arkhangelskiella concava* Gartner, p. 37, pl. 14, fig. 2, 3; pl. 16, fig. 5-7; pl. 17, fig. 7; pl. 18, fig. 22, 23; pl. 19, fig. 6; pl. 21, fig. 7; pl. 22, fig. 13-15.
1969 *Gartnerago concavum* (Gartner, 1968), Bukry, p. 24, pl. 4, fig. 2-6.
1669 *Laffittius obliquus* (Reinhardt, 1967) Noël, p. 197, pl. 3, fig. 1-5.
1970 *Gartnerago obliquum* (Reinhardt, 1967) Noël, p. 79, pl. 26, fig. 1-7.
1972 *Gartnerago concavum* (Gartner, 1968) Bukry, 1969—Forchheimer, p. 26, pl. 3, fig. 5.

Remarks: Examination of the same specimens in both SEM and LM (Plate 6, Figures 3-10) reveals that *Arkhangelskiella concava* Gartner is a junior synonym of *Discolithus segmentatus* Stover (see also Bukry, 1969, p. 24). Synonymy with *Arkhangelskiella inclinata* Reinhardt proposed by Reinhardt (1970) is not followed because its holotype, a cross-polarized light micrograph, shows an extinction pattern characteristic for species of the genus *Broinsonia* Bukry. The micrograph of the paratype of *Arkhangelskiella inclinata* Reinhardt (*in* Reinhardt, 1965, pl. 2, fig. 6) is shown as *Arkhangelskiella cymbiformis* Vekshina (*in* Reinhardt, 1966, pl. 22, fig. 15). Since description and preservation of the holotype of *Arkhangelskiella oblata* Reinhardt (*in* Reinhardt, 1966, pl. 13, fig. 2) are very poor, and this species has been put into synonymy with *Arkhangelskiella obliqua* Stradner by Reinhardt (1967, p. 174), it must be rejected by ICBN art. 34(1) and art. 38. Therefore, *Discolithus segmentatus* Stover remains the earliest valid description of this imperforated species of the genus *Gartnerago* Bukry.

As discussed above (see remarks under *Gartnerago obliquum* [Stradner]), this species is most likely a (diagenetic?) morphotype of *Gartnerago obliquum* (Stradner). Therefore, it may be considered synonymous with *Gartnerago obliquum* (Stradner). Overgrown *Gartnerago striatum* (Stradner) do not show that closing of the central area perforations even in samples with strongly overgrown assemblages (cf. *Laffittius confossus* Noël, 1969, p. 198, pl. 3, fig. 6).

Gartnerago striatum (Stradner, 1963) Forchheimer, 1972
(Plate 4, Figures 1-15)

1963 *Arkhangelskiella striata* Stradner, p. 176, pl. 1, fig. 1, 1a.
non 1966 *Arkhangelskiella striata* Stradner, 1963—Stover, p. 137, pl. 2, fig. 3, 4.
1968 *Zygolithus striatus* (Stradner, 1963) Stradner, Adamiker, and Maresch, partim, p. 38, pl. 33.
1969 *Laffittius confossus* Noël, p. 198, pl. 3, fig. 6; pl. 2, fig. 5.
1972 *Gartnerago striatum* (stradner, 1963) Forchheimer, p. 29, pl. 3, fig. 1, 3.
1972 *Gartnerago diversum* Thierstein *in* Roth and Thierstein, p. 436, pl. 15, fig. 9-15.

Remarks: This species shows remarkable variability through time. Rather small specimens first occur in the middle Albian of Northern Europe (Stradner et al., 1968). Large specimens have been found in late Albian to Coniacian samples at Site 258. Two micrographs of specimens with slightly different morphology have been given by Forchheimer (1972). Although the shield construction of all specimens illustrated by Forchheimer (1972, pl. 3, fig. 1, 3) and in this report (Plate 4, Figures 1-15) is basically the same, the relative width of the different cycles of elements in the shields is subject to variations. When seen from the proximal side, all specimens of *Gartnerago striatum* (Stradner) found on Naturaliste Plateau show an outermost cycle of elongated elements. This feature is normally considered typical for species of the genus *Kamptnerius* Deflandre. The specimens illustrated here might represent, together with *Kamptnerius (?) pertusus* Forchheimer (1972, p. 30 pl. 5, fig. 1, 2) an evolutionary line leading to *Kamptnerius magnificus* Deflandre. The Hauterivian occurrences of this species given by Stradner (1963) and Forchheimer (1972) originate from a too large species interpretation (both authors included *Arkhangelskiella striata* Stradner *in* Stover [= *Cretarhabdus loriei* Gartner] in their synonymy lists). *Gartnerago striatum* (Stradner) differs from *Gartnerago obliquum* (Stradner) by having several rows of perforations in each quadrant of the central area. Overgrown *Gartnerago striatum* (Stradner) still have open perforations in the central area (cf. *Laffittius confossus* Noël, 1969, pl. 3, fig. 6) thus showing a different overgrowth behavior than *Gartnerago obliquum* (Stradner).

Known range: Cenomanian-Coniacian.

Genus KAMPTNERIUS Deflandre, 1959

Type species: *Kamptnerius magnificus* Deflandre, 1959.

Kamptnerius magnificus Deflandre, 1959
(Plate 8, Figures 1-9; Plate 9, Figures 1-11)

1959 *Kamptnerius magnificus* Deflandre, p. 135, pl. 1, fig. 1-4.
1963 *Kamptnerius magnificus* Deflandre, 1959—Stradner, p. 178, pl. 2, fig. 3.
1963 *Kamptnerius punctatus* Stradner, p. 182, pl. 2, fig. 3.
1964 *Kamptnerius ? minimus* Reinhardt, p. 752, pl. 1, fig. 5.
1964 *Kamptnerius magnificus* Deflandre, 1959—Bramlette and Martini, p. 301, pl. 2, fig. 1-3.
1966 *Kamptnerius magnificus* Deflandre, 1959—Stover, p. 144, pl. 4, fig. 28-30.
1968 *Kamptnerius (?) tabulatus* Perch-Nielsen, p. 42, pl. 6, fig. 4.
1968 *Kamptnerius magnificus* Deflandre, 1959—Gartner, p. 39, pl. 2, fig. 1, 2; pl. 3, fig. 7; pl. 6, fig. 10; pl. 10, fig. 11-13; pl. 12, fig. 3; pl. 14, fig. 11, 12; pl. 15, fig. 10; pl. 16, fig. 17-19; pl. 17, fig. 11, 12; pl. 21, fig. 12.
1969 *Kamptnerius magnificus magnificus* (Deflandre, 1959) Bukry, p. 25, pl. 5, fig. 7-9.

1969 *Kamptnerius magnificus sculptus* (Deflandre, 1959) Bukry, p. 25, pl. 5, fig. 10-12.
1969 *Kamptnerius percivalii* Bukry, p. 25, pl. 6, fig. 1-3.
1969 *Kamptnerius punctatus* Stradner, 1963—Bukry, p. 26, pl. 6, fig. 4, 5.
1970 *Kamptnerius magnificus* Stradner, 1963—Cepek, p. 242, pl. 24, fig. 5, 6; pl. 26, fig. 5.
1970 *Kamptnerius pseudopunctatus* Cepek, p. 242, pl. 24, fig. 7-9.
1970 *Kamptnerius magnificus* Deflandre, 1959—Noël, p. 82, pl. 27, fig. 1-5; pl. 28, fig. 1-5.
1971 *Kamptnerius magnificus* Deflandre, 1959—Manivit, p. 107, pl. 14, fig. 10-14; pl. 20, fig. 11.
1971 *Kamptnerius punctatus* Stradner, 1963—Manivit, p. 108, pl. 14, fig. 8, 9.
1972 *Kamptnerius punctatus* Stradner, 1963—Forchheimer, p. 30, pl. 4, fig. 1, 3; pl. 5, fig. 5, 6.

Remarks: A great number of different morphological types of *Kamptnerius magnificus* Deflandre have been described and illustrated. The common features of all "species" include *Gartnerago*-type shield construction, frequently asymmetric flange, central area filled with elongated subaxial elements. The different species have been distinguished by number and arrangement of pores in the central area, central cross of small elements, and width of proximal cycles of the shield. The more the specimens have been illustrated, the more difficult it has become to differentiate them. Only in clayey, well-preserved samples can *Kamptnerius punctatus* Stradner be identified. In overgrown chalky samples all specimens are imperforated *Kamptnerius magnificus* Deflandre. Although no statistical counts have been made, it is obvious from the literature and from the range chart (Table 8b) that (imperforated) *Kamptnerius magnificus* Deflandre and (perforated) *Kamptnerius* species tend to have reciprocal abundances, synchronous to the reciprocal abundance of (perforated) *Gartnerago obliquum* (Stradner) and (imperforated) *Gartnerago segmentatum* (Stover). The published data give a total range for imperforated *Kamptnerius magnificus* Deflandre from upper Turonian (Stradner, 1963; Stover, 1966; Bukry, 1969; Cepek, 1970; Thierstein, this paper) to late Maestrichtian (Deflandre, 1959; Stradner, 1963; Bramlette and Martini, 1964; Stover, 1966; Cepek, 1970) and for perforated *Kamptnerius* species from Turonian (Stradner, 1963; Thierstein, this paper) to Maestrichtian (Bramlette and Martini, 1964; Gartner, 1968; Cepek, 1970). Since the maximum ranges of perforated and imperforated *Kamptnerius* species are equal and local differences in stratigraphic occurrence may be correlated with the lithology of the samples and the preservation of their nannofossil assemblages (Bramlette and Martini, 1964, p. 302; Gartner, 1968, p. 40; Thierstein, this paper), the two morphotypes should be considered to be conspecific.

Genus LITHRAPHIDITES Deflandre, 1963

Type species: *Lithraphidites carniolensis* Deflandre, 1963.

Lithraphidites alatus Thierstein, 1972
(Plate 3, Figures 5-11)

1972 *Lithraphidites alatus* Thierstein *in* Roth and Thierstein, p. 438, pl. 3, fig. 1-8.

Remarks: With the original description of this species only specimens of umbrella-like shape have been illustrated, although specimens with one prominent peak on the sides of the four blades (Plate 3, Figures 5-11) were included in the species definition. Because various transitional specimens between these two shapes have been encountered in Cenomanian samples from the Atlantic and Central Europe, and no stratigraphic differentiation was possible, they were all included in the species *Lithraphidites alatus* Thierstein. This species has recently been reported from the Cenomanian of the Central Pacific (Roth, 1973). Its first occurrence is a world-wide marker for the base of the Lower Cenomanian.

Known range: Cenomanian.

Genus MICULA Vekshina, 1959

Type species: *Micula decussata* Vekshina, 1959 (= *Discoaster staurophorus* Gardet, 1955).

Micula staurophora (Gardet, 1955) Stradner, 1963
(Plate 12, Figures 1-11)

1955 *Discoaster staurophorus* Gardet, p. 534, pl. 10, fig. 96.
1959 *Micula decussata* Vekshina, p. 71, pl. 1, fig. 6; pl. 2, fig. 11.
1963 *Micula staurophora* (Gardet, 1955) Stradner, p. 8, pl. 4, fig. 12.
1964 *Micula staurophora* (Gardet, 1955) Stradner, 1963—Bramlette and Martini, p. 318, pl. 6, fig. 7-11.
1968 *Micula staurophora* (Gardet, 1955) Stradner, 1963—Perch-Nielsen, p. 86, pl. 31, fig. 1-5.
1968 *Micula decussata* Vekshina, 1959—Gartner, p. 47, pl. 2, fig. 5-8; pl. 4, fig. 18; pl. 9, fig. 18-20; pl. 18, fig. 7; pl. 20, fig. 15.
1968 *Tetralithus gothicus* Deflandre, 1959—Gartner, p. 42, pl. 24, fig. 4.
1969 *Micula decussata decussata* Vekshina, 1959—Bukry, p. 67, pl. 40, fig. 5, 6.
1969 *Tetralithus pyramidus* Gardet, 1955—Bukry, p. 64, pl. 38, fig. 1.
1970 *Micula staurophora decussata* (Vekshina, 1959) Noël, p. 98, pl. 37, fig. 1-8, pl. 38, fig.1, 2.
1971 *Micula staurophora* (Gardet, 1955) Stradner, 1963—Thierstein, p. 40, pl. 3, fig. 62, 63.
1971 *Micula staurophora decussata* (Vekshina, 1959) Noël, 1970—Clocchiatti, pl. 21, fig. 5; pl. 22, fig. 2.
1971 *Micula staurophora concava* (Stradner, 1963) Noël, 1970—Clocchiatti, pl. 21, fig. 6; pl. 22, fig. 1.
1973 *Micula decussata* Vekshina, 1959—Roth, p. 729.

Remarks: Evidence for the synonymy of *Micula decussata* Vekshina with *Discoaster staurophorus* Gardet has been presented by Noël (1970, p. 99) and by Clocchiatti (1971a). Erroneously this species is listed as *Micula decussata* in the species lists of the tables in this paper. *Micula staurophora (Gardet) shows remarkable variability as shown on Plate 12. In well-preserved samples (e.g., 258*-6-2, 110 cm), specimens consisting of eight distinct elements (Plate12, Figures 1, 2, and 10) are found together with specimens consisting of only four visible elements (Plate 12, Figures 4-8), the latter having an extinction pattern under crossed nicols typical for that of *Micula pyramida* (Gardet, 1955) n. comb. (Plate 12, Figure 8). Since transitional shapes between these two species may be abundant and usually cannot be attributed with certainty to either one of the two species in either the LM or the SEM they are considered to be conspecific. Their morphological variability seems to originate in different stages of preservation, since specimens with slender, elongated elements are found more frequently in samples containing well-preserved or slightly etched assemblages (e.g., Samples 258-10-1, 119 cm or 258-6-2, 110 c.m) and cubic specimens in samples containing overgrown assemblages (e.g., Sample 258-8, CC).

Known range: middle Turonian-Maestrichtian.

Genus PODORHABDUS Noël, 1965

Type species: *Podorhabdus grassei* Noël, 1965.

Podorhabdus albianus Black, 1967

1965 *Rhabdosphaera* sp. Black, p. 133, fig. 10.
1967 *Podorhabdus albianus* Black, p. 143.
1968 *Prediscosphaera ?orbiculofenestra* Gartner, p. 21, pl. 25, fig. 23-25; pl. 26, fig. 8.
1970b *Podorhabdus dietzmanni* (Reinhardt, 1965) Reinhardt, 1967—Reinhardt (partim), p. 87, text-fig. 107b; pl. 6, fig. 4.
1971 *Podorhabdus orbiculofenestrus* (Gartner, 1968) Thierstein, p. 478, pl. 8, fig. 9-17.
1972 *Podorhabdus orbiculofenestrus* (Gartner, 1968) Thierstein, 1971—Roth and Thierstein, 1972, pl. 6, fig. 1-7.
1973 *Podorhabdus orbiculofenestrus* (Gartner, 1968) Thierstein, 1971—Thierstein, p. 39.

Remarks: *Podorhabdus albianus* Black is the earliest description of this stratigraphically valuable species. Its uppermost occurrence observed by the author is uppermost Cenomanian. Higher occurrences as reported by Manivit (1971) originate from the inclustion of *Podorhabdus dietzmanni* (Reinhardt) in this species.

Known range: middle Albian-Cenomanian.

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REFERENCES

Belford, D. J., 1960. Upper Cretaceous foraminifera from the Toolonga Calcilutite and Gingin Chalk, Western Australia: Dept. Nat. Devel. Bur. Min. Res. Geol. Geophys. Gull., v. 57, p. 1.

Black, M., 1967. New names for soma coccolith taxa: Geol. Soc. London, Proc., v. 1640, p. 139.

_____, 1972. British Lower Cretaceous coccoliths. I. Gault Clay: Paleontogr. Soc., v. 1, p. 1.

Borsetti, A. M. and Cati, F., 1972. Il nannoplankton calcareo vivente nel Tirreno centro-meriodionale: Gior. Geol., v. 38, p. 395.

Bramlette, M. N. and Martini, E., 1964. The great change in calcareous nannoplankton fossils between Maestrichtian and Danian: Micropaleontology, v. 10, p. 291.

Bukry, D., 1969. Upper Cretaceous coccoliths from Texas and Europe: Kansas Univ. Paleont. Contrib. Art. 51, p. 1.

_____, 1971a. Cenozoic calcareous nannofossils from the Pacific Ocean: San Diego Soc. Natl. Hist. Trans., v. 16, p. 303.

_____, 1971b. Coccolith stratigraphy Leg 6, DSDP. *In* Fischer, A. G. et al., Initial Reports of the Deep Sea Drilling Project, Volume 6: Washington (U.S. Government Printing Office), p. 965.

_____, 1973. Coccolith stratigraphy, eastern equatorial Pacific, Leg 16, DSDP. *In* Van Andel, T. H., Heath, G. R., et al., Initial Reports of the Deep Sea Drilling Project, Volume 16: Washington (U.S. Government Printing Office), p. 653.

Bukry, D. and Percival, S. F., 1971. New Tetiary calcareous nannofossils: Tulane Studies Geol. Paleont., v. 8, p. 123.

Burckle, L. H., Saito, T., and Ewing, M., 1967. A Cretaceous (Turonian) core from the Naturaliste Plateau southeast Indian Ocean: Deep-Sea Res., v. 14, p. 421.

Caratini, C., 1963. Contribution à l'étude des coccolithes du Cenomanien supérieur et du Turonien inférieur de la region de Rouen: Thèse Fac. Sci., Univ. Alger (Publ. Lab. Geol. Appliquée).

Cepek, P., 1970. Zur Vetikalverbreitung von Coccolithen-Arten in der Oberkreide NW-Deutschlands: Geol. Jb., v. 88, p. 235.

Cepek, P. and Hay, W. W., 1969. Calcareous nannoplankton and biostratigraphic subdivision of the Upper Cretaceous: Gulf Coast. Assoc. Geol. Soc. Trans., v. 19, p. 323.

Clocchiatti, M., 1971a. Contribution à l'étude due nannoplancton calcaire du Néogène d'Afrique du Nord: Mém. Mus. Nat. Hist. Nat., N. Sér. C, v. 23.

_____, 1971b. Sur l'existence de coccosphères portant des coccolithes de *Gephyrocapsa oceanica* et de *Emiliania huxleyi* (Coccolithophoridés): C.R. Acad. Sci. Paris, v. 273, p. 318.

Deflandre, G., 1959. Sur les nannofossiles calcaires et leur systématique: Rev Micropaleontol., v. 2, p. 127.

Forchheimer, S., 1972. Scanning electron microscope studies of Cretaceous coccoliths from the Koepingsberg Borehole No. 1, SE Sweden: Sver. Geol. Undersök., Arsbok, v. 65, Ser. C, no. 668.

Gaarder, K. R., 1970. Three new taxa of *Coccolithinae:* Nytt. Mag. Bot., v. 17, p. 113.

Gartner, S., 1968. Coccoliths and related calcareous nannofossils from Upper Cretaceous deposits of Texas and Arkansas: Kansas Univ. Paleont. Contrib., Art. 48.

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

_____, 1968. Annotated index and bibliography of the calcareous nannoplankton II: J. Paleont., v. 42, p. 584.

_____, 1969. Annotated index and bibliography of the calcareous nannoplankton III: J. Paleont., v. 43, p. 568-588.

_____, 1970a. Annotated index and bibliography of the calcareous nannoplankton IV: J. Paleont., v. 44, p. 558.

_____, 1970b. Annotated index and bibliography of the calcareous nannoplankton V: Phycologia, v. 9, p. 157.

_____, 1971. Annotated index and bibliography of the calcareous nannoplankton VI: Phycologia, v. 10, p. 315.

Manivit, H., 1971. Les nannofossiles calcaires du Crétacé francais (de l'Aptien au Danien): Essai de biozonation appuyée sur les stratotypes). Thèse Doctorat d'Etat.

Markali, J. and Paasche, E., 1955. On two species of *Umbellosphaera* a new marine coccolithophorid genus: Nytt. Mag. Bot., v. 4, p. 95.

Martini, E., 1970. Standard Paleogene calcareous nannoplankton zonation: Nature, v. 226, p. 560.

_____, 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation: Plankt. Conf. 2nd Rome 1970 Proc. Farinacci, H. (Ed.), Roma (Tecnoscienza), v. 2, p. 739.

Martini, E. and Worsley, T., 1970. Standard Neogene calcareous nannoplankton zonation: Nature, v. 225, p. 289.

McIntyre, A. and Bé, A. W. H., 1967. Modern *Coccolithophoridae* of the Atlantic Ocean. I. Placoliths and cyrtoliths: Deep-Sea Res., v. 17, p. 187.

Noël, D., 1969. *Arkhangelskiella* (coccolithes crétacés) et formes affines du Bassin de Paris: Rev. Micropaleontol., v. 11, p. 191.

_____, 1970. Coccolithes Crétacés. La craie Campanienne du Bassin de Paris: Paris (Ed. Centre Nat. Rech. Sci.).

Perch-Nielsen, K., 1972. Remarks on Late Cretaceous to Pleistocene coccoliths from the North Atlantic. *In* Laughton, A. S., Berggren, W. A., et al., Initial Reports of the Deep Sea Drilling Project, Volume 12: Washington (U.S. Government Printing Office), p. 1003.

Reinhardt, P., 1965. Neue Familien für fossile Kalkflagellaten (Coccolithophoriden, Coccolithineen): Monatsber. Deutch. Akad. Wiss. Berlin, v. 7, p. 30.

_____, 1966. Zur Taxionomie und Biostratigraphie des fossilen Nannoplanktons aus dem Malm, der Kreide und dem Alttertiär Mitteleuropas: Freib. Forsch., C196, p. 5.

_____, 1967. Fossile Coccolithen mit rhagoiden Zentralfeld. (Fam. (Fam. Ahmuellerellaceae, Subord. Coccolithinae): Neues Jb. Geol. Palaont. Monatsh., v. 3, p. 169.

_____, 1970. Synopsis der Gattungen und Arten der mesozoischen Coccolithen und anderer kalkiger Nannofossilien, Teil II: Freib. Forsch., C265, p. 43.

Roth, P. H., 1973. Calcareous Nannofossils—Leg 17, Deep Sea Drilling Project. *In* Winterer, E. L., Ewing, J. L., et al., Initial Reports of the Deep Sea Drilling Project, Volume 17: Washington (U.S. Government Printing Office), p. 695.

Roth, P. H., Baumann, P., and Bertolino, V., 1971. Late Eocene-Oligocene calcareous nannoplankton from Central and Northern Italy: Plankt. Conf. 2nd Rome Proc., Farinacci, A. (Ed.), Roma (Tecnoscienza), v. 2, p. 1069.

Roth, P. H. and Thierstein, H. R., 1972. Calcareous nannoplankton: Leg 14 of the Deep Sea Drilling Project. *In* Hayes, D. E., Pimm, A. C., et al., Initial Reports of the Deep Sea Drilling Project, Volume 14: Washington (U.S. Government Printing Office), p. 421.

Sclater, J. G., Anderson, R. N., and Bell, M. L., 1971. Elevation of ridges and evolution of the Central Eastern Pacific: J. Geophys. Res., v. 76, p. 7888.

Stover, L. E., 1966. Cretaceous coccoliths and associated nannofossils from France and the Netherlands: Micropaleontology, v. 12, p. 133.

Stradner, H., 1963. New contributions to Mesozoic stratigraphy by means of nannofossils. World Petrol. Congr., Proc. 6th, Sect. 1, paper 4.

Stradner, H., Adamiker, D., and Maresch, O., 1968. Electron microscope studies on Albian calcareous nannoplankton from the Delft 2 and Leidschendam 1 Deepwells, Holland: Verh. Nederl. Akad. Weetensch., Afd. Naturk., Eerste Reeks, v. 24, p. 4.

Thierstein, H. R., 1971. Tentative Lower Cretaceous calcareous nannoplankton zonation. Ecolog. Geol. Helv., v. 64, p. 459.

_____, 1973. Lower Cretaceous calcareous nannoplankton biostratigraphy: Abh. Geol. B.A. (Wien), v. 29.

Thierstein, H. R., Franz, H. E., and Roth, P. H., 1972. Scanning electron and light microscopy of the same small object: Micropaleontology, v. 17, p. 501.

PLATE 1

Cribrosphaerella primitiva Thierstein, n. sp.
(Figures 1, 8, 12, 13, SEM ×7700; Figures 2-7, 9-11, SEM ×3300.)

Figure 1	Sample 258-5-3, 115 cm; Santonian; proximal side; holotype (1122/5) A978; slightly overgrown specimen.
Figure 2	Same specimen as Figure 1; phase contrast.
Figure 3	Same specimen as Figure 1; transmitted light.
Figure 4	Same specimen as Figure 1; cross-polarized light.
Figure 5	Same specimen as Figure 8; phase contrast.
Figure 6	Same specimen as Figure 8; transmitted light.
Figure 7	Same specimen as Figure 8; cross-polarized light.
Figure 8	Sample 258-5-3, 115 cm; Santonian; proximal side; paratype (1122/3) A979; slightly overgrown specimen.
Figure 9	Same specimen as Figure 12, phase contrast.
Figure 10	Same specimen as Figure 12; transmitted light.
Figure 11	Same specimen as Figure 12; cross-polarized light.
Figure 12	Sample 258-5-3, 115 cm; Santonian; distal side; paratype (1122/1) A980.
Figure 13	Sample 258-14, CC; Cenomanian; distal side; hypotype (1021/11) A981; slightly etched specimen.

PLATE 1

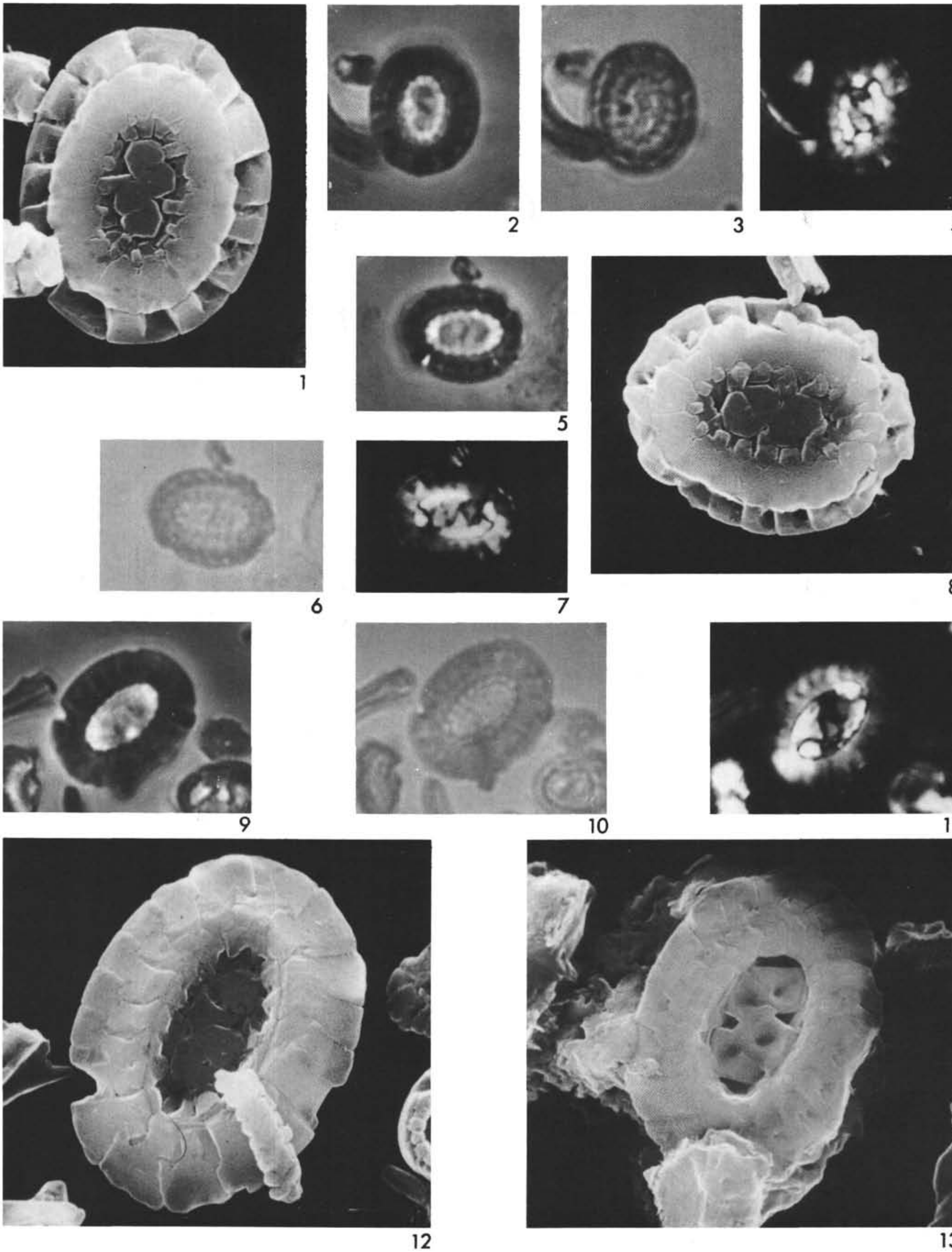

PLATE 2

Gartnerago nanum Thierstein, n. sp.
Sample 258-14-1, 85 cm; Cenomanian.

Figure 1	Proximal side; SEM, ×7300; paratype (1027/5) A975; slightly etched specimen.
Figure 2	Same specimen as Figure 1; phase contrast, ×3200.
Figure 3	Same specimen as Figure 1; transmitted light, ×3200.
Figure 4	Same specimen as Figure 1; cross-polarized light, ×3200.
Figure 5	Same specimen as Figure 8; phase contrast, ×3200.
Figure 6	Same specimen as Figure 8; transmitted light, ×3200.
Figure 7	Same specimen as Figure 8; cross-polarized light, ×3200.
Figure 8	Proximal side; SEM, ×6700; holotype (1027/7) A974; slightly etched specimen.
Figure 9	Proximal side; SEM, ×9200; paratype (1027/9) A976; well-preserved specimen.
Figure 10	Distal side; SEM, ×9200; paratype (1031/1) A977; well-preserved specimen.
Figure 11	Same specimen as Figure 10; phase contrast, ×3200.
Figure 12	Same specimen as Figure 10; transmitted light, ×3200.
Figure 13	Same specimen as Figure 10; cross-polarized light, ×3200.

PLATE 2

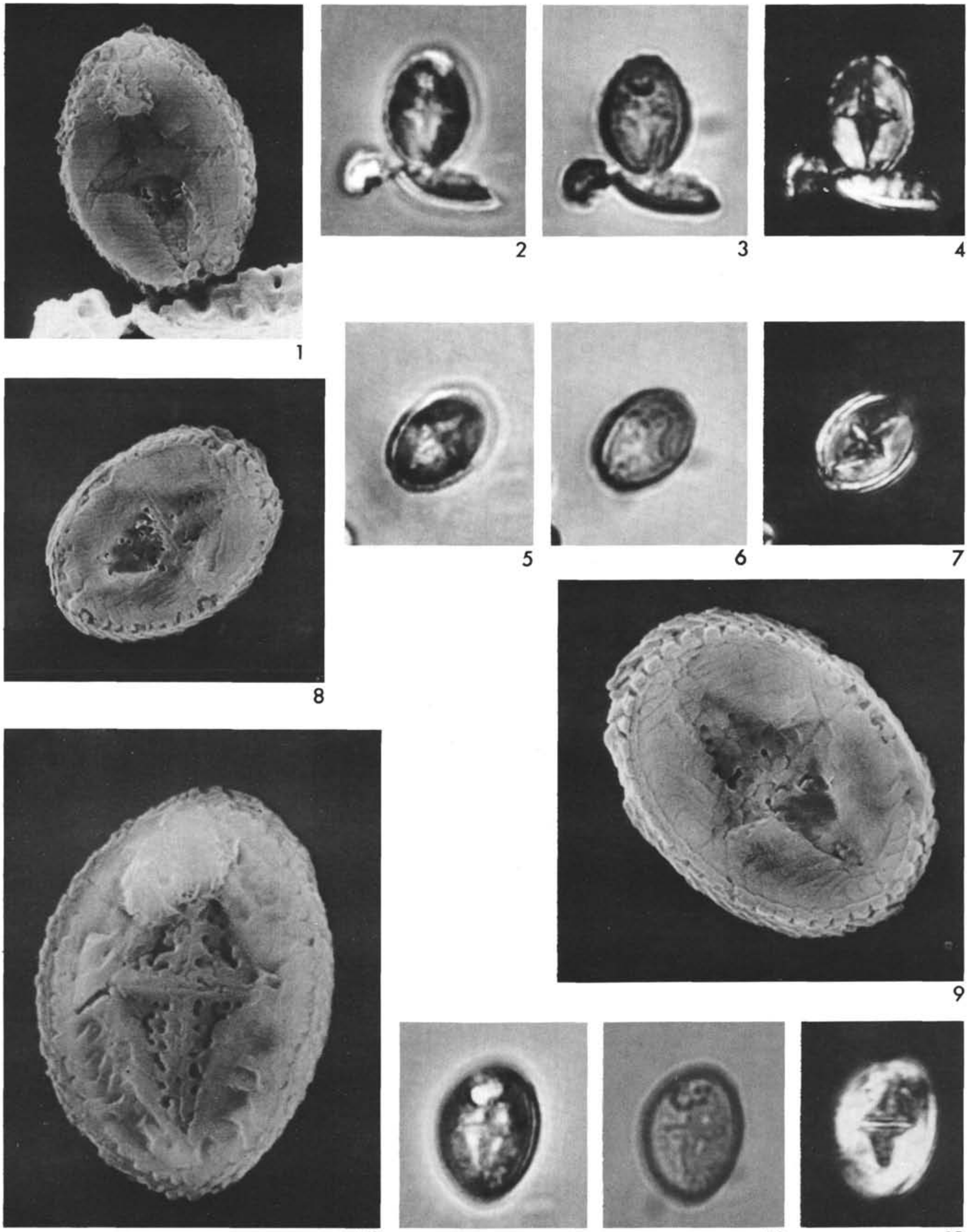

PLATE 3

Figures 1-4	*Vagalapilla aachena* Bukry, 1969. Sample 258-8, CC; Coniacian. 1. Distal side; SEM, ×7500; (1037/5). 2. Same specimen as Figure 1; phase contrast, ×3200. 3. Same specimen as Figure 1; transmitted light, ×3200. 4. Same specimen as Figure 1; cross-polarized light, ×3200.
Figures 5-11	*Lithraphidites alatus* Thierstein, 1972. Sample 258-14, CC; Cenomanian. 5. Same specimen as Figure 7; phase contrast, low focus, ×3200. 6. Same specimen as Figure 7; phase contrast, high focus, ×3200. 7. SEM, ×6000; (1021/6). 8. SEM, ×8300; (1020/11). 9. Same specimen as Figure 7; transmitted light, ×3200. 10. Same specimen as Figure 7; cross-polarized light, high focus, ×3200. 11. Same specimen as Figure 7; cross-polarized light, low focus, ×3200.
Figures 12-14	Preservation of coccospheres of *Watznaueria barnesae* (Black, 1959) Perch-Nielsen, 1968. 12. Sample 258-6-2, 110 cm; Coniacian; SEM, ×6000; (986/12); variably etched coccoliths. 13. Sample 258-8, CC; Coniacian; SEM, ×5800; (1038/9); slightly overgrown coccoliths. 14. Sample 258-10-1, 119 cm; Coniacian; SEM, ×5600; (1033/5); slightly overgrown coccoliths.

PLATE 3

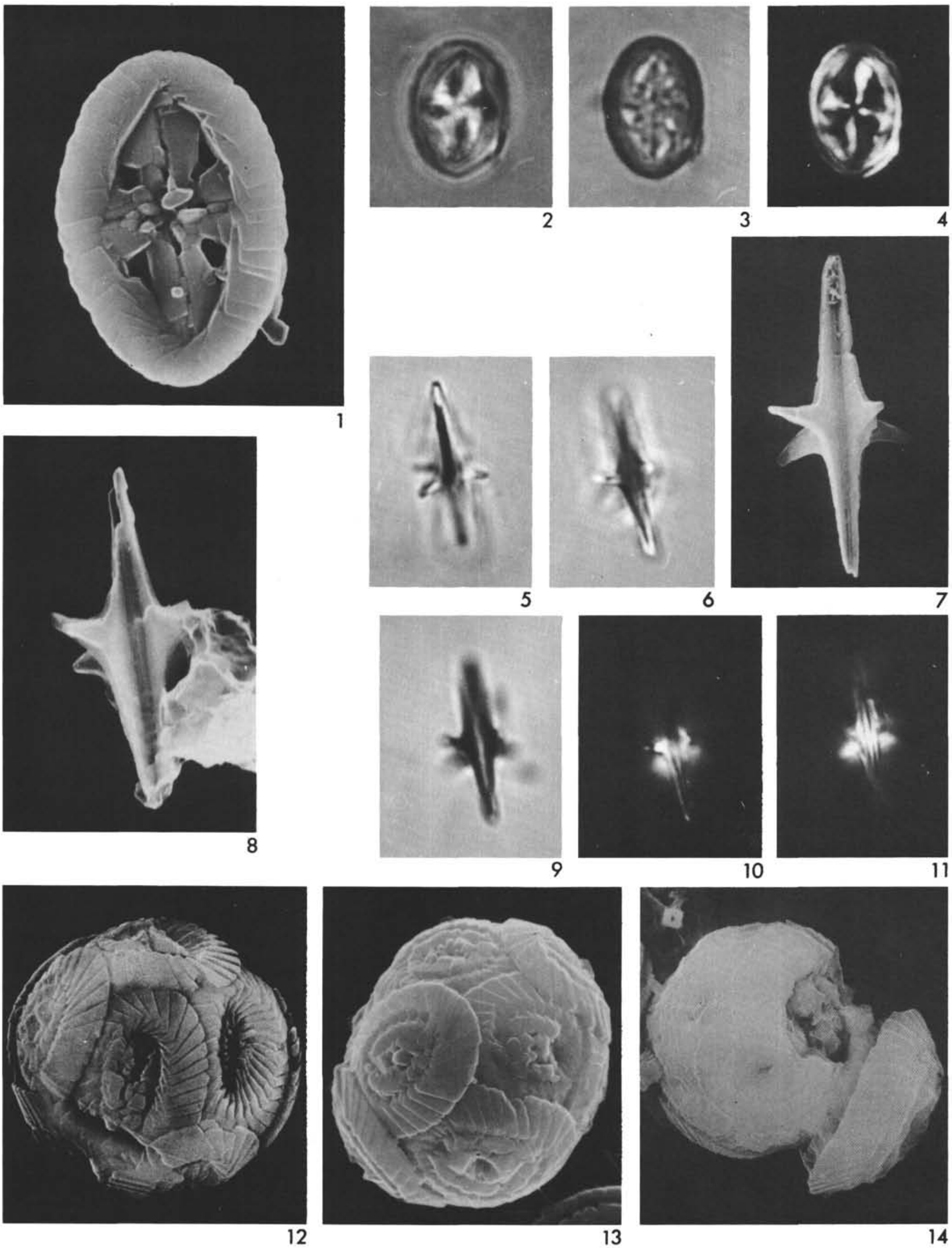

PLATE 4

Gartnerago striatum (Stradner, 1963) Forchheimer, 1972

Figures 1-4, Sample 258-12-4, 139 cm; Turonian;
Figures 5-8, Sample 258-14-1, 85 cm; Cenomanian;
Figures 9-15, Sample 258-14, CC; Cenomanian.
(Figures arranged in stratigraphic order)

Figure 1	Proximal side; SEM, ×5300; (1011/3).
Figure 2	Same specimen as Figure 1; phase contrast, ×3200.
Figure 3	Same specimen as Figure 1; transmitted light, ×3200.
Figure 4	Same specimen as Figure 1; cross-polarized light, ×3200.
Figure 5	Same specimen as Figure 8; phase contrast, ×3200.
Figure 6	Same specimen as Figure 8; transmitted light, ×3200.
Figure 7	Same specimen as Figure 8; cross-polarized light, ×3200.
Figure 8	Distal side; SEM, ×6400; (1030/12).
Figure 9	Proximal side; SEM, ×6500; (1020/6).
Figure 10	Distal side; SEM, ×6000; (1020/1).
Figure 11	Distal side; SEM, ×5800; (1022/1).
Figure 12	Proximal side; SEM, ×5800; (1020/4).
Figure 13	Same specimen as Figure 12; phase contrast, ×3200.
Figure 14	Same specimen as Figure 12; transmitted light, ×3200.
Figure 15	Same specimen as Figure 12; cross-polarized light, ×3200.

PLATE 4

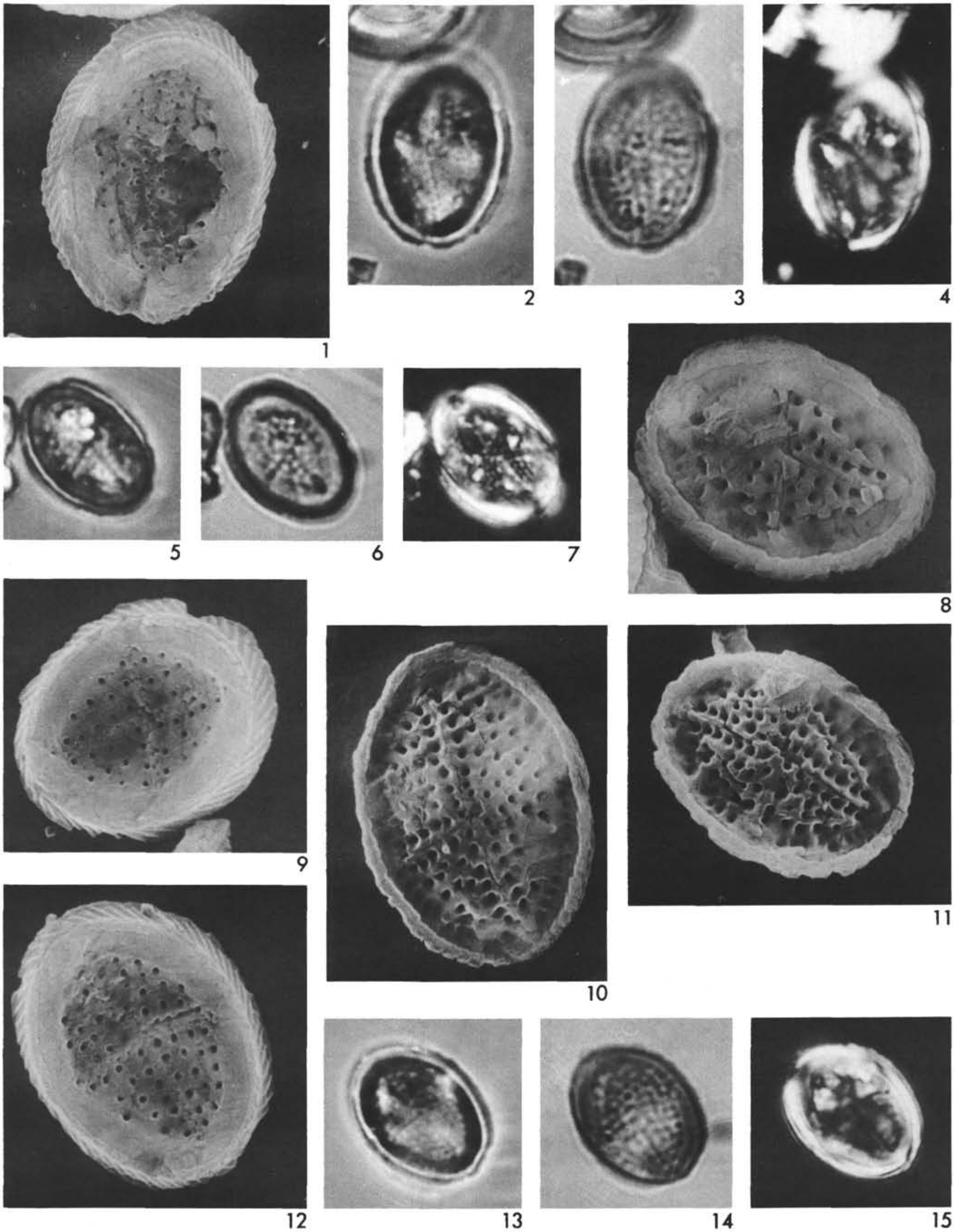

PLATE 5

(Figures arranged in stratigraphic order.)

Figures 1, 2 — *Gartnerago segmentatum* (Stover, 1966) n. comb.
1. Sample 258-8, CC; Coniacian; distal side; SEM, ×5300; (1037/1); moderately overgrown specimen.
2. Sample 258-10-1, 119 cm; Coniacian; proximal side; SEM, ×6300; (1007/4); moderately overgrown specimen with all perforations closed.

Figures 3-9 — *Gartnerago obliquum* (Stradner, 1963) Reinhardt, 1970
3. Sample 258-10-1, 119 cm; Coniacian; proximal side; SEM, ×6300; (1022/12); slightly overgrown specimen of the *Gartnerago costatum costatum* (Gartner, 1968) Bukry, 1969 morphotype.
4. Sample 258-10-1, 119 cm; Coniacian; distal side; SEM, ×6000; (1009/1); specimen with some of the perforations closed by overgrowth.
5. Sample 258-12-4, 139 cm; Turonian; distal side; SEM, ×6000; (1011/7); etched specimen.
6. Sample 258-12-4, 139 cm; Turonian; proximal side; SEM, ×6800; (1012/1) slightly etched specimen of the *Gartnerago costatum costatum* (Gartner, 1968) Bukry, 1969 morphotype.
7. Same specimen as Figure 6; phase contrast, ×3300.
8. Same specimen as Figure 6; transmitted light, ×3300.
9. Same specimen as Figure 6; cross-polarized light, ×3300.

PLATE 5

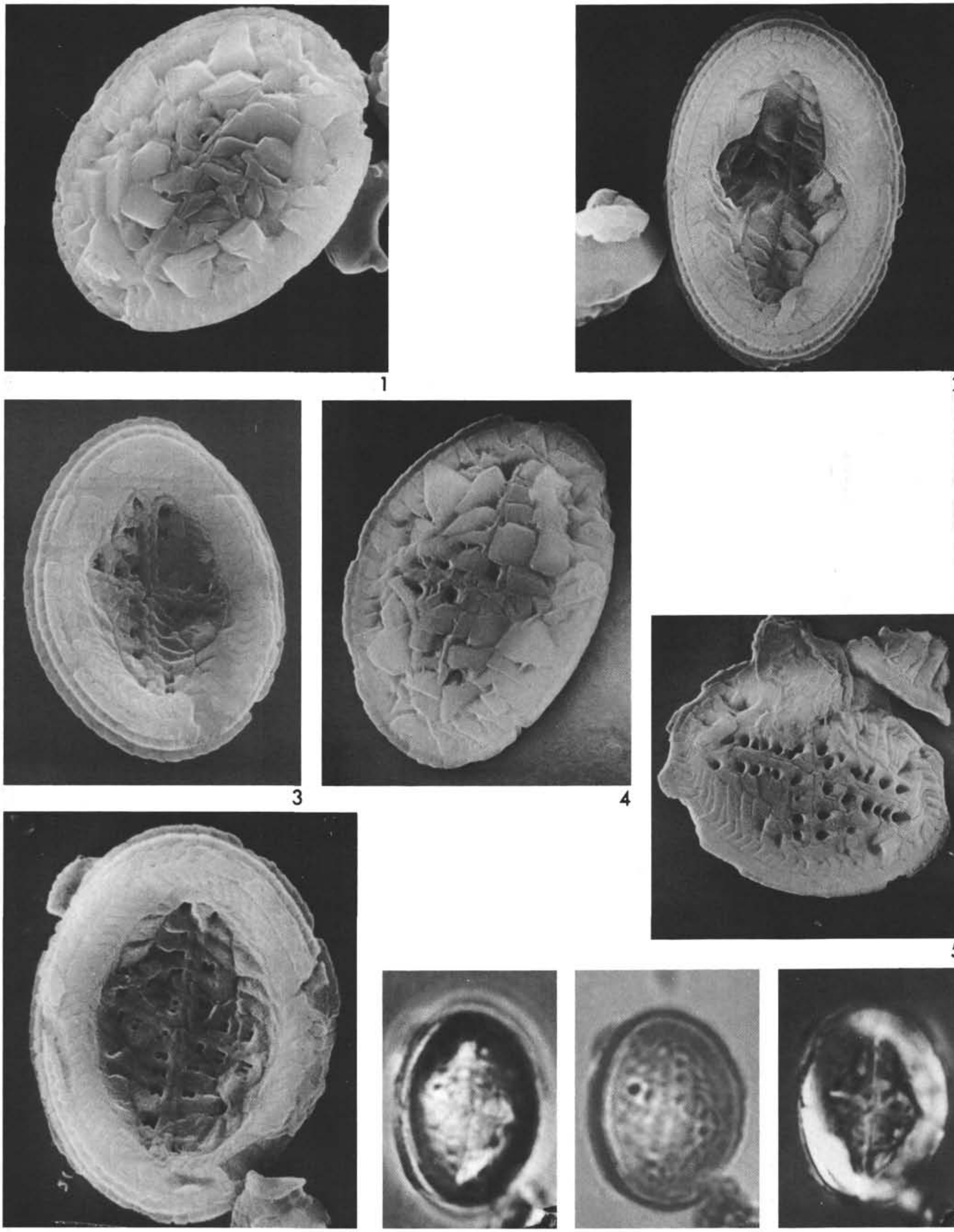

PLATE 6

(Figures arranged in stratigraphic order)

Figures 1, 2 — Sample 258-6-2, 110 cm; Coniacian.

1. *Gartnerago segmentatum* (Stover, 1966) n. comb. Distal side; SEM, ×6300; (992/1); moderately overgrown specimen.
2. *Gartnerago obliquum* (Stradner, 1963) Reinhardt, 1970. Distal side; SEM, ×6800; (988/5); specimen with some perforations closed by moderate overgrowth.

Figures 3-10 — *Gartnerago segmentatum* (Stover, 1966) n. comb. Sample 258-8, CC; Coniacian. Figure 3, SEM ×5000; Figures 4-7, 9, 10, LM ×3300; Figure 8, SEM ×4700.

3. Distal side; (1035/4); moderately overgrown specimen.
4. Same specimen as Figure 3; phase contrast.
5. Same specimen as Figure 3; transmitted light.
6. Same specimen as Figure 3; cross-polarized light.
7. Same specimen as Figure 8; phase contrast.
8. Proximal side; (1038/7), moderately overgrown specimen.
9. Same specimen as Figure 8; transmitted light.
10. Same specimen as Figure 8; cross-polarized light.

PLATE 6

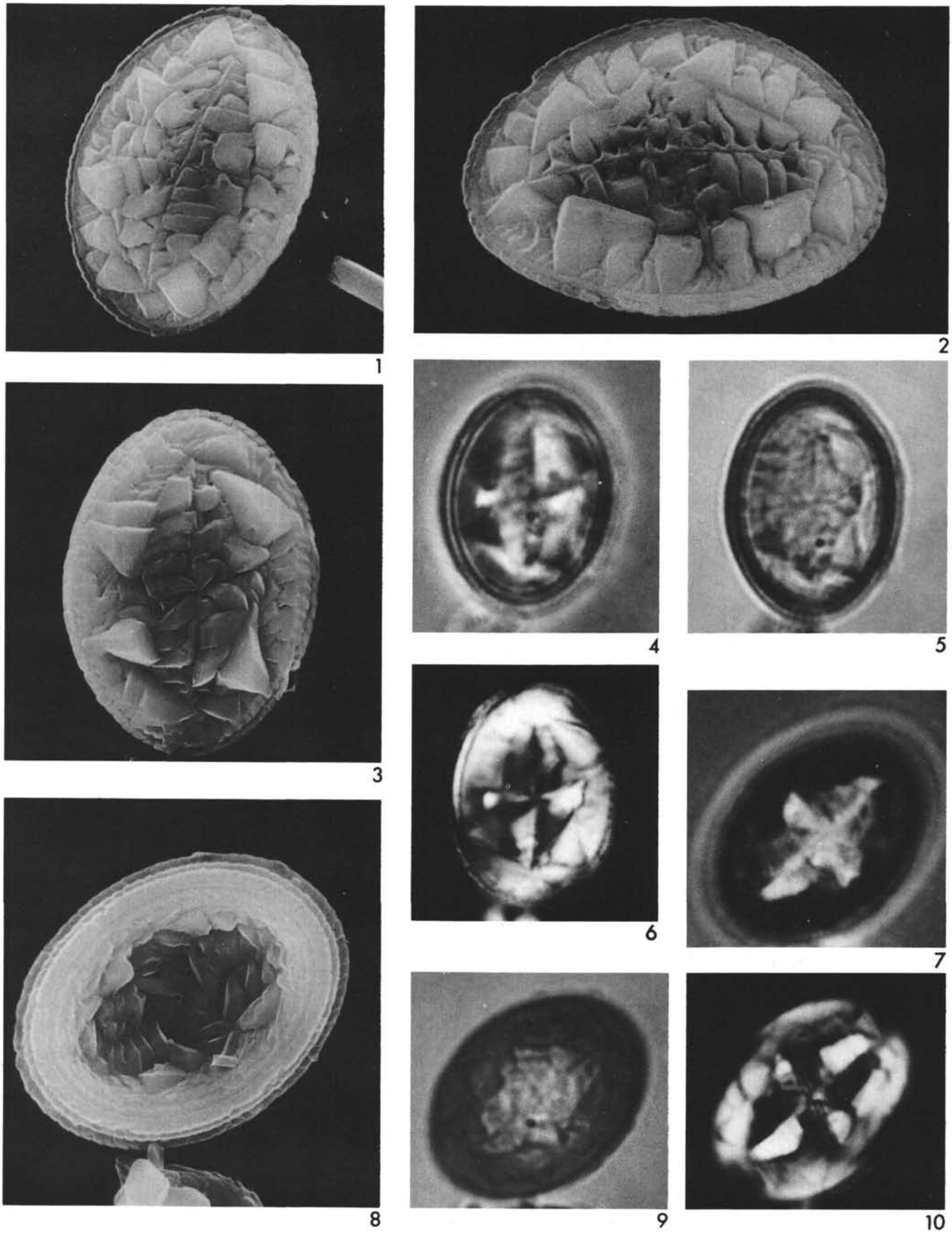

PLATE 7

Sample 258-6-2, 110 cm; Coniacian

(Figures arranged in stratigraphic order)

Figures 1-5 — *Gartnerago obliquum* (Stradner, 1963) Reinhardt, 1970. Figure 1, SEM, ×5300; Figures 2-5, SEM, ×3300.

1. Distal side; (990/7); specimen with central area perforations partly closed by moderate overgrowth.
2. Same specimen as Figure 1; phase contrast, low focus.
3. Same specimen as Figure 1; phase contrast, high focus.
4. Same specimen as Figure 1; transmitted light.
5. Same specimen as Figure 1; cross-polarized light.

Figure 6 — *Gartnerago segmentatum* (Stover, 1966) n. comb. Proximal side; SEM, ×6800; (985/10); central area perforations almost completely closed by moderate overgrowth.

Figures 7-10 — *Gartnerago obliquum* (Stradner, 1963) Reinhardt, 1970. Figures 7, 9, 10, SEM, ×3200; Figure 8, SEM, ×4800.

7. Same specimen as Figure 8; phase contrast.
8. Proximal side; (988/9); central area perforations partly closed by slight overgrowth.
9. Same specimen as Figure 8; transmitted light.
10. Same specimen as Figure 8; cross-polarized light.

PLATE 7

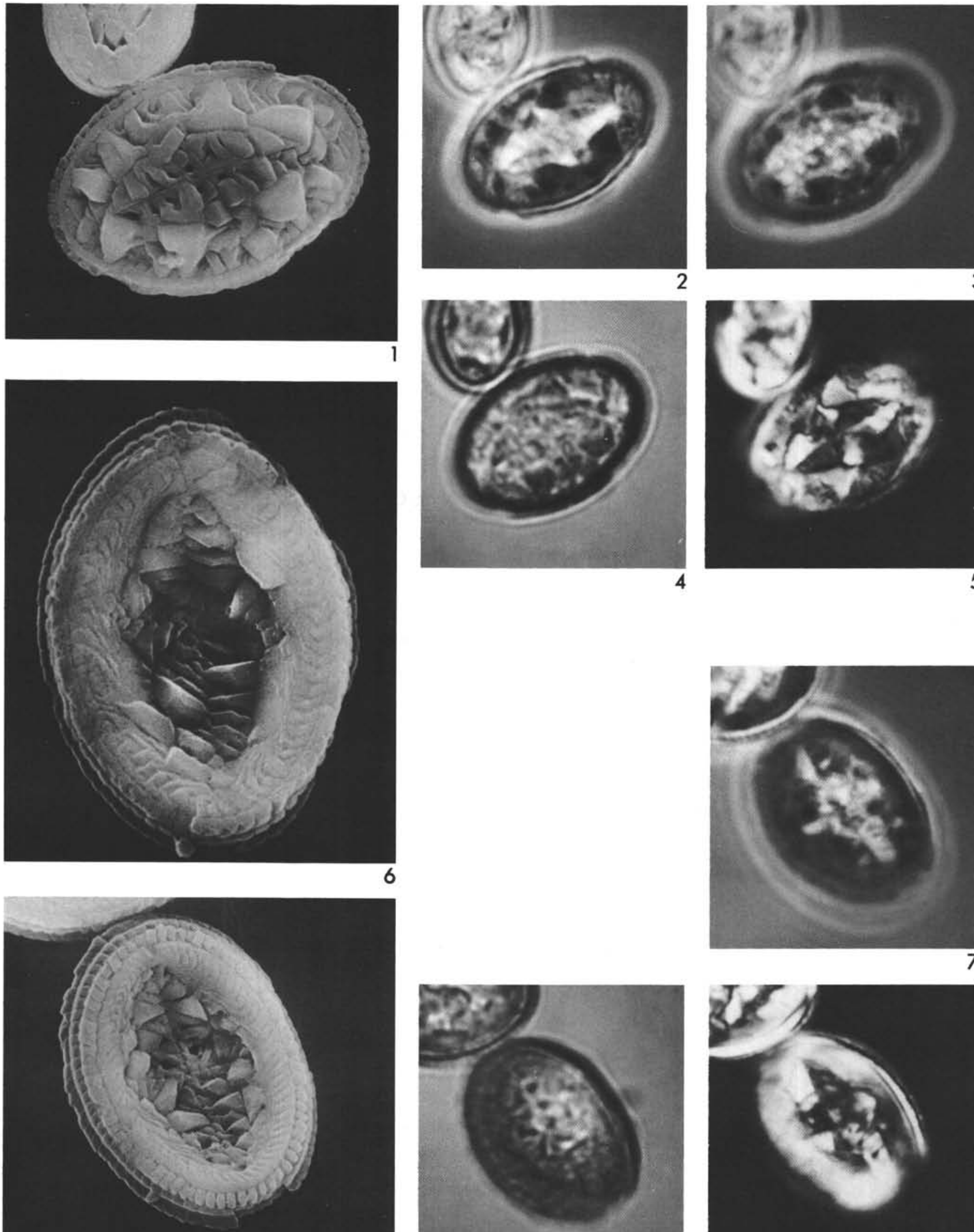

PLATE 8

Kamptnerius magnificus Deflandre, 1959
(Figures arranged in stratigraphic order)

Figures 1, 2 — Sample 258-10-1, 119 cm; Coniacian.
1. Proximal side; SEM, ×5300; (1013/10); all perforations covered by moderate overgrowth.
2. Proximal side; SEM, ×3500; (1034/12); all perforations closed by moderate overgrowth.

Figures 3, 4 — Sample 258-10-1, 119 cm; Coniacian.
3. Distal side; SEM, ×5400; (1023/6); "*Kamptnerius punctatus* Stradner, 1963" morphotype with initiating overgrowth.
4. Proximal side; SEM, ×5900; (1022/5); slightly etched "*Kamptnerius pseudopunctatus* Čepek, 1970" morphotype with only a few perforations.

Figures 5-9 — Sample 258-12-4, 139 cm; Turonian.
5. Proximal side, SEM, ×5800; (1009/9); moderately etched "*Kamptnerius punctatus* Stradner, 1963" morphotype.
6. Distal side, SEM, ×7500; (1010/3); "*Kamptnerius pseudopunctatus* Čepek, 1970" morphotype, with only a few perforations and signs of overgrowth in the central area and with etched shield.
7. Same specimen as Figure 6; phase contrast, ×3300.
8. Same specimen as Figure 6; cross-polarized light, ×3300.
9. Same specimen as Figure 6; transmitted light, ×3300.

PLATE 8

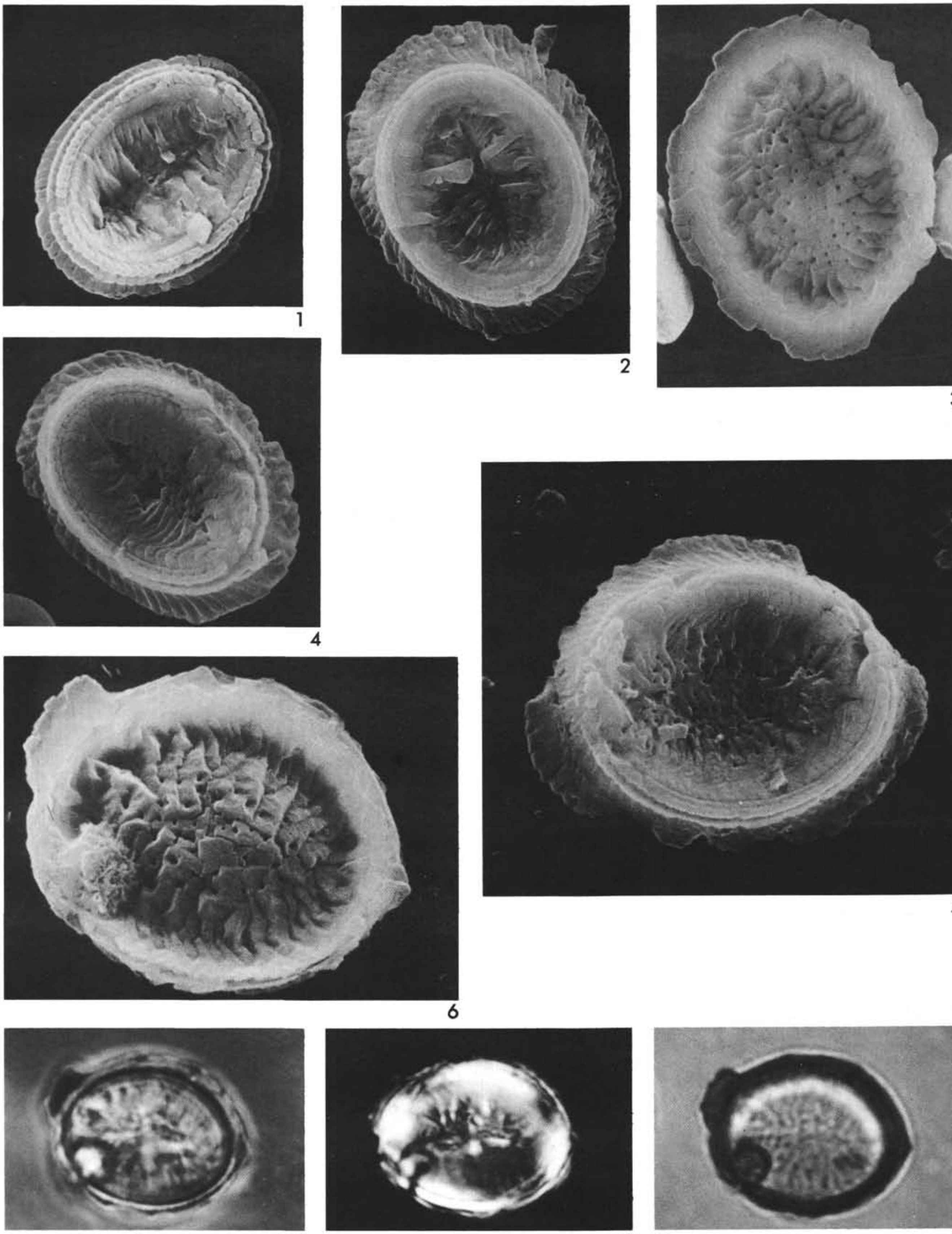

PLATE 9

Kamptnerius magnificus Deflandre, 1959

Figures 1-5, Sample 258-6-2, 110 cm; Coniacian.
Figures 6-11, Sample 258-8, CC; Coniacian.
(Figures arranged in stratigraphic order)

Figure 1	Proximal side; SEM, ×4500; (986/8); well-preserved "*Kamptnerius pseudopunctatus* Cepek, 1970" morphotype with a few perforations.
Figure 2	Same specimen as Figure 1; phase contrast, ×3200.
Figure 3	Same specimen as Figure 1; transmitted light, ×3200.
Figure 4	Distal side; SEM, ×4600; (988/7); specimen with moderately overgrown elements.
Figure 5	Same specimen as Figure 1; cross-polarized light, ×3200.
Figure 6	Proximal side; SEM, ×5000; (1015/7); specimen with strongly overgrown elements, covering almost completely the central area cross structure.
Figure 7	Distal side; SEM, ×5800; (1014/8) specimen with strongly overgrown elements.
Figure 8	Distal side; SEM, ×4200; (1037/3); specimen with strongly overgrown elements. covering completely the central area cross structure.
Figure 9	Same specimen as Figure 8; phase contrast, ×3200.
Figure 10	Same specimen as Figure 8; transmitted light, ×3200.
Figure 11	Same specimen as Figure 8; cross-polarized light, ×3200.

PLATE 9

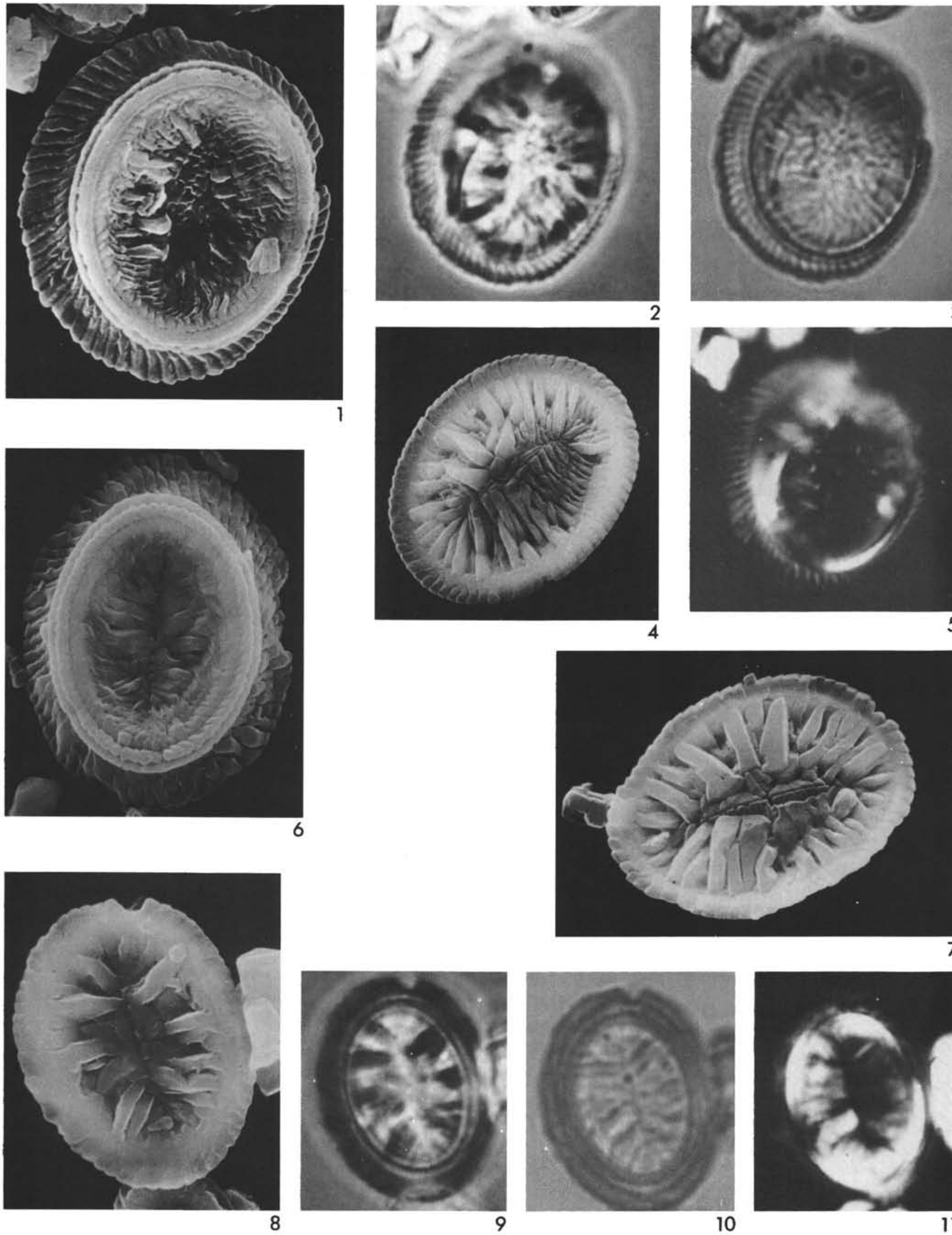

PLATE 10

(Figures arranged in stratigraphic order)

Figures 1-6 *Broinsonia enormis* (Shumenko, 1968) Manivit, 1971. Sample 258-8, CC; Coniacian. Figures 1, 5, 6, SEM ×6300; Figures 2-4, LM ×3200.

1. Distal side; (1037/11); moderately overgrown specimen, central area closed by plates; structure identical to that of the holotypes of *Arkhangelskiella enormis* Shumenko, 1968, pl. 1, fig. 3, and *Broinsonia bevieri* Bukry, 1969, pl. 1, fig. 8.
2. Same specimen as Figure 1; phase contrast.
3. Same specimen as Figure 1; transmitted light.
4. Same specimen as Figure 1; cross-polarized light.
5. Distal side; (1017/3); moderately overgrown specimen, small central area with some almost completely closed perforations; transitional specimen to *Broinsonia furtiva* Bukry, 1969.
6. Distal side; (1017/5); moderately overgrown specimen, central area partly closed; transitional specimen to *Broinsonia furtiva* Bukry, 1969.

Figures 7-14 ?*Broinsonia furtiva* Bukry, 1969. Sample 258-10-1, 119 cm; Coniacian.

7. Distal side; SEM, ×6300, (1034/6); partially overgrown specimen with a number of perforations. Axial cross-bar structure still recognizable (with base of central process?). Transitional specimen to *Broinsonia furtiva* Bukry, 1969, as shown on Plate 11, Figures 5-8.
8. Distal side; SEM, ×6300; (1031/8); slightly overgrown specimen.
9. Distal side; SEM, ×6300; (1004/5); partly overgrown specimen.
10. Distal side; SEM, ×6800; (1034/2); partly overgrown specimen with central process.
11. Same specimen as Figure 10; SEM, ×7400; (1034/1); tilted 60°.
12. Proximal side; SEM, ×5800; (1006/6); partly overgrown specimen.
13. Distal side; SEM, ×5800; (1033/2); slightly overgrown and etched specimen with central process.
14. Same specimen as Figure 13; SEM, ×5300; (1033/1); tilted 60°.

PLATE 10

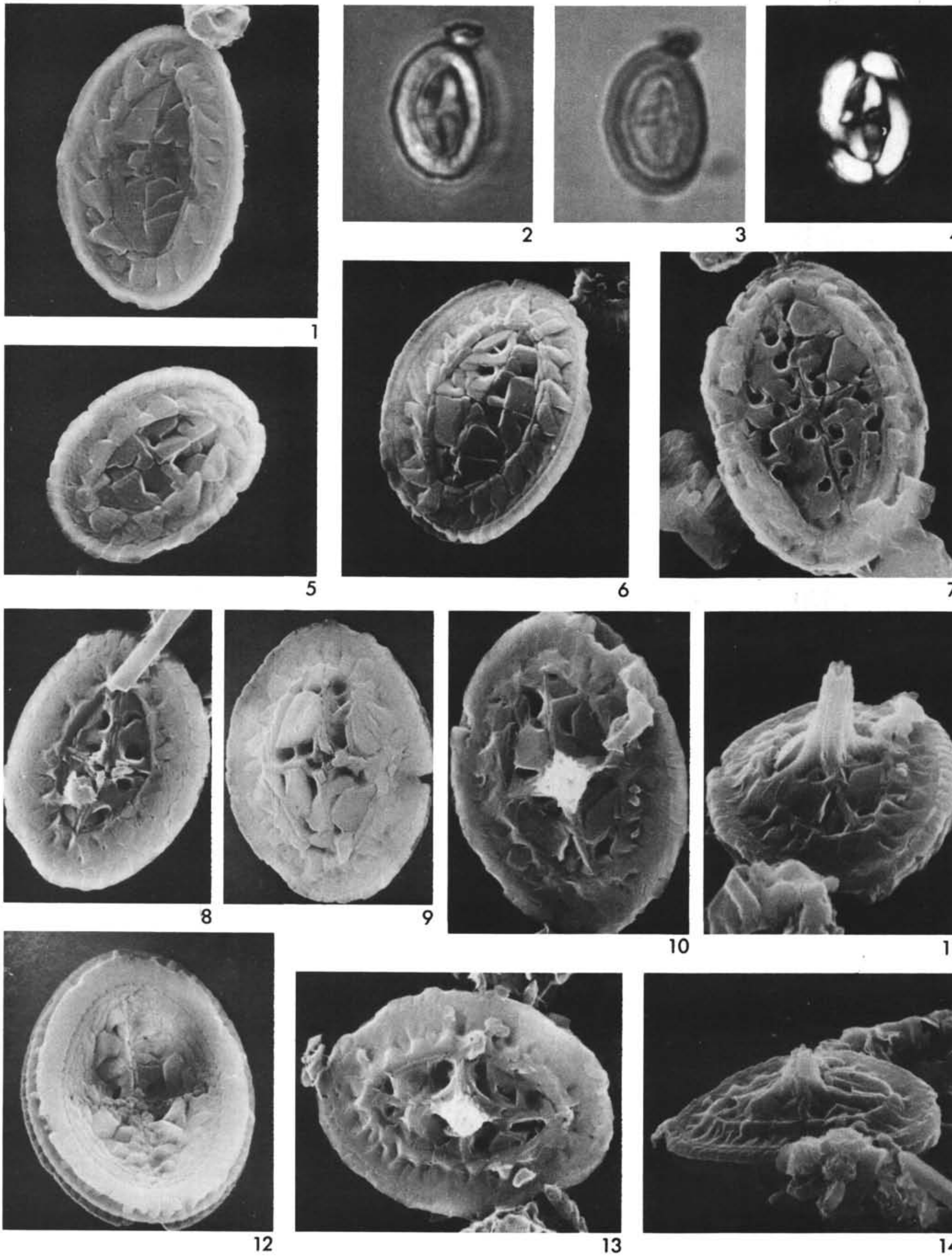

PLATE 11

(Figures arranged in stratigraphic order)

Figures 1-8 *Broinsonia furtiva* Bukry, 1969. Sample 258-6-2, 110 cm; Coniacian. Figures 1, 8, SEM ×6300; Figures 2-7, LM ×3200.

1. Proximal side; (988/11); slightly etched specimen with perforations.
2. Same specimen as Figure 1; phase contrast.
3. Same specimen as Figure 1; transmitted light.
4. Same specimen as Figure 1; cross-polarized light.
5. Same specimen as Figure 8; phase contrast.
6. Same specimen as Figure 8; transmitted light.
7. Same speicmen as Figure 8; cross-polarized light.
8. Distal side; (990/1); slightly etched specimen with perforations.

Figures 9-16 *Broinsonia enormis* (Shumenko, 1968) Manivit, 1971. Sample 258-8, CC, Coniacian. Figures 9, 16, SEM ×6300; Figures 10-15, SEM ×3200.

9. Distal side; (1036/3); moderately overgrown specimen.
10. Same specimen as Figure 9; phase contrast.
11. Same specimen as Figure 9; transmitted light.
12. Same specimen as Figure 9; cross-polarized light.
13. Same specimen as Figure 16; phase contrast.
14. Same specimen as Figure 16; transmitted light.
15. Same specimen as Figure 16; cross-polarized light.
16. Proximal side; (1036/9); moderately overgrown specimen with small central area. Transitional specimen to *Broinsonia parca* (Stradner, 1963).

PLATE 11

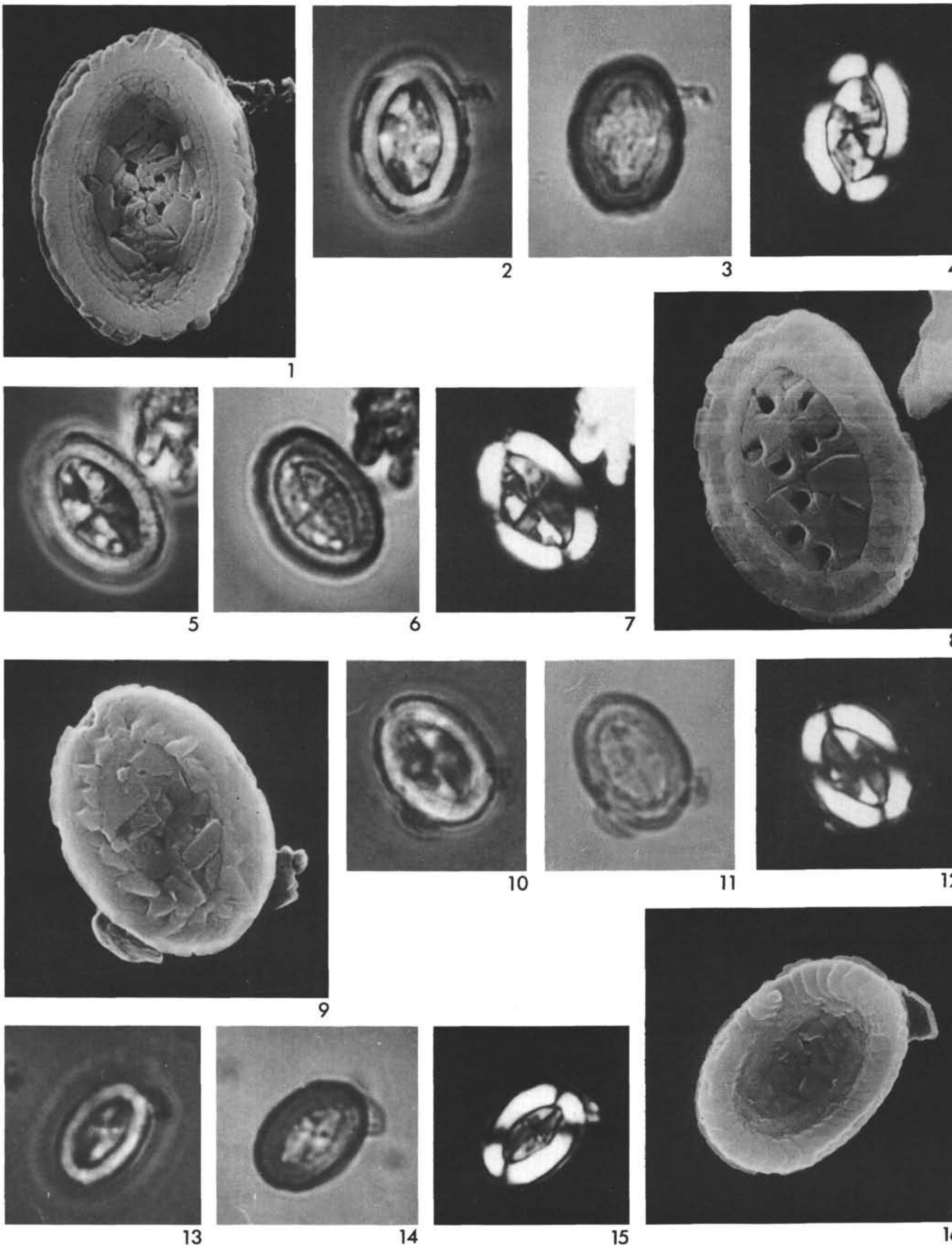

PLATE 12

Micula staurophora (Gardet, 1955) Stradner, 1963
(Figures arranged in stratigraphic order)

Figures 1, 2 — Sample 258-6-2, 110 cm; Coniacian.
1. SEM, ×3500; (986/5); etched specimen, consisting of eight elements. Similar morphotypes from this well-preserved assemblage have the typical extinction pattern under crossed nicols, as described and illustrated by Bramlette and Martini (1964, pl. 6, fig. 9), which shows the eight elements extinct and a bright diagonal cross at 45° to crossed nicols.
2. SEM, ×3600; (986/7); side view of the same specimen as Figure 1, tilted 45°.

Figure 3 — Sample 258-8, CC; Coniacian; SEM, ×6800; (1014/6); specimen with cubical shape from an assemblage with moderate overgrowth.

Figures 4-10 — Sample 258-10-1, 119 cm; Coniacian.
4. SEM, ×8200; (1027/3); same specimen as Figure 5, tilted 50°.
5. SEM, ×8000; (1027/1); "*Micula pyramida* (Gardet, 1955)" morphotype, with four heavy, inclined elements.
6. Same specimen as Figure 5; phase contrast, ×3500.
7. Same specimen as Figure 5; transmitted light, ×3500.
8. Same specimen as Figure 5; cross-polarized light, ×3500. The four elments (= overgrown diagonal bars of *M. staurophora*) appear bright when the sutures between them are parallel to nicols.
9. SEM, ×6900; (1008/9); tilted 50°. Transitional specimen between Figures 10 and 4. The elements of the four proximal and four distal crystallites are grown together.
10. SEM, ×7500; (1023/12); specimen tilted 50° with 8-armed *Micula staurophora* structure, showing initiating overgrowth.

Figure 11 — Sample 258-12-4, 139 cm; Turonian; SEM, ×9500; (1010/8); specimen showing eight extended arms from an assemblage with signs of etching and overgrowth.

PLATE 12