24. LATE EOCENE TO EARLY MIOCENE DIATOMS FROM THE SOUTHWEST ATLANTIC[1]

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ABSTRACT

This chapter presents the stratigraphic distribution of 154 diatom species in a composite upper Eocene to lower Miocene section recovered in cores from Holes 511 and 513A. The section is divided into 12 biostratigraphic zones based on the highest and lowest occurrences of 11 species. Abundance curves for several diatom species in the vicinity of the Eocene/Oligocene and Oligocene/Miocene boundaries are presented; they suggest that abundance changes may have utility as stratigraphic tools, at least on a local scale. Taxonomic notes on all species studied are presented and eight new species are described.

OBJECTIVES AND BACKGROUND

The primary objective of this chapter is to present data on the distribution and relative abundance of diatom species in sediment samples from Holes 511 and 513A. Second, because of the rare opportunity presented by the recovery, in those holes, of a composite upper Eocene to lower Miocene section, we propose a local diatom zonation consisting of 12 biostratigraphic zones based on the highest or lowest occurrences of 11 species. Third, abundance curves for selected species in the vicinity of the Eocene/Oligocene and Oligocene/Miocene boundaries and in the correlative lower Oligocene interval of both holes are presented as ancillary tools for correlation in the Southwest Atlantic. Finally, taxonomic references to all species considered in this chapter and descriptions of new species are presented. These basic data are given, with minimal interpretation, in keeping with the concept of an "initial report" which is intended as a basis for future research.

Sites 511 and 513 are located in the South Atlantic Ocean at 51°00.28′S; 46°58.30′W and 47°34.99′S; 24°38.40′W, respectively. Site 511 is situated about 10 km south of Site 330 (DSDP Leg 36) in the basin province of the Falkland Plateau in 2589 meters of water. Site 513 is located on the lower flank of the Mid-Atlantic Ridge near the southeastern margin of the Argentine Basin in 4373 meters of water (Fig. 1).

Hole 511 was drilled and continuously cored to a sub-bottom depth of 632 meters. Diatoms are abundant and are well to moderately well preserved throughout; they range in age from early Oligocene to late Eocene.

Hole 513A was washed to 56.5 meters sub-bottom and then drilled to 75.5 meters; the interval from 75.5 to 85 meters was washed, and the remainder of the hole below 85 meters was continuously cored to 587 meters sub-bottom, where basement basalt was encountered. A portion of the continuously cored interval between Cores 12 and 33 contains abundant and well- to moderately well preserved diatoms, early Miocene to early Oligocene in age. Together, Holes 511 and 513A comprise a late Eocene to early Miocene record of diatom evolution in the South Atlantic Ocean that is apparently uninterrupted by disconformities.

Because time-equivalent early Oligocene intervals were cored at both sites, it was possible directly to correlate and contrast the sections in Holes 511 and 513A. Correlation is made on the basis of the extinction or highest stratigraphic occurrence of the calcareous nannofossil *Isthmolithus recurvus*. In Hole 513A the highest occurrence of *I. recurvus* occurs at the top of Core 31; in Hole 511 this datum occurs at the top of Core 4 (Wise, this volume). Therefore, the interval in Hole 513A from the lower part of Core 28 through Core 33 corresponds to the interval in Hole 511 from Core 1 through Core 6 (see Fig. 2). In this chapter we refer to this interval as the correlative interval.

MATERIAL AND METHODS

All samples used in this study were collected by shipboard scientists during Leg 71. A total of 154 samples were processed for shore-based investigation. Samples from each hole were examined by both authors in order to provide some cross-checking of results. However, primary responsibility for Hole 511 was delegated to Gombos, for Hole 513A to Ciesielski. Sediment samples were processed by standard techniques using hydrogen peroxide and hydrochloric acid to clear the diatom valves of all organic and calcareous material. The residue was washed free of acid and stored in vials.

Two strewn slides were prepared from the treated sample using Hyrax (n.d. = 1.71) mounting medium and 22 × 22 mm cover slips. In preparing slides we attempted to achieve uniform distribution of sample material on the cover slips. Then the remaining residue was passed through stacked 63-μm and 38-μm sieves. Residue retained on each sieve and the fine material which passed through both sieves were removed and stored in separate vials.

Sieving resulted in the separation of the residue into three size fractions: (1) greater than 63 μm; (2) 38–63 μm; (3) less than 38 μm. Fraction 1 contains mostly radiolarians and very large diatoms, Fraction 2 mainly diatoms and smaller radiolarians, and Fraction 3 the smaller diatoms, broken fragments of diatoms and radiolarians, and silt and clay. Slides were prepared from each fraction, except for Fraction 3 (see following discussion), in the same manner as those of the unsieved fraction.

It appears that most of the stratigraphically significant diatom species, at least in the Paleogene, commonly occur in the size range

[1] Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office).

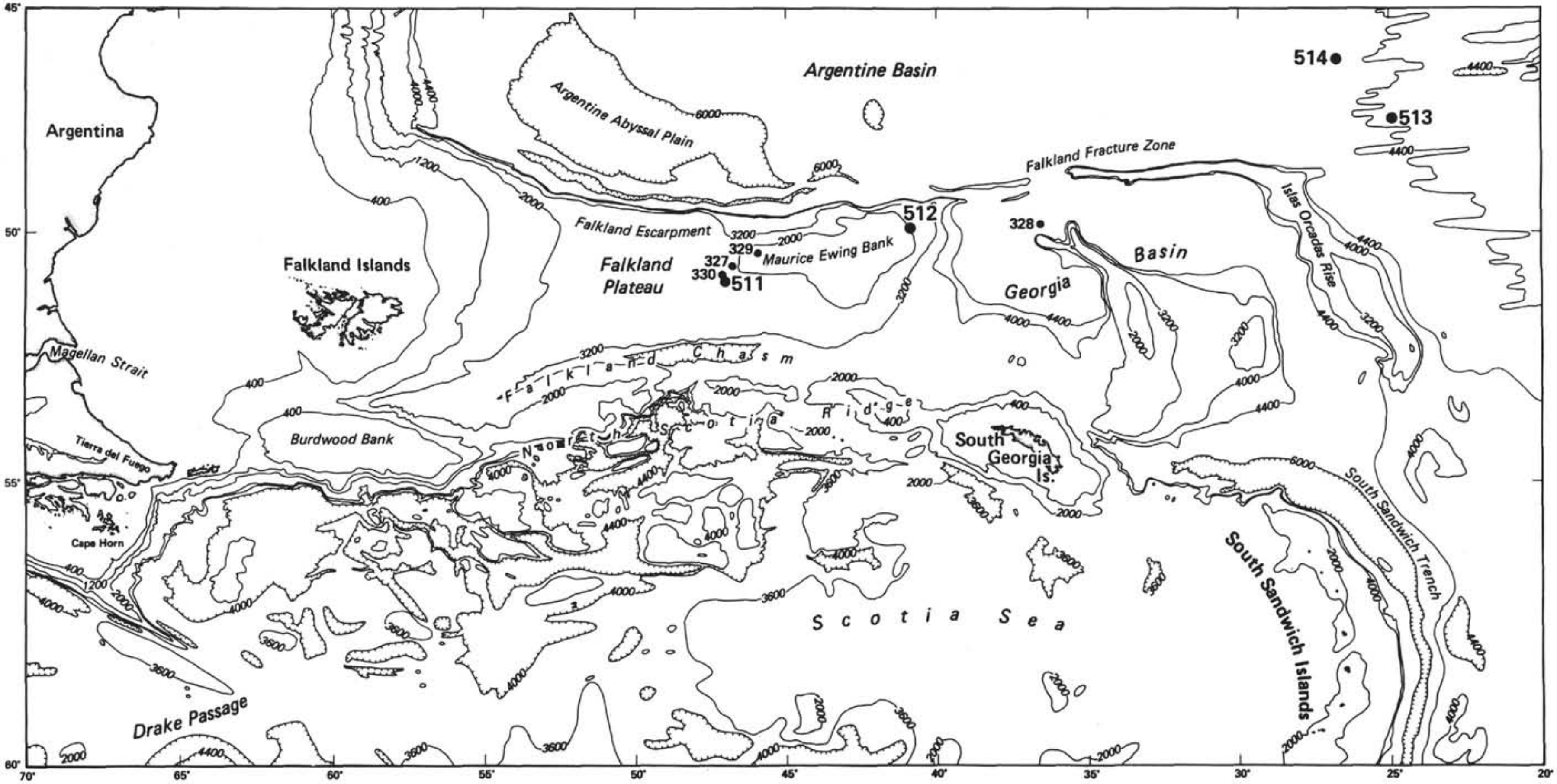

Figure 1. Location map of Leg 71 sites.

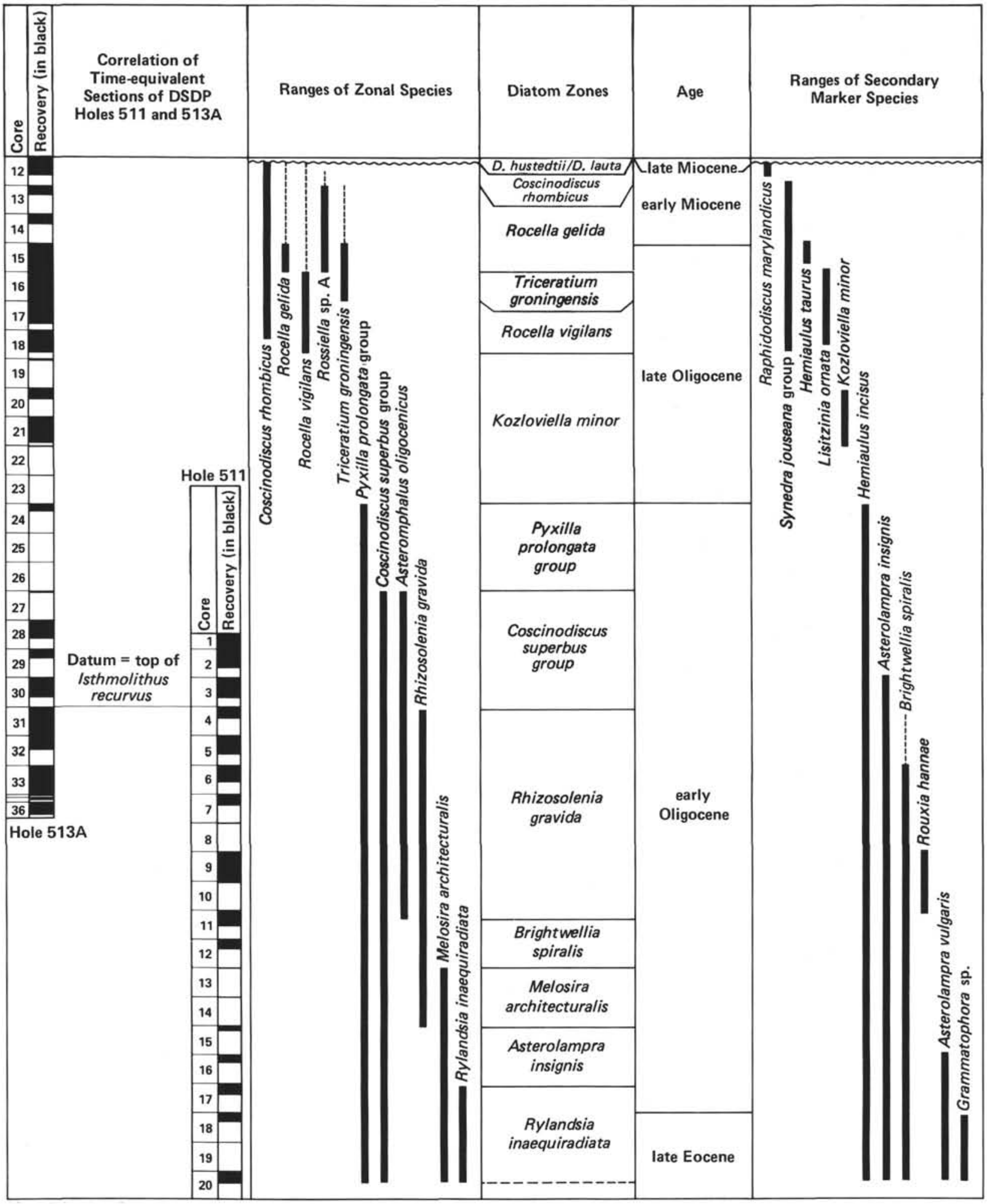

Figure 2. Correlation of Holes 513A and 511 showing zones described in text and ranges of zonal and secondary marker species.

represented by Fraction 2. We have found, through experience, that by observing only those slides prepared from unsieved residue we often failed to detect, or detected only after extensive examination of the slide, important marker species that were subsequently observed in preparations of sieved material. Failure to detect such forms in strewn slides of unsieved material may be due to obfuscation or dilution by fine material such as clay particles, reduced relative abundance resulting from preservational phenomena such as dissolution, or naturally low relative abundances such as would be expected at either end of a species evolutionary range.

Sieving artificially concentrates less abundant large forms and thus enables us to arrive at a more complete understanding of the qualitative aspects of the total floral assemblage. Since the purpose of this study is to determine the biostratigraphic ranges of the various species, we have examined the sieved material to increase the precision by which the highest and lowest stratigraphic occurrences of certain species can be determined.

Examination of sieved material also enhances detection of subtle abundance variations within lineages that might otherwise go undetected. An example of this is illustrated in Figure 3, in which abundance changes observed for three species of the genus *Rocella* are plotted against depth in Hole 513A. Marked changes in abundance are noted for all three species. Such abundance changes may serve as useful stratigraphic datums, at least regionally. Identification of rare sporadic occurrences of some species above their highest abundant occurrences may also indicate reworking.

Age	Hole 513A Core	Section	Sample Interval in cm
late Miocene	12	1	9-11
		1	12-14
early Miocene		1	123-125
		2	128-130
		2	131-133
		3	32-34
		3	99-101
		3	102-104
		4	44-46
		4	122-124
		4	125-127
	13	0	5-6
		1	18-20
		1	67-69
		2	17-19
		2	78-80
		CC	
	14	1	27-29
		1	77-79
		2	92-94
		2	129-131
		6	50-52
late Oligocene	15	1	21-23
		1	132-134
		2	46-48
		3	38-40
		4	35-37
		4	131-133
		5	40-42
		5	125-127
		6	29-31
		6	106-108
		7	55-57
	16	1	23-25
		1	109-111
		2	26-28
		3	23-25
		4	57-59
		5	35-37
		5	112-114
		6	34-36
		7	12-14
	17	1	96-98
		2	15-17
		3	115-117
		4	21-23
		5	115-117
	18	1	17-19
		2	70-72
		2	143-145
		3	70-72
		4	70-72
		4	143-145
		5	64-66
	19	1	34-36
	20	1	88-90
		2	84-86
		3	44-46
	21	1	70-72
		2	76-78
		3	70-72
		4	76-78
		5	70-72
		6	41-43
	22	CC	
	24	1	16-18

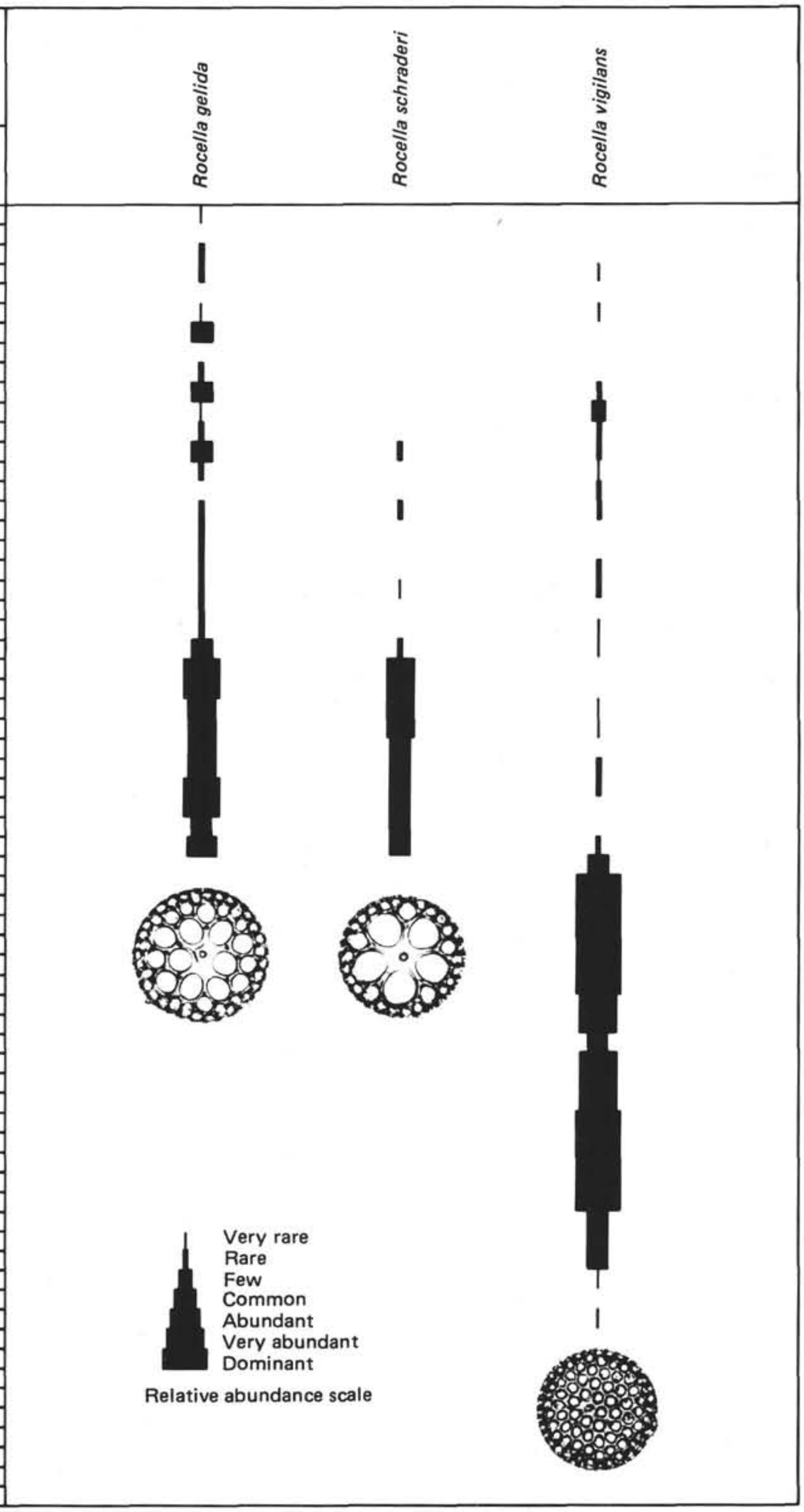

Figure 3. Ranges and abundances of three species of *Rocella* in Hole 513A.

We found that detection of smaller diatom species such as *Melosira architecturalis* and some species of *Sceptroneis, Grammatophora,* and *Pterotheca* was not improved by examination of slides prepared from Fraction 3, since those species are in no way concentrated by the sieving process. We therefore used slides prepared from unsieved material for determining the relative abundances of these and other small species.

In order to construct our range and abundance charts (Figs. 4–5), we observed the following procedure, with variation as noted. On one slide of the unsieved residue, two traverses were made at ×400 (higher magnifications were employed when necessary for identification). Counts of each species were recorded per field of view. The same procedure was followed for one slide prepared from Fraction 2. Ciesielski elected to scan the slide of Fraction 2 at ×600 magnification, thus reducing by about 20% the area of the cover slip which would have been observed at ×400. Considering the variability in sample density from slide to slide such a difference was considered insignificant. The absolute counts thus obtained were then converted into the relative abundance categories shown in Table 1, and plotted on the range charts (Figs. 4–5).

After making counts during two traverses we routinely made five additional passes; any species found during these additional traverses were included in the category of very rare. Two or three traverses of Fraction 1 were made by Gombos and any species observed in that fraction but not observed in Fraction 2 were categorized as very rare.

LOWER MIOCENE TO UPPER EOCENE DIATOM ZONES FOR THE SOUTHWEST ATLANTIC OCEAN

Twelve diatom biostratigraphic zones are proposed for the composite lower Miocene to upper Eocene section recovered in Cores 12 through 33 of Hole 513A and Cores 1 through 20 of Hole 511. Because the biogeographic distribution and ecologic affinities of the zone-index species employed in this zonation are not well defined, the proposed zonation should be used with caution outside the Southwest Atlantic region. General age relationships of the diatom zones are based on age determinations inferred from foraminifer, calcareous nannofossil, and radiolarian zones identified in the cores by shipboard scientists (Figs. 6–7).

To define the zones, species were chosen which met one or more of the following criteria: distinctive morphology (to minimize ambiguity); sufficient abundance (in moderately to well-preserved assemblages) to permit detection without excessive time expenditure; robust or heavily silicified valves that are dissolution resistant so it may reasonably be expected that the diatoms will be preserved in otherwise poorly preserved assemblages; and known occurrences (from published reports) in other Atlantic cores.

Table 1. Abundance categories used in this chapter.

Specimen Counts[a]	Category	Symbol
1	Very rare	VR
2–5	Rare	R
6–10	Frequent	F
11–50	Common	C
51–100	Abundant	A
101–500	Very abundant	VA
501–1000	Dominant	D

[a] Based on counts per field of view during two traverses of 22 × 22 mm cover slip at ×400 of one slide of unsieved material and one slide of Fraction 2 (38–63 μm). (See text for detailed discussion.)

DEFINITION OF DIATOM ZONES

The following zonal definitions are presented in the order youngest to oldest. Figure 8 presents a graphic summary of the zones and definitions.

Coscinodiscus rhombicus Partial-Range Zone

Definition. The top of this zone is defined as the highest occurrence of *Coscinodiscus rhombicus;* the base of the zone is defined as the highest occurrence of *Rossiella* sp. A.

Reference section. Sample 513A-12-1, 123–125 cm to 513A-12-4, 44–46 cm.

Age. Early Miocene

Discussion. Even though the highest occurrence of *Coscinodiscus rhombicus* in Hole 513A was observed in Sample 513A-12-4, 44–46 cm, the top of the zone is placed higher in the hole in Sample 513A-12-1, 123–125 cm or at the early Miocene/late Miocene unconformity (see Fig. 5), because Weaver and Gombos (in press) have shown that *C. rhombicus*, in high southern latitudes, ranges nearly to the early Miocene/middle Miocene boundary. Weaver and Gombos (in press) have furthermore demonstrated that this species exhibits a dramatic decrease in abundance over the middle part of its range, where it is very rare. We assume the rare and sporadic occurrence of this species in Hole 513A, Core 12 represents a portion of the low-abundance part of its range and that the more abundant terminal portion of the range is not present because of the unconformity in the upper part of Core 12.

Rocella gelida Concurrent-Range Zone

Definition. The top of this zone is defined as the highest occurrence of *Rossiella* sp.; the base is defined as the lowest occurrence of *Rocella gelida.*

Reference section. Sample 513A-12-4, 122–124 cm to 513A-15-7, 55–57 cm.

Age. Late Oligocene to early Miocene

Discussion. In Hole 513A the highest occurrence of *Rossiella* sp. is assumed to be represented by the last consistent occurrence of that species in Sample 513A-12-4, 122–124 cm. A single occurrence of *R.* sp. in Sample 513A-12-2, 128–130 cm is presumed to have resulted from reworking.

Triceratium groningensis Partial-Range Zone

Definition. The top of this zone is defined as the lowest occurrence of *Rocella gelida;* the base is defined as the lowest occurrence of *Triceratium groningensis.*

Reference section. Sample 513A-16-1, 23–25 cm to 513A-16-7, 12–14 cm.

Age. Late Oligocene

Rocella vigilans Partial-Range Zone

Definition. The top of this zone is defined as the lowest occurrence of *Triceratium groningensis;* the base is defined as the lowest occurrence of *Rocella vigilans.*

Reference section. Sample 513A-17-1, 96–98 cm to 513A-18-5, 64–66 cm.

Hole 511 Core/Section (interval in cm)	*Asterolampra acutiloba*	*A. affinis*	*A. gradiata*	*A. grevillei*	*A. insignis*	*A. marylandica*	*A. punctifera*	*A. schmidtii*	*A. tela*	*A. vulgaris*	*A. vulgaris* v. *hyalina*	*Asteromphalus oligocenicus*	*Baxteria brunii*	*Brightwellia coronata*	*B. hyporea*	*B. spiralis*	*Coscinodiscus spiralis*	*C. bulliens* v. 1	*C. excavatus* v. *tuberosa*	*C. marginatus*	*C. superbus* group	*Craspedodiscus moelleri*	*Entogonia* (fragments)	*Ethmodiscus rex* (fragments)	*Goniothecium odontella*	*Grammatophora* sp.	*Hemiaulus caracteristicus*	*H. incisus*	*H. pacificus*	*H. reflexispinosus*	*H.* sp.	*Hyalodiscus* sp.	*Melosira architecturalis*	*Pseudopyxilla dubia*	*Pseudorutilaria monile*	*Pseudotriceratium chenevieri*
1-1, 140-142																																				
1-2, 71-73																																				
1-3, 132-134		VR			C		R	C												VA	C				VR		VR	R	C					VR		R
1-4, 16-18		VR	VR	VR	C			C	VR					VR					VR	VA	R	VR		C	VR			R	C					VR		R
2-1, 101-103		F			C	VR		C												VA	C			C	VR		R	F	C		VR		VR			R
2-2, 101-103		R			C	VR		C		VR		R				VR		VR		VA	C	VR	VR	C	R		R	R	C				VR	R		C
2-3, 101-103		C			C	VR		F												VA	F		VR	C	VR			R	C					R		R
2-4, 21-23		R			C			F				R								VA	C	VR		C	R		R	R	C				R	VR		F
3-1, 67-69		R		R	C	VR	F	F				R				VR				VA	VA		VR	C	VR			C	C	VR				VR		R
3-2, 67-69		F			C		F	C		VR		R				VR				VA	VA		R	C	R		VR	C	C							C
3-3, 67-69	VR	R			C		F	F				R				VR				C	VA			C	VR			C	F	VR						R
3-4, 67-69		R			F	R		F				R								A	VA	VR		C			R	R	R				VR			R
4-1, 10-12		R			F			C				VR								A	VA	VR	VR	C				R	R							R
4-2, 10-12		R			F			F				R								A	VA	VR	VR	C			R	R	R		VR					F
4-3, 10-12		R			F		R	F		VR		F				VR				VA	VA		VR	C				R	VR							
5-1, 10-12		R			C			F				R				VR				VA				A	R		VR	C	R	VR						
5-2, 10-12		R	R		A			C		VR		R				R				VA	C			C			R	C	R							
5-3, 10-12		R	R		C			R	R			R				VR				VA	VR			C	VR		R	C	R							R
5-4, 10-12		R		VR	C			R				R								A			VR	C	VR			C	R							R
5-5, 15-17		C	VR		C		R		VR			F								C		VR	VR	C	R		R	C	R	VR		VR	VR			R
6-1, 23-25		R			C		R				R	R				R				VA				C	VR		VR	C	R							F
6-2, 23-25					C					VR		R				R	VR			C	C			C	VR		R	C	R			VR				
6-3, 23-25	R	VR			C					VR						R				VA							R	C	R							
7,CC			R		C							R				R				C							F	F	R							
8,CC		R			C							R				R				C					VR		R	F	R							
9-1, 111-113				VR	C	VR			R							R				C	A				R		C	A	R	R	VR					
9-2, 82-84	R	R	R		F											R				C	VA						C	A	F							
9-3, 82-84		R	VR		R											R				C	C				VR		C	C	F	VR			VR			
9-4, 82-84	R	R			C				R			R			VR	R				C	VA						C	C	F							
9-5, 82-84		R	R		F	VR			VR			VR				R				C	A	VR			R		C	C	F							R
9-6, 82-84					C				VR			VR				F				C	A				VR		C	C	R							
9-7, 32-34		R			F		R		R	VR						F				C	A						C	C	R		VR					
10-1, 11-13		R			F				VR			VR				R				C	A				VR		A	C	R					VR		R
11-1, 30-32		R			R	R						VR				F				C	A			R	R		C	C	VR			VR		VR		
11-2, 30-32		R			R							VR				R			VR	C	VA			R			C	C					R			
11-3, 30-32		R	VR		R				VR		VR				VR	F				C	C			R	VR		C	C	R			VR	VR			
11-4, 6-8		C	VR		C				VR							C				C	A			R			R	C	R							
12-1, 11-13		R	F		R				F	VR		VR	VR			VR				C	VR						C	A	R			VR		R		
12-2, 11-13		R	F		R				F							R				C	F						A	C	F				R			
13-1, 6-8		R	R		R		VR		R				R			R				C					R		C	C	F			R	C	VR		
15-1, 13-15		R			R				F	VR					VR	R	VR			A	VR		VR		VR		C	F	R			F	C			
16-1, 22-24		R			R					R			VR		VR	R	R			C	F			C	VR		F	R	VR			VR	C			
16-2, 22-24		R			R					R						R		R		A	VR		R	C	R		F	F	VR		R	R	C	VR		R
17-1, 83-85		R			VR					R			VR			R				A	R		VR	A	F		R	C		VR	R	VR	C			
17-2, 83-85		R								R						R				A	F	VR	VR	C	R		R	R		VR	R		C	VR		
17-2, 102-104		R			R					R			R			R				C	F	VR	VR	C	R		VR	R	VR		R		C		VR	
17-3, 7-9		R								VR						R				A	C		VR	C	R		R	VR		VR	R	VR	C	VR		R
17-3, 22-24		F			R					R			F			R				A	A		R	C	R		C	R				R	C	VR		
18-1, 21-23					F					R						VR				VA	R		R	C	R		C	R				VR	A			
18-1, 40-42		R			R					R			R			R	R			VA	C			C	R		C	F			VR	VR	C			
18-2, 21-23		R			F					F						R		VR		VA			R	C	C	R	C	R				R	C	R		R
18,CC		R			R					R			VR			R				C	R	VR		C	R	F	C	C				R	C			
20-1, 23-25		C			F					C						F				C				C	R	F	F	R				VR	C	VR		C
20-2, 23-25		F			R					C			C		VR	R		R		C	R	VR		C	F	F	C	F	R	VR		R	C	R		F
20-3, 23-25		R			R					F			R			F				C	F		VR	C	VR	F	C	C				R	C			F

Figure 4. Stratigraphic distribution and relative abundances of diatom species in Hole 511. (VR, very rare; R, rare; F, frequent; C, common; A, abundant; D, dominant.)

Age. Late Oligocene

Discussion. For this zonation the lowest occurrence of *Rocella vigilans* is considered to be represented by the lowest common occurrence of the species. In Hole 513A very rare and sporadic occurrences of *R. vigilans* were observed as low as 513-20-20, 84–86 cm, but we believe that the lowest common occurrence of *R. vigilans* is a more readily detectible datum.

Kozloviella minor Interval Zone

Definition. This zone corresponds to the interval between the lowest occurrence of *Rocella vigilans* and the highest occurrence of *Pyxilla prolongata* group.

Reference section. Sample 513A-19-1, 34–36 cm to 513A-22,CC.

Age. Late Oligocene

Discussion. In Hole 513A, the range of *Kozloviella minor* is entirely within this zone.

Pyxilla prolongata Partial-Range Zone

Definition. The top of this zone is defined as the highest occurrence of *Pyxilla prolongata* and related *Pyxilla* species (see taxonomic section); the base is defined as the highest occurrence of the *Coscinodiscus superbus* group (see taxonomic section).

Reference section. Sample 513A-24-1, 16–18 cm to 513A-25,CC.

Age. Early Oligocene

Discussion. The extinction of *Pyxilla prolongata* and other *Pyxilla* species was used by Gombos (1977) and Schrader (1976) to define the Oligocene/Miocene boundary in Holes 328B and 278, respectively. Jousé (1979) and this study indicate that *P. prolongata* and related species do not range beyond the early Oligocene/late Oligocene boundary. Inadequately dated core material and undetected unconformities probably led to the misinterpretation of this datum in Holes 328B and 278. A

P. radiosoreticulatum	*Pterotheca aculeifera*	*P. danica*	*P. danica* (elongate variety)	*P. major*	*P. spada*	*Pyrgupyxis eocena*	*Pyxilla prolongata* group	*Rhizosolenia gravida*	*R. praebarboi*	*Rouxia granda*	*R. hannae*	*Rylandsia biradiata*	*R. inaequiradiata*	*Sceptroneis grunowii*	*S. ligulatus*	*S. pesplanus*	*S. tenue*	*Stephanopyxis eocenicus*	*S. hyalomarginatus*	*Stictodiscus novae zealandicae*	*Thalassiosira hydra*	*Triceratium macroporum*	*T. macroporum* (concave form)	*Triceratium unguiculatum* group	*Trinacria excavata*	*T. excavata* f. *tetragona*	*T. simulacrum*	Genus and species uncertain #1	Genus and species uncertain #2	Genus and species uncertain #3	Diatom Zones	Age
																																Quat.
		VR	VR	VR	VR	R	VA		R						R							R		C	C		VR					
		R	R		VR	R	VA		VR						R			F	F			R		F	C		VR		VR			
R		F	R	VR	R	VR	D		R						F			C	F		VR	R		C	C		VR		F			
		F	R	VR	R		VA		R						F			C	C		R	R		C	C		R					
		R	VR	VR		VR	VA		R						R			C	F		R			C	F		R		VR			
VR		R	R	VR	R	VR	VA		VR						R			C	F		R	R	R	C	F		R				*Coscinodiscus superbus*	
		R	VR		VR	R	VA		R						R			C	F		F	R		F	R		R					
R		R	R		R		VA								F			C	F		R	F	F	C	C		VR					
			R			R	VA		VR						R			R	R			R		C	R							
		VR	R	R	R		VA								VR			R	R		F	R	VR	R	R		VR					
		VR	VR		R		VA		R						R			R	R		R			R					VR			
		R	VR	VR		R	D		R						F			R	F		C	R	VR	F	F		VR		R			
						R	D								R			R	R		VR	R		R	R		VR					
VR		VR				VR	VA	R	R						F			R	R		C	R		C	R				R			
VR		R					VA	R	R						F				R		F	VR		C	R				F			
		R	VR				VA	R	R						F				R		F	R		C	F		VR		VR			
		R					VA	R	R						R						C			C					R			
			VR		VR		VA	R	C					R	F	R					C	R		C	R		VR					
		VR					VA	R	C						R						F	VR		A	R				F			
VR		VR		VR			VA	F	VA	VR					R	F		R	R		C	R	R	C	C		VR		R			
		R				VR	VA	R	VA						R						C	R		C	R				R			
							VA	R	C						F						F		R	C	F		R				*Rhizosolenia gravida*	early Oligocene
		VR					VA	R	F						R						F	R		C	VR		VR					
VR		R	VR	VR			VA	F	VA		VR			R	R				VR		C	R	R	F	R				R			
		VR		VR			VA	C	VA						VR						C		R	C	F				R			
		R	VR	VR			VA	F	VA		VR			VR	R						F	R	VR	R	VR		VR		VR			
				R			VA	C	VA						R						C		R	R	R				VR			
		R					VA	F	VA					VR	R				VR		F	VR	R	R	R							
				VR			VA	A	VA						R						C	VR	R	C	R				VR			
R		VR	VR	R			VA	C	C		F			R	R		R				R	VR	R	F	R							
		R					VA	C	C						C						F	C	C	F	F				R			
R		R	VR	VR			VA	F	C		VR				VR		VR				R	R	F	F	R							
			VR				VA	F	C		R				R						F	R	R	F	R							
R		VR		VR			VA	C	C					VR	R		VR				C	R	F	F	R						*Brightwellia spiralis*	
		R	VR	VR			VA	F	A						R							R	F	F	VR		VR					
R		VR	VR				VA	R	C					VR	R		VR				R	R	R	F	VR					R		
C							A	C	F												VR	R	R	C	R							
		F	VR				VA	R	R								R				VR	F	R	R	VR		R		R		*Melosira architecturalis*	
R		F	R	VR			VA	VR							R							C		F	R		VR	R	R			
VR	VR	R	R				VA		C			VR		VR	F		F					VR		R		VR		VR				
		R	R				VA		F						R					VR		R		R	C	VR	C	VA			*Asterolampra insignis*	
		F	R	R			VA		F	R			R		VR		VR					R		VR			C			R		
		R	R	R			VA		F				F		VR							R			R		R		VR	F		
		R	VR				VA		R				VR	F	R							F		R	VR		R		VR	R		
		VR	R	R		VR	VA		R				VR		VR							VR		VR			R		R	R		
		F	R	VR			VA		F	R				VR	R		R					R		F	R		F		R	R	*Rylandsia inaequiradiata*	
		R	VR				VA		R						VR							VR			R	VR	C	VA	VR			
VR		R	R	R			VA		C					VR	C							VR		R	VR			R				
		F	VR				VA		R				R		R							R		R	C		C	VA				
VR			F				VA		R						F		C					F		F	R		F	VA	VR	R		late Eocene
		VR	R				D		R	F					R							F		R			R					
	VR	R	VR	VR		VR	D		VR	F			R		R		R					R	VR	R			F	VR				
		F					D		R	F					C		F					R		F	VR	VR	C	R	VR			

Figure 4. (Continued).

more detailed discussion of this historical problem is given in Weaver and Gombos (1981).

Coscinodiscus superbus Partial-Range Zone

Definition. The top of this zone is defined as the highest occurrence of the *Coscinodiscus superbus* group (see taxonomic section); the base is defined as the highest occurrence of *Rhizosolenia gravida*.

Reference section. Sample 513A-26,CC to 513A-30-5, 5–7 cm.

Age. Early Oligocene

Rhizosolenia gravida Concurrent-Range Zone

Definition. The top of this zone is defined as the highest occurrence of *Rhizosolenia gravida;* the base is defined as the lowest occurrence of *Asteromphalus oligocenicus*.

Reference section. Sample 511-5-1, 10–12 cm to 511-11-2, 30–32 cm.

Age. Early Oligocene

Brightwellia spiralis Interval Zone

Definition. This zone is defined as the interval between the lowest occurrence of *Asteromphalus oligocenicus* and the highest occurrence of *Melosira architecturalis*.

Reference section. Sample 511-11-3, 30–32 cm to 511-12-1, 11–13 cm.

Age. Early Oligocene

Melosira architecturalis Partial-Range Zone

Definition. The top of this zone is defined as the highest occurrence of *Melosira architecturalis;* the base is defined as the lowest occurrence of *Rhizosolenia gravida*.

Reference section. Sample 511-12-2, 11–13 cm to 511-15-1, 13–15 cm.

Age. Early Oligocene

Discussion. Rare and sporadic occurrences of *Melosira architecturalis*, a small and easily reworked species,

Hole 513A Core/Section (interval in cm)	Actinoptychus splendens	A. undulatus	Asterolampra affinis	A. insignis	A. punctifera	A. schmidtii	A. tela	A. vulgaris	A. vulgaris v. hyalina	Asteromphalus oligocenicus	A. symmetricus	Brightwellia spiralis	Cestodiscus pulchellus	C. sp.	Coscinodiscus apiculatus	C. deformans	C. endoi	C. marginatus	C. nodulifer	C. praenitidus	C. rhombicus	C. superbus group	Denticulopsis dimorpha	D. hustedtii	D. lauta	Dicladia sp.	Ethmodiscus rex (fragments)	Hemiaulus caracteristicus	H. incisus	H. polymorphus	H. polycystinorum	H. taurus	Kozloviella minor	Lisitziana ornata	Melosira architecturalis
12-1, 9-11		R														R	R	A	VR				VA	C	C		C								
12-1, 123-125																	R	C									F								
12-2, 128-130			R				R											VA									F								
12-3, 32-34																		C									F								
12-3, 99-101							R						R				R	VA	VR								F			R					
12-4, 44-46															R			A	VR		R						F								
12-4, 122-124											R		R				R	A									F			R					
13-0, 5-6			F								F		F					VA									C			VR					
13-1, 18-20			C				R				F		R					D			R						C			VR					
13-1, 67-69											R		VA					VA									C								
13-2, 17-19											F							VA									C			R		VR			
13-2, 78-80			A				C				F							VA			F						C					VR			
13,CC,			C				R				F							VA			R						C								
14-1, 27-29			VR								R		R					VA		F							C					VR		VR	
14-1, 77-79							R				R		R					VA									C					R			
14-2, 92-94			VR				R				VR							VA									C					R			
14-2, 129-131							R				VR		R					VA		C							A					R			
14-6, 50-52			VR	VR			R				R							VA									A					C			
15-1, 21-23			C				R						C					A									C					C			
15-1, 132-134			C				VR				VR		VR					A			VR						C					F			
15-2, 46-48			A				VR				VR							A	VR								C					F			
15-3, 38-40			A				R				VR		R					VA			VR						C					C			
15-4, 35-37			C				F				R		R					A			VR						C					C			
15-4, 131-133			C				R						VR					VA									C		VR			C			
15-5, 40-42			C				F						F					A		F							F					C		VR	
15-5, 125-127			C				R											VA			VR						F					C			
15-6, 29-31			C										F					A		C	R						C					F			
15-6, 106-108			C				R											D			C						F					F			
15-7, 55-57			F				VR				R		VR					VA			F						A					F		VR	
16-1, 23-25		C	F								VR		F					C			C						C							F	
16-1, 109-111			F															C			C						C							C	
16-2, 26-28			F															C			C						C					VR		C	
16-3, 23-25		R	C										R					A			C						F					R		F	
16-4, 57-59		R	C															A			R						C					R		F	
16-5, 35-37		R	C										F					C			C						C							F	
16-5, 112-114			C										R					C			F						F							VA	
16-6, 34-36		C	C								R							A			R						F			VR				A	
16-7, 12-14		R	R															A			C						F		VR					A	
17-1, 96-98			C				C						R					C									C							C	
17-2, 15-17			C				VR						VR					VA			R						F							R	
17-3, 115-117			R				VR						R					R									F					R		C	
17-4, 21-23		R											R					C									C			VR		R		VA	
17-5, 115-117			R				F						R					C									C					R		C	
18-1, 17-19		VR	VR															C		R	R						C					R		VA	
18-2, 70-72			R															A			C						F					VR		VA	
18-3, 70-72			R															VA		F							F					VR		VA	
18-4, 70-72			VR								VR		VR					C		F							C			VR				C	
18-4, 143-145			VR															A									F							A	
18-5, 64-66			R															VA									F					R		VA	
19-1, 34-36			C										F					C									F								
20-1, 88-90			F															VA									F								
20-2, 84-86																		VA									F						C		
20-3, 44-46		R									R		C					C									C						R		
21-1, 70-72			R															C									F						R		
21-2, 76-78			VR															A									F						C		
21-3, 70-72																		A									F								
21-4, 76-78		R																VA									R								
21-5, 70-72		R	R															VA									F						R		
21-6, 41-43			R										VR					F			F						F						R		
22,CC																		C									C						VR		
24-1, 16-18																		R																	
24-2, 27-29																		C									F		R						
25,CC	VR		VR			R							VR					A		C							F		R						
26,CC			R		R	C	VR						F					VA				C					A		C	F	VR		VR		
27-1, 17-19						R	R											D									F		R						
28-1, 20-22			R		R	A	R											VA				VA					F		F	VR					
28-2, 38-40						C	C											VA				A					A		F	VR					
28-3, 31-33					VR	R												VA				C					C		R						
28-4, 135-137					R	C												C				VA					C		F	VR					
29-1, 80-82					R	C		VR	VR									A				D					A		F						
29-2, 97-99		VR				R												C				D					C		VR	VR					
30-1, 42-44			VR	R		VR												VA				D					C		F						
30-2, 29-31		C																D				VA					C			R	R				
30-3, 30-32		C				VR												D				VA							C		F	R	C		
30-4, 36-38			R	R			C											D				VA							VR		C				
30-5, 5-7		C	F	R		A	VR											VA				VA					C		VR	C	VA				
31-1, 105-107			VR	R			R											VA				VA					R		F	C	VA				
31-2, 21-23		C	R	F			VR											VA				C					C		C	C	VA				
31-3, 105-107			R	F			VR											VA				F					C		F	C	VA				
31-4, 21-23		F		F														VA				R					C		F	C	A				
31-5, 105-107				VR														VA									F		R	C	A				
31-6, 18-20		C	VR	F			VR											VA				VR					C		C	C	VA				
31-7, 21-23			R															VA				C				VR			R	R	A				
32-1, 5-7				R										VR				R				R							F	C	F				
32-1, 130-132		VR	VR	R										R				R											C	F	C				
32-2, 68-70		R		VR														C				VA							R	R	C				
32-3, 68-70				R	VR							VR		R				R											C	F	C				
32-3, 124-126		VR			R			VR						VR				R				VA							C	C	A				
33-1, 132-134		R	R		VR									A				VA											C	F	C				
33-2, 138-140			R	C	R							F		VA				VA											A		C				VR
33-3, 132-134			R	VR	VR							R		VA				VA								VR		VR	C	C	VA				
33-4, 138-140				VR								VR		VA				A											R		A				
33-5, 132-134				VR										VA				A											C	A	A				
33-6, 138-140			VR	F	R									VA				VA									C		C						
33-7, 61-63				R										VA				A											F						R

Figure 5. Stratigraphic distribution and relative abundances of diatom species in Hole 513. (VR, very rare; R, rare; F, frequent; C, common; A, abundant; D, dominant.)

Navicula bendaensis	N. udintsevii	N. maleinterpretaria	Pleurosigma (fragments)	Podosira polita	Pseudodimerogramma filiformis	Pseudotriceratium cheneveri	Pyxilla prolongata group	Raphidodiscus marylandicus	Rhizosolenia gravida	R. praebarboi	R. styliformis	Rocella gelida	R. vigilans	Rossiella sp.	Rouxia granda	R. obesa	Sceptroneis facialis	S. pesplanus	S. pupa	S. tenue	Total S. spp. and fragments	Skeletonema barbadense	Stictodiscus sp.	Synedra jouseana	S. miocenica	Stephanopyxis spp.	Thalassiosira primalabiata	Triceratium groningensis	T. groningensis f. quadrata	T. macroporum	T. unguiculatum group	Diatom Zones	Age
											R	VR											VR	R								D. hustedtii/D. lauta	l. Miocene
		R										F												F									
		C						F			R	R	VR	R										C	R	R							
								R				R	VR											F									
		C						C				C												C		VR						Coscinodiscus rhombicus	
		C					VR	F				C												C		F							
			R					F				C	R	R									VR	C	R	R							
										R		R	R	C										C	F	F		R					
		VR								F		C	R	VA							F		C	C	C			R					
			R							F		R	R	A									C	F	F								
						C				R				A							F		C	VA	A								
			R							F		R	R	VA									C	C	C								early Miocene
			R		VR			VR		F		F		A									C	A	C								
			R			VR				F		R		VA									F	VA	C	F	F	VR					
			R			VR				F		R		VA									C	A	C		C						
			R			R				F		R		VA									C	A	C		C						
			VR			R				R		R		VA									R	VA	R	R	R	VR				Rocella gelida	
			F			R				C		R		VA									C	A	C		R						
			F							R		C		C									C	C	C		C	F	R				
			R							R		VA		C									C	C	C		R	F	VR				
			F							R		VA		C									C	C	C	F	C	C	VR				
			R							C		A	VR	C									C	A	C		C	C	VR				
			R							F		C	VR	C									C	A	C	F	C	C	C				
			C							F		A		C									C	A	C		C	C	VR				
			F							C		C	F	F									C	A	C	C	C	C	VR				
			R							R		VA	R	R									F	A	C		F	C					
			F							F		A		F									C	A	C	F	C	C					
			F							R		A		F									C	A	C		C	VA					
			C									A	R										VR	A	A		C	VA					
			F							F			A										F	A	C	F	F	C					
			R										D											A	C		R	R					
			R										D										R	A	C		VR	C					
			VR							R			D										R	VA	C	R		C					
										VR			D										R	A	R	R	C	R					
										R			A	VR									R	A	C		C	R				Triceratium groningensis	
			R							VR			D										F	A	C		R	C					
			VR							F			VA								R		R	VA	F	A	F	C					
										R			VA											A	R	VR	C	C			VR		
										R			C										A	A		R							
						VR				C			VA										VA	A	A	R					VR		
													VA										C	C		R							
										R			VA									R	VA	C	C	R							
						R				R			D											A	A		R						
										R			D										VR	VA	A	C	R				VR	Rocella vigilans	late Oligocene
						F							VA										VR	C	C	C	VR						
										VR			VA											VA	C	F	R						
										VR			C										F	C	C	C					VR		
													C										R	C	C								
													C										VR	C	C	C							
													VR										R	C	C								
						R				VR														D	D	F							
						VR				R			VR											VA	VA	R							
						R			VR	R														A	A	F	R						
										R														D	D	C	VR						
						R				R														C	A		R					Kozloviella minor	
																								A	A	C							
						VR				VR														A	A		R						
						R																		VA	VA	C	R						
										VR														C	A		R						
									VR	R														C	R								
							R																										
							R			R																						Pyxilla prolongata	
							F																										
										R						VA									VR	R							
										R																							
										R					VR																		
										VR					F																		
										VR					R																		
							VR			R					R																	Coscinodiscus superbus	
							VR			C					R																		
										F																							
							R			F																							
							VR			VR																C							
								R		VR	F										VR					F					VR		
							R			R																							
							R			F											VR					C					VR		
							F		R	R						VR																	
							F		C	F						VR			F	C	A					A					R		early Oligocene
									F	R								F	F														
	R						VR		F	R								F	F	C	A					C							
									R	VR								R	F														
C	VR								R	F								F	F	A	VA					C				VR			
									R	R								F	VR	F	F					C							
	VR								R	VR									F	C	C					C							
									VR	VR								F	F	C	C					C							
									F	R								F		C	R					F						Rhizosolenia gravida	
R									R	C					R					R										VR			
							R		VR	R									F		A					C					VR		
									VR	C								F		C	R					F							
									R	C										F		VR								R	R		
	VR			VR			R		R	F							F		VR		F	R				VA				R	R		
									R	C										F		VR											
	VR						C		F	R									VR		R	F				F							
	VR								R	F										F		C									R		
									VR	R												F									VR		

Figure 5. (Continued).

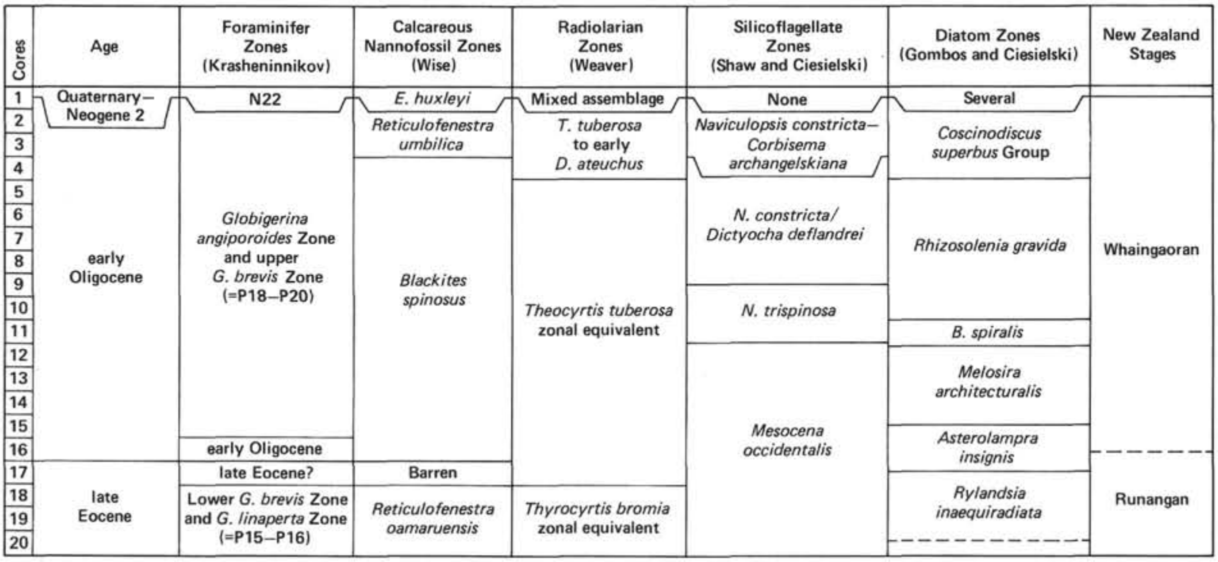

Figure 6. Age determination for Cores 1 through 20 of Hole 511 based on foraminifers (Krasheninnikov and Basov, this volume), calcareous nannofossils (Wise, this volume), and radiolarians (Weaver, this volume).

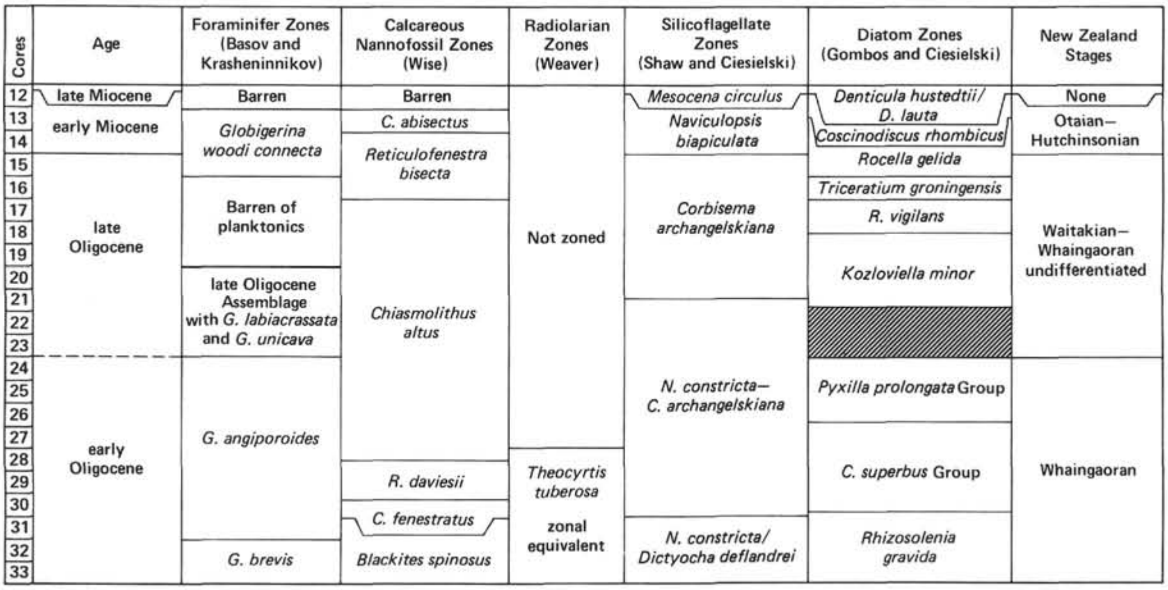

Figure 7. Age determinations for Cores 12 through 33 of Hole 513A based on foraminifers (Krasheninnikov and Basov, this volume), calcareous nannofossils (Wise, this volume), and radiolarians (Weaver, this volume).

were observed throughout the Oligocene section in Hole 511. The highest consistent occurrence of *M. architecturalis* was observed in Sample 12-2, 11–13 cm and is taken as the datum used to define the top of this zone.

Asterolampra insignis Interval Zone

Definition. This zone is defined as the interval between the lowest occurrence of *Rhizosolenia gravida* and the highest occurrence of *Rylandsia inaequiradiata*.

Reference section. Sample 511-16-1, 22–24 cm to 511-16-2, 22–24 cm.

Age. Early Oligocene

Rylandsia inaequiradiata Range Zone

Definition. This zone is defined as the interval between the highest and lowest occurrences of *Rylandsia inaequiradiata*.

Reference section. Sample 511-17-1, 83–85 cm to 511-20-3, 23–25 cm.

Age. Late Eocene to early Oligocene

Discussion. The occurrence of *Rylandsia inaequiradiata* in Hole 511 is generally rare and sporadic. Because cores below Core 20 are barren of diatoms, it is not possible precisely to identify the lower stratigraphic limit of this species in Hole 511.

Zone Names	Zonal Definitions
	Highest occurrence of *Coscinodiscus rhombicus*
Coscinodiscus rhombicus PRZ	
	Highest occurrence of *Rossiella* sp. A
Rocella gelida CRZ	
	Lowest occurrence of *Rocella gelida*
Triceratium groningensis PRZ	
	Lowest occurrence of *Triceratium groningensis*
Rocella vigilans PRZ	
	Lowest occurrence of *Rocella vigilans*
Kozloviella minor IZ	
	Highest occurrence of *Pyxilla prolongata* group
Pyxilla prolongata PRZ	
	Highest occurrence of *Coscinodiscus superbus* group
Coscinodiscus superbus PRZ	
	Highest occurrence of *Rhizosolenia gravida*
Rhizosolenia gravida CRZ	
	Lowest occurrence of *Asteromphalus oligocenicus*
Brightwellia spiralis IZ	
	Highest occurrence of *Melosira architecturalis*
Melosira architecturalis PRZ	
	Lowest occurrence of *Rhizosolenia gravida*
Asterolampra insignis IZ	
	Highest occurrence of *Rylandsia inaequiradiata*
Rylandsia inaequiradiata RZ	
	Lowest occurrence of *Rylandsia inaequiradiata*

Figure 8. Definition of zones proposed in this chapter. (PRZ = partial-range zone; CRZ = concurrent-range zone; IZ = interval zone; RZ = range zone.)

Despite its lower abundance relative to other zonal species used here, *R. inaequiradiata* was chosen to define our lowest zone because (1) it is a distinct species which is virtually impossible to confuse with its evolutionary predecessor *R. biradiata;* (2) it is generally possible to detect its presence in a slide preparation within 3 to 5 traverses of the cover slip at ×400; and (3) it is one of the few planktonic species we observed in Hole 511 whose range terminates just above the Eocene/Oligocene boundary.

COMPARISON WITH OTHER ZONATIONS

McCollum (1975), Schrader (1976), Gombos (1977), and Weaver and Gombos (in press) proposed diatom zonation schemes for Eocene to Miocene sediments cored at southern high-latitude sites. Figure 9 illustrates the correlation of the zones of those authors with the zones proposed in this report. Some of these correlations are discussed in the zonal definitions. Gombos (1977) proposed two zones for the interval in Hole 328B

This Chapter	Weaver & Gombos 1981	Gombos 1976	Schrader 1976	McCollum 1975
Coscinodiscus rhombicus	*Coscinodiscus rhombicus*			*Coscinodiscus* sp. 1
Rocella gelida	*Bogorovia veniamini*			
Triceratium groningensis		*Bogorovia veniamini*	*Bogorovia veniamini*	Not zoned
Rocella vigilans				
Kozloviella minor				
Pyxilla prolongata	Not zoned			
Coscinodiscus superbus		*Pyrgupyxis prolongata*	*Pyxilla* species	*Pyxilla prolongata*
Rhizosolenia gravida				
Brightwellia spiralis			Base not defined	
Melosira architecturalis		*Melosira architecturalis*		
Asterolampra insignis		Two lower zones not correlated (see text)		
Rylandsia inaequiradiata				

Figure 9. Correlation of previously proposed zones with those proposed in this chapter.

below the *Melosira architecturalis* Zone: the *Hemiaulus incisus* Zone and the *Pyrgupyxis eocena/Pterotheca aculeifera* Zone. The base of the *M. architecturalis* Zone and the top of the *H. incisus* Zone are coincident, defined by the last occurrence of *Stephanopyxis superba* v. *trispinosa*, which was very rare and sporadic in Hole 511. The base of the *H. incisus* Zone and the top of the *Pyrgupyxis eocena/Pterotheca aculeifera* Zone are coincident, defined by the last occurrence of *P. aculeifera*, a species which was observed in Hole 511 but not in the correlative interval in Hole 513A (see the following discussion). Because of the dubious nature of the datums used to define the two lowermost zones of Gombos (1977), it was not possible to correlate them with the zones proposed earlier.

COMPOSITIONAL AND ABUNDANCE CHANGES IN HOLES 511 AND 513A

Because Holes 511 and 513A are separated by about three and a half degrees of latitude (Fig. 1), the floral assemblages in the correlative early Oligocene interval of each hole were analyzed to determine the effect this separation may have had on the biogeographic distribution of diatoms at that time. Results of this analysis indicate that both holes have many species in common in the correlative interval. Six species found in Hole 511 were not, however, observed in Hole 513A: *Hemiaulus pacificus, Pterotheca aculeifera, P. danica, P. major, P. spada*, and *Thalassiosira hydra*. Conversely, two species found in Hole 513A were not observed in Hole 511: *Skeletonema barbadensis* and *Cestodiscus* sp. A. The possible significance of one of these compositional differences is discussed later; the others are presented as guidelines for future paleobiogeographic research.

Figures 10–14 illustrate relative abundance curves for *Rhizosolenia gravida, H. incisus, Coscinodiscus superbus* group, *Pyxilla prolongata* group, and *Pterotheca* spp. for the correlative interval in Holes 513A and 511. The curves are constructed from specimen counts made during our analysis of prepared slides, as described in the material and methods section earlier. Independent correlation between Hole 513A, Core 31 and Hole 511, Core 4 is based on the extinction of the calcareous nannofossil *Isthmolithus recurvus* (Wise, this volume). The curves were initially constructed to determine how closely diatom datums could be correlated between the two holes. Taking into consideration coring gaps and sample spacing, the curves illustrated in Figures 10–14 are closely comparable, thus corroborating the correlation of the two intervals.

An interesting discrepancy is revealed by the abundance curves for *Pyxilla prolongata* group (Fig. 13). Although the two curves are very similar in peak abundance, abundances in Hole 511 are generally an order of magnitude greater than those in Hole 513A. Reasons for this discrepancy are uncertain, but differential dissolution must be considered as a possible cause for the abundance differences, because sediments at Site 513 were deposited 1794 meters deeper than sediments at Site 511. However, *Pyxilla* species are rather robust and are assumed to be relatively resistant to dissolution. Also, the diatom assemblage in Hole 513A exhibits a high diversity and valves are moderately to well preserved throughout the hole, suggesting favorable preservational conditions.

Prominent in the list of major species differences between Hole 513A and Hole 511 that were observed in the correlative interval are species of *Pterotheca*. Because *Pterotheca* valves are completely hyaline and therefore present minimum surface area to exposure to seawater, they should be expected to be preserved and detected in an otherwise well-preserved assemblage, unless other factors are involved.

We speculate (see taxonomic section) that *Pterotheca* may represent resting spores of *Pyxilla*, but because both species are extinct, we cannot determine whether our speculation is valid or, if it is valid, what the relative proportions or conditions of resting-spore formation were.

If *Pterotheca* does represent resting spores of *Pyxilla*, we may assume from Figures 13–14 that the proportion of *Pterotheca* to *Pyxilla* is naturally low. Given this assumption, the apparent absence of *Pterotheca* from Hole 513A, where the relative abundance of *Pyxilla* is generally an order of magnitude lower than in Hole 511, is not unusual and need not be explained by dissolution. *Pterotheca* may be present in Hole 513A material, but in such low amounts as to pass undetected on slides. In that case, the abundance differences of *Pyxilla* between

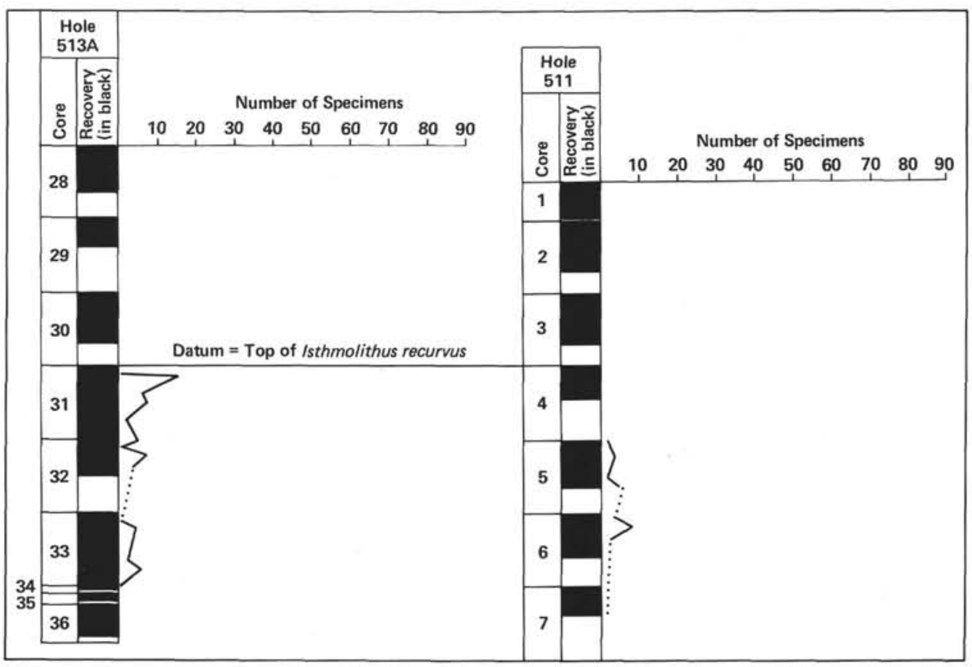

Figure 10. Abundance curve of *Rhizosolenia gravida* in the correlative interval of Holes 513A and 511. (Dotted lines are extrapolations across coring gaps.)

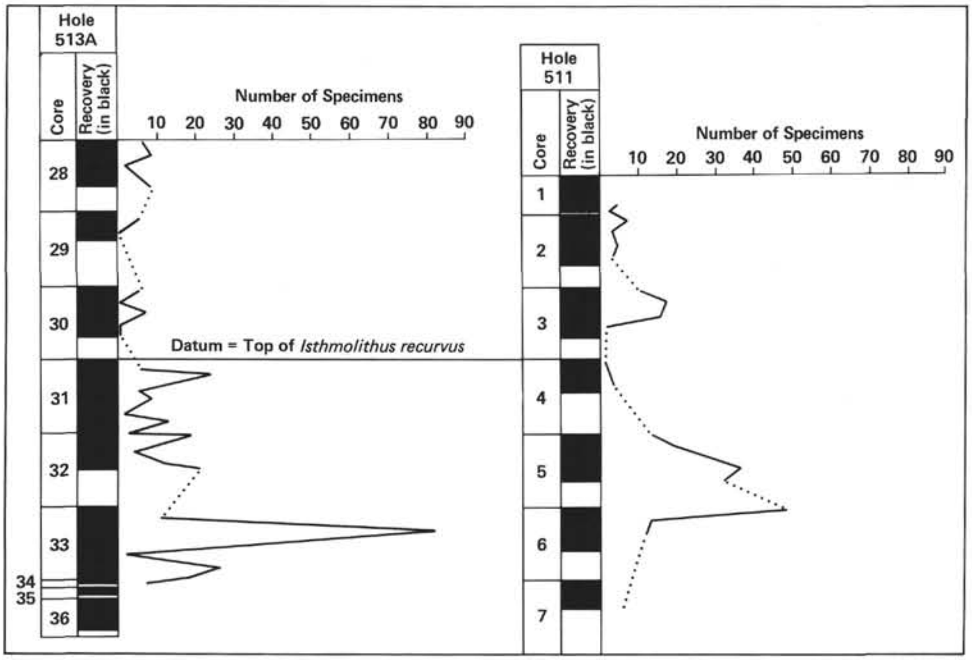

Figure 11. Abundance curve of *Hemiaulus incisus* in the correlative interval of Holes 513A and 511. (Dotted lines are extrapolations across coring gaps.)

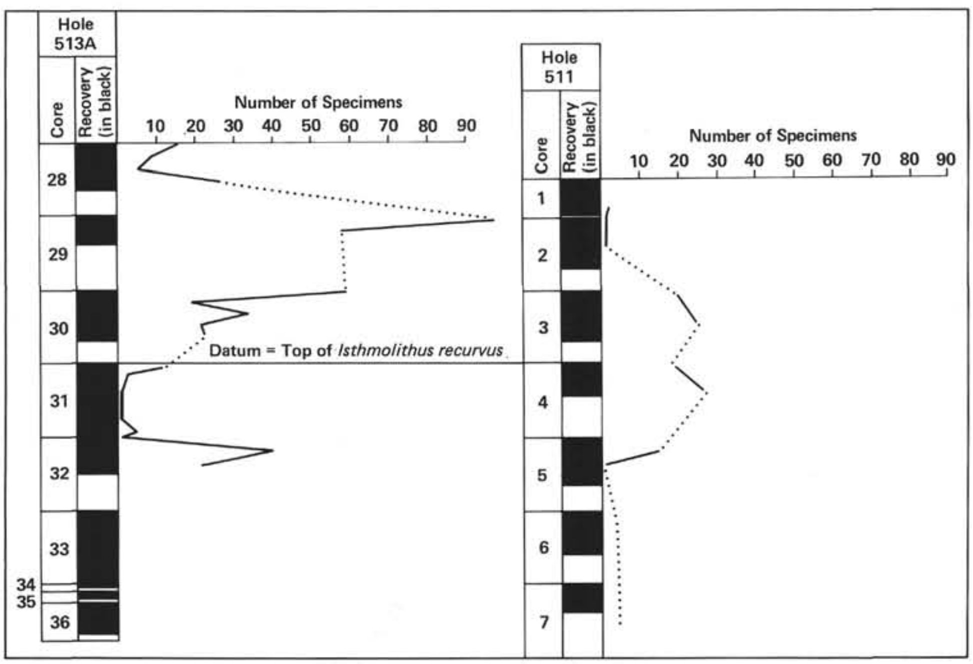

Figure 12. Abundance curve of *Coscinodiscus superbus* group in the correlative interval of Holes 513A and 511. (Dotted lines are extrapolations across coring gaps.)

Holes 513A and 511 could be explained by paleoceanographic conditions at the time of deposition that favored increased production of *Pyxilla* at the more southerly Site 511 and not in Hole 513A.

Figures 15–17 illustrate abundance changes for *P. prolongata* group, *Asterolampra vulgaris*, and *Melosira architecturalis* in the vicinity of the Eocene/Oligocene boundary in Hole 511. Considerable coring gaps occur over this interval, making detailed documentation of abundance changes across the boundary impossible; however, general trends are apparent.

Approaching the boundary, *P. prolongata* group and *A. vulgaris* both exhibit trends toward decreased abundance, *M. architecturalis* toward increased abundance. According to Kennett (1978) there was general reduction in water temperature in the sub-Antarctic followed by a

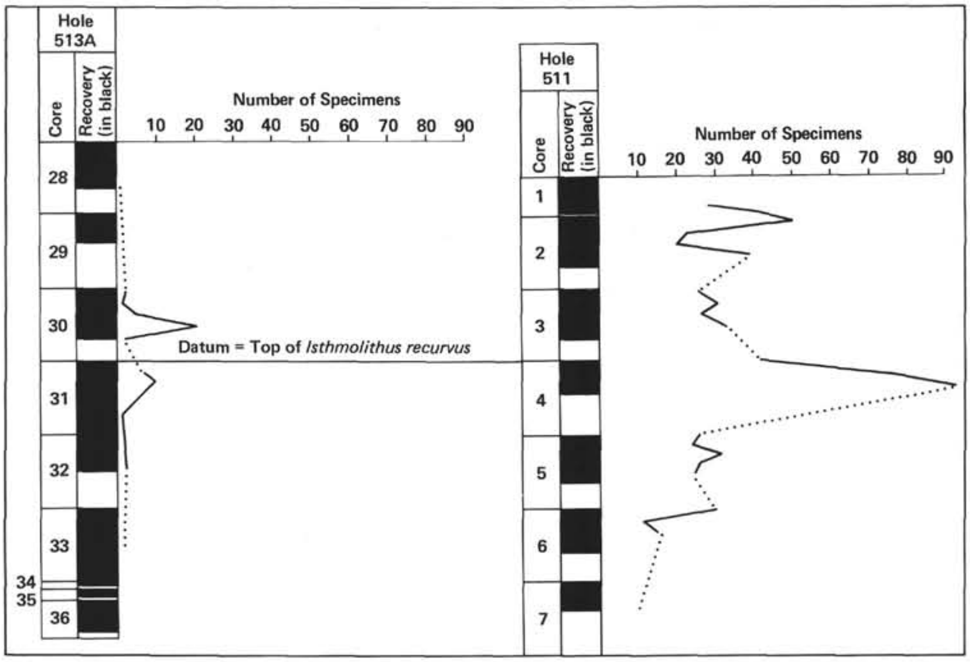

Figure 13. Abundance curve of *Pyxilla prolongata* group in the correlative interval of Holes 513A and 511. (Dotted lines are extrapolations across coring gaps.)

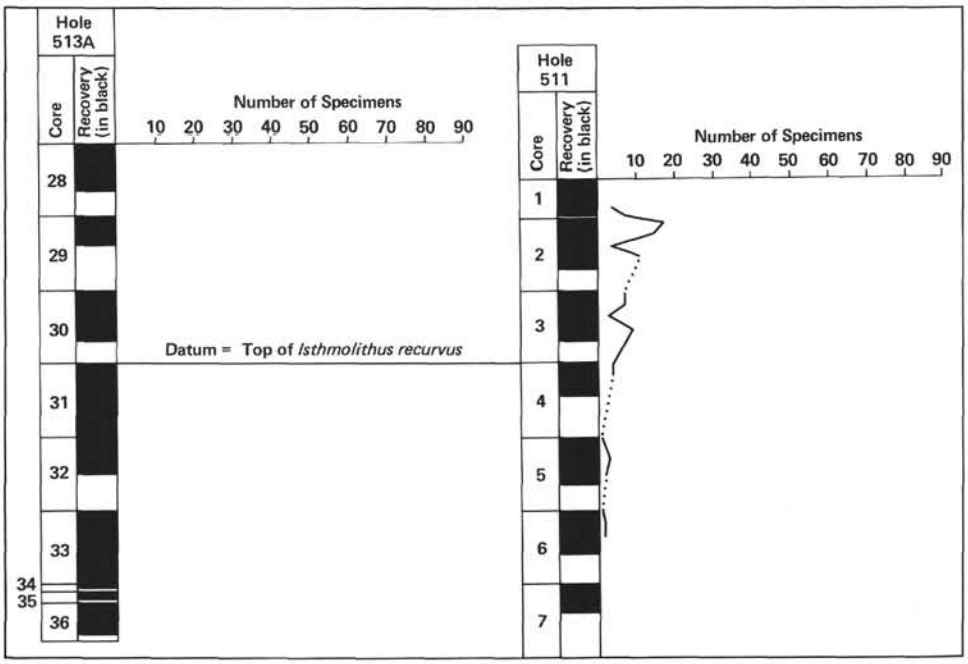

Figure 14. Abundance curve of *Pterotheca* spp. in the correlative interval of Holes 513A and 511. (Dotted lines are extrapolations across coring gaps.)

dramatic temperature drop at or about the Eocene/Oligocene boundary, possibly because of increased sea-ice formation around Antarctica at the time. If this temperature change is reflected in the diatom abundance curves, it would suggest that *P. prolongata* group and *A. vulgaris* had affinities for warm water and *M. architecturalis* for cooler water.

Figures 18–21 illustrate abundance changes for *Rocella vigilans, R. gelida, Triceratium groningensis*, and *Rossiella* sp. in the vicinity of the Oligocene/Miocene boundary in Hole 513A. The sudden decrease of *Rocella vigilans* followed by a sudden increase in *R. gelida* reflect the evolutionary transition from the former to the latter which takes place just below the Oligocene/Miocene boundary and is a useful stratigraphic datum.

T. groningensis exhibits an acme followed by a sudden decrease in abundance below the Oligocene/Miocene boundary. *Rossiella* sp. exhibits a sudden increase

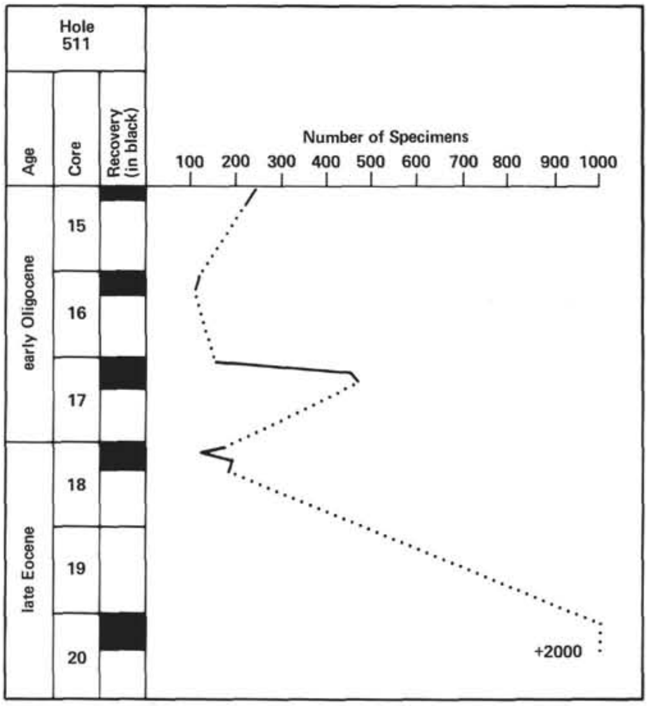

Figure 15. Abundance curve of *Pyxilla prolongata* in the vicinity of the Eocene/Oligocene boundary in Hole 511. (Dotted lines are extrapolations across coring gaps.)

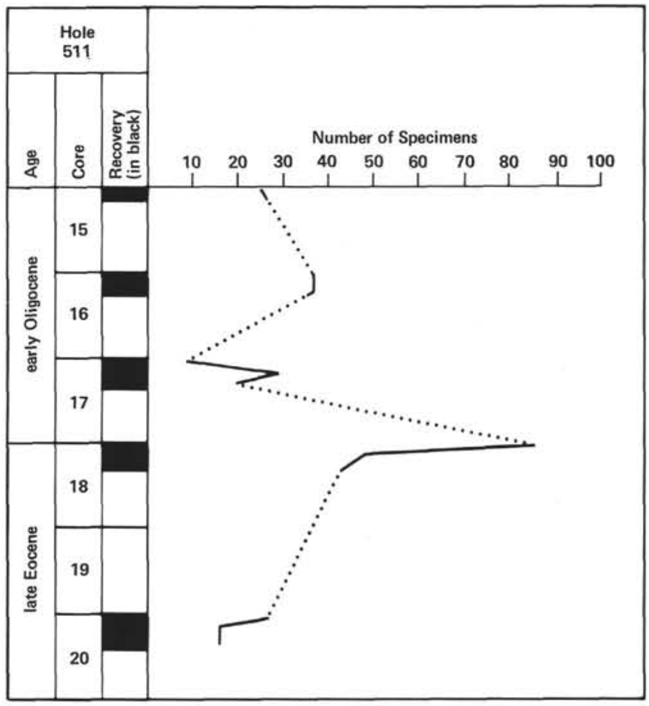

Figure 17. Abundance curve of *Melosira architecturalis* in the vicinity of the Eocene/Oligocene boundary in Hole 511. (Dotted lines are extrapolations across coring gaps.)

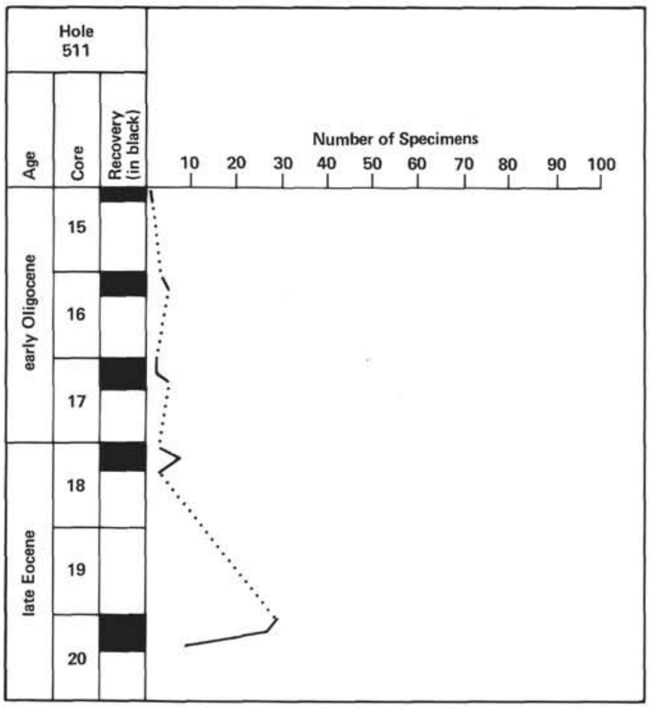

Figure 16. Abundance curve of *Asterolampra vulgaris* in the vicinity of the Eocene/Oligocene boundary in Hole 511. (Dotted lines are extrapolations across coring gaps.)

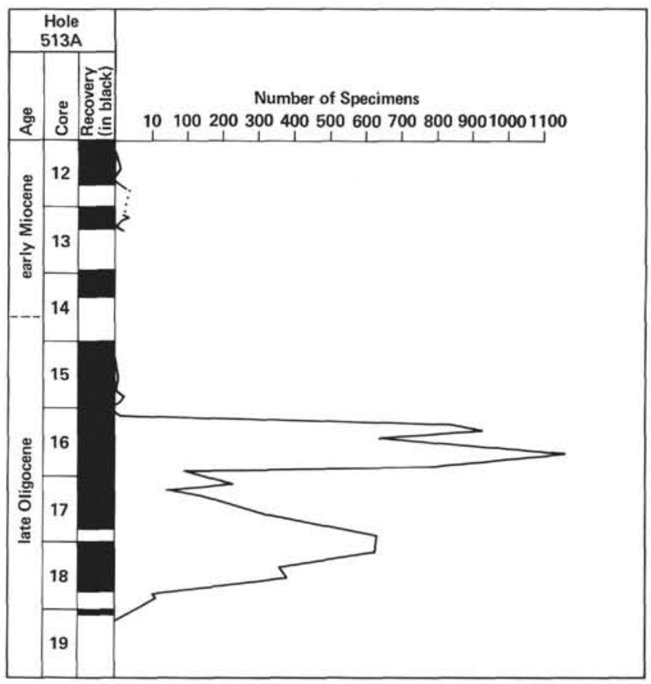

Figure 18. Abundance curve of *Rocella vigilans* in the vicinity of the Oligocene/Miocene boundary in Hole 513A. (Dotted lines are extrapolations across coring gaps.)

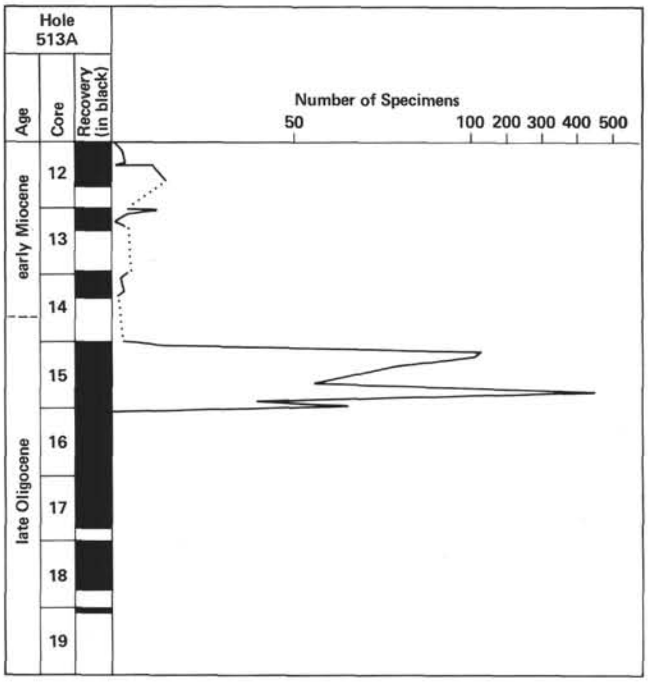

Figure 19. Abundance curve of *Rocella gelida* in the vicinity of the Oligocene/Miocene boundary in Hole 513A. (Dotted lines are extrapolations across coring gaps.)

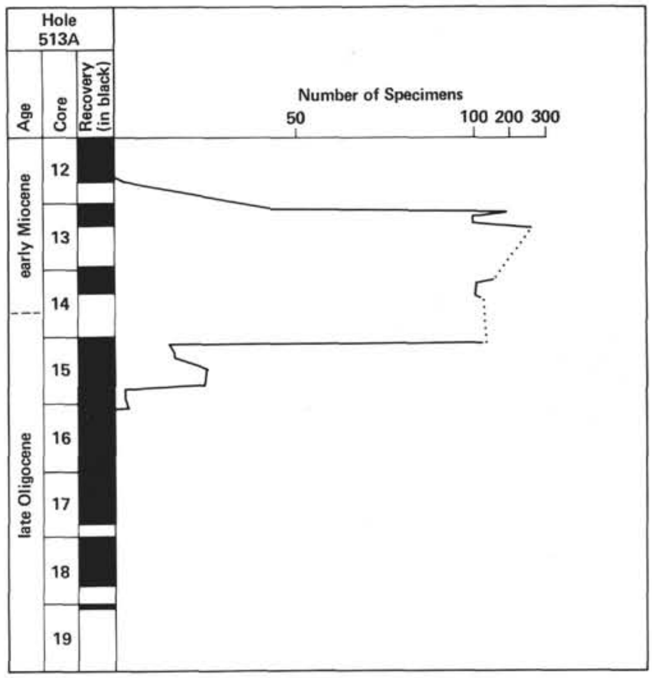

Figure 21. Abundance curve of *Rossiella* sp. in the vicinity of the Oligocene/Miocene boundary in Hole 513A. (Dotted lines are extrapolations across coring gaps.)

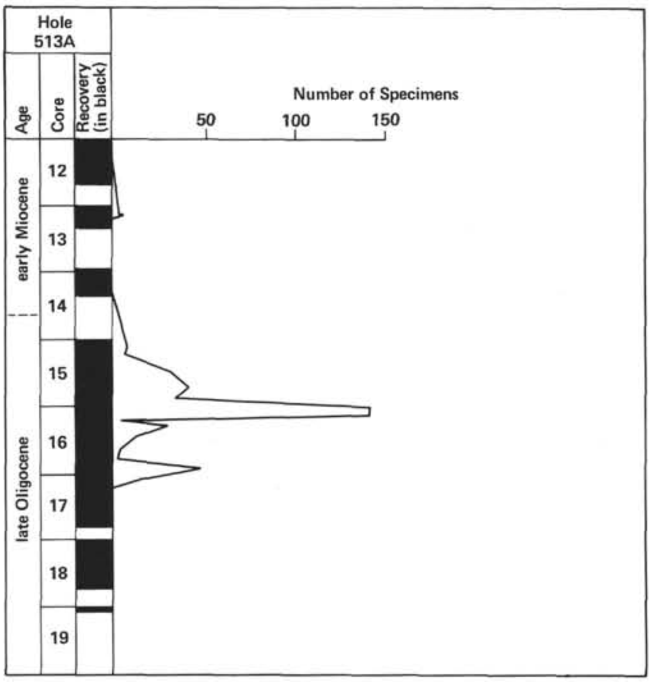

Figure 20. Abundance curve of *Triceratium groningensis* in the vicinity of the Oligocene/Miocene boundary in Hole 513A.

in abundance just below the Oligocene/Miocene boundary and reaches its acme just after it.

SUMMARY AND CONCLUSIONS

The biostratigraphic distribution of diatom species in Holes 511 and 513A has been demonstrated. Together these holes comprise a continuous record of diatom evolution from late Eocene to early Miocene time. On the basis of the lowest and highest stratigraphic occurrences of 11 diatom species it was possible to subdivide the upper Eocene to lower Miocene section into 12 zones, which are considered local in nature, since they have not been tested outside the region of the Southwest Atlantic. Changes in relative abundance of selected species in the vicinity of the Oligocene/Miocene and the Eocene/Oligocene boundaries suggest that such changes may be useful as secondary stratigraphic tools.

FLORAL REFERENCES AND TAXONOMIC NOTES

Following is an alphabetical listing of diatom taxa. For each species, we have cited the original reference and additional references which are perhaps more readily available and more modern in their stratigraphic treatment. More complete taxonomic references to many of the species listed below may be found in VanLandingham (1967–1978). Genera and species of uncertain position are listed at the end.

This listing includes all species recorded on the range charts (Figs. 4–5) but is not a complete list of all species in the assemblages. Since the emphasis in this study was on documenting the ranges of the predominant constituents of the assemblages, species represented by solitary occurrences were, in most cases, not included in the range charts. Other rare species, some of the benthic species, and form genera such as *Xanthiopyxis* were not included either. Because of time restrictions, we decided to concentrate on those species which characterize the assemblages and those which have potential use in biostratigraphy. The present material presents excellent opportunities for detailed taxonomic studies; however, such studies are inappropriate in the *Initial Reports of the Deep Sea Drilling Project*. It is hoped that this report will serve as a basis for future investigations of the type which could not be included here.

Several new species were discovered during the course of this study. These are described in a separate section following the floral references and taxonomic notes.

Genus *ACTINOPTYCHUS* Ehrenberg, 1841

Actinoptychus splendens (Shadbolt) Ralfs, 1861
(No illustration)

Reference. Ralfs *in* Pritchard, 1861, p. 840.

Actinoptychus undulatus (Bailey) Ralfs, 1861
(No illustration)

Reference. Ralfs *in* Pritchard, 1861, p. 839, pl. 5, fig. 88.

Genus *ASTEROLAMPRA* Ehrenberg, 1844

Asterolampra acutiloba Forti, 1912
(Plate 1, Fig. 8)

References. Forti *in* Tempère and Peragallo, 1912, p. 337, no. 696–698; Forti, 1913, p. 1564, pl. 3, figs. 1, 5–6, 9.
Remarks. Rare and sporadic in the lower Oligocene of Hole 511.

Asterolampra affinis Greville, 1862
(No illustration)

References. Greville, 1862, p. 48, pl. 8, figs. 26–27; Schrader and Fenner, 1976, text-figure 40, nos. 4, 10; Gombos, 1980, p. 234.
Remarks. Rare in the lower Oligocene, common to abundant in the upper Oligocene and lower Miocene.

Asterolampra grevillei (Wallich) Greville, 1860
(No illustration)

References. Greville, 1860, p. 113, pl. 4, fig. 21; Ralfs *in* Pritchard, 1861, p. 853; Rattray, 1890, p. 644; Wolle, 1890, pl. 81, fig. 15; De Toni, 1894, p. 1405; Peragallo, 1897–1908, p. 405, pl. 110, fig. 3; Hustedt, 1930, p. 489, fig. 274; Gombos, 1975, p. 315, pl. 6, figs. 2, 8–9; Fenner, 1979, p. 511, pl. 18, fig. 3.
Synonyms. *Asteromphalus grevillei* Wallich, 1860, p. 47, pl. 2, fig. 15; *Asterolampra rotula* Greville, 1860, p. 111, pl. 3, fig. 5; *A. variabilis* Greville, 1860, p. 111, pl. 6, fig. 8; *Asteromphalus variabilis* (Greville) Rattray, 1890, p. 655.

Asterolampra insignis Schmidt, 1888
(No illustration)

References. Schmidt, 1888, pl. 137, figs. 1–3; Schrader and Fenner, 1976, p. 965, pl. 21, fig. 15; Gombos, 1977, p. 592, pl. 25, figs. 2, 4; Fenner, 1979, p. 511; Gombos, 1980, pp. 235–236, pl. 10, fig. 48; pl. 13, fig. 52.
Remarks. Rare to common in the lower Oligocene of Holes 511 and 513A.

Asterolampra marylandica Ehrenberg, 1844
(Plate 1, Fig. 7)

References. Ehrenberg, 1844, p. 76, fig. 10; Hustedt, 1930, p. 485, fig. 271.

Asterolampra punctifera (Grove) Hanna, 1927
(Plate 2, Figs. 4–8; Plate 5, Figs. 8–10)

Reference. Hanna, 1927, p. 109, pl. 17, fig. 3.
Synonym. *Asterolampra affinis* v. *punctifera* Grove *in* Schmidt, 1896, pl. 202, fig. 18.
Remarks. Lower Oligocene. The occurrence of this species is not well documented in Hole 511.

Asterolampra schmidtii Hajós, 1976
(Plate 2, Figs. 1–3; Plate 4, Figs. 9–10)

Reference. Hajós, 1976, p. 827, pl. 21, fig. 6.
Remarks. Hajós (1976) reports this species from the lower Oligocene of Hole 280A. It is rare to common in the lower Oligocene of Holes 511 and 513A.

Asterolampra sp. A
(Plate 3, Figs. 1–4)

Description. Valves circular, convex, central portion nonaerolated; aerolated segments fasiculate, with 7 areolae in 10 μm measured radially, 3–4 marginal spinules per aerolated segment; inner margins of areolated segments slightly curved. Number of rays variable, commonly 10, with labiate processes at marginal ends. Diameter 133 μm.
Age. Early Oligocene to early Miocene.

Asterolampra vulgaris Greville, 1862
(Plate 1, Figs. 1–3)

References. Greville, 1862, p. 47, pl. 7, figs. 17–20; Schmidt, 1888, pl. 137, figs. 10, 12; pl. 202, figs. 14–16; Schrader and Fenner, 1976, p. 592, pl. 25, figs. 1, 3, 5; Gombos, 1980, pp. 239–240, pl. 4, figs. 20–24.
Remarks. In Hole 511 this species exhibits its greatest abundance in the upper Eocene.

Genus *ASTEROMPHALUS* Ehrenberg, 1845

Asteromphalus oligocenicus Schrader and Fenner, 1976
(Plate 5, Figs. 5–7)

Reference. Schrader and Fenner, 1976, pp. 965–966, pl. 21, figs. 8, 13–14; pl. 28, fig. 1.
Remarks. Schrader and Fenner (1976) report this species from the upper Oligocene of Hole 338 in the Norwegian Sea; Fenner (1979) reports it from Hole 354 on the Ceara Rise; in Holes 511 and 513A it occurs in the lower Oligocene.

Asteromphalus symmetricus Schrader and Fenner, 1976
(Plate 5, Fig. 11)

Reference. Schrader and Fenner, 1976, p. 966, pl. 21, figs. 7, 10–12.
Remarks. Schrader and Fenner report this species from the upper Oligocene of Hole 338 in the Norwegian Sea. In Hole 513A it ranges from upper Oligocene to lower Miocene, being more common in the lower Miocene.

Genus *BAXTERIA* Van Heurck, 1893

Baxteria brunii Van Heurck, 1893
(Plate 21, Figs. 5–7)

References. Van Heurck, 1893, p. 79; Van Heurck, 1896, p. 460, fig. 190.
Remarks. This species is rhombic in outline and the valve surface is covered with large pores. In girdle view the characteristic terminal elevations and the prominent marginal spines can be seen. Observed in the upper Eocene and lower Oligocene of Hole 511; most common in the upper Eocene.

Genus *BRIGHTWELLIA* Ralfs, 1861

Brightwellia coronata (Brightwell) Ralfs, 1861
(No illustration)

References. Ralfs *in* Pritchard, 1861, p. 940; Hanna and Brigger, 1964, p. 8, pl. 2, fig. 2; Fenner, 1979, p. 512, pl. 2, fig. 5; pl. 3, fig. 1.
Synonym. *Brightwellia pulchra* Grunow *in* Van Heurck, 1883, pl. 128, fig. 9.
Remarks. Very rare in the lower Oligocene of Hole 511, probably reworked.

Brightwellia hypoborea Grunow, 1883
(No illustration)

References. Grunow *in* Van Heurck, 1883, pl. 128, fig 8; Schmidt, 1888, pl. 138, fig. 22; Fenner 1979, p. 512, pl. 2, fig. 4.
Remarks. Very rare in Hole 511, probably reworked.

Brightwellia spiralis Gleser, 1964
(Plate 23, Figs. 1–3)

Reference. Gleser *in* Scheshukova-Poretskaya and Gleser, 1964, p. 82, pl. 2, fig. 3.
Remarks. This species is rare, but consistent, in the lower lower Oligocene of Hole 511. It becomes sporadic in occurrence in the later part of the lower Oligocene in both Hole 511 and Hole 513A. This species occurs only as fragments; no complete valves were observed.

Genus *CESTODISCUS* Greville, 1865

Cestodiscus pulchellus Greville, 1865
(No illustration)

Reference. Greville, 1865, p. 123, pl. 11, fig. 5.
Remarks. Rare to common in the upper Oligocene and lower Miocene of Hole 513A.

Cestodiscus sp.
(Plate 8, Figs. 4-6)

Remarks. This species is characterized by an umbonate central part; the areolae are arranged in parallel radial rows; outer part of valve surface is arched and surrounds a central depression from which arises an umbo. Rare to abundant in the lower Oligocene of Hole 513A; not observed in the lower Oligocene of Hole 511.

Genus *COSCINODISCUS* Ehrenberg, 1838

Coscinodiscus apiculatus Ehrenberg, 1844
(No illustration)

References. Ehrenberg, 1844, p. 77; Hustedt, 1930, pp. 449-452, fig. 248.

Coscinodiscus bulliens Schmidt, 1886
(Plate 23, Figs. 4-5)

References. Schmidt, 1886, pl. 61, fig. 11; Hajós, 1976, p. 825, pl. 6, figs. 5-6; Fenner, 1979, p. 514, pl. 2, figs. 2-3.
Remarks. A variety of *Coscinodiscus bulliens* in which the ring of enlarged areolae is characterized by large areolae separated by two or three somewhat smaller areolae. This variety is not named, but is shown on the range chart for Hole 511 (Fig. 4) as *Coscinodiscus bulliens* v. 1.

Coscinodiscus deformans Schrader, 1976
(No illustration)

Reference. Schrader, 1976, p. 630, pl. 11, figs. 1-2.

Coscinodiscus endoi Kanaya, 1959
(No illustration)

Reference. Kanaya, 1959, pp. 76-77, pl. 3, figs. 8-11; Schrader, 1976, p. 630, pl. 11, figs. 4, 8-10, 12.

Coscinodiscus excavatus Greville var. _tuberosa_ Fenner, 1979
(Plate 23, Fig. 6)

Reference. Fenner 1979, p. 514, pl. 10, figs. 11-12; pl. 11, figs. 1-3.
Remarks. This variety with two excavations lying opposite each other was observed only in Cores 1 and 11 of Hole 511 where it was represented by single specimens.

Coscinodiscus marginatus Ehrenberg, 1841
(No illustration)

Reference. Hustedt, 1930, pp. 416-418, fig. 223.

Coscinodiscus nodulifer Schmidt, 1878
(No illustration)

Reference. Schmidt, 1878, pl. 59, figs. 20-23.

Coscinodiscus praenitidus Fenner, 1976
(Plate 22, Figs. 4-5)

Reference. Fenner *in* Schrader and Fenner, 1976, p. 972, pl. 14, figs. 7-9, 12; pl. 27, fig. 8; pl. 35, fig. 24; pl. 36, fig. 5.
Remarks. Rare to common, but sporadic in occurrence, in the upper Oligocene of Hole 513A.

Coscinodiscus rhombicus Castracane, 1886
(Plate 14, Figs. 1-5)

References. Castracane, 1886, p. 164, pl. 22, fig. 11; Forti, 1913, p. 1568; Schrader and Fenner, 1976, p. 972, pl. 21, figs. 1-3, 5.
Remarks. Common in the upper Oligocene of Hole 513A, rare in the lower Miocene of the same hole. This species differs from *Coscinodiscus lewisianus* by the random pattern of areolae on its surface.

Coscinodiscus superbus Hardman, 1889
(Plate 4, Figs. 1-8)

References. Hardman *in* Rattray, 1889, p. 458; Fenner, 1979, p. 516, pl. 13, figs. 1-5; pl. 14, figs. 1-4.
Synonyms. *Cestodiscus pulchellus* Greville, 1866, p. 123, pl. 11, fig. 5; *C. robustus* Jousé, 1974, p. 345, pl. 1, figs. 14-15.
Remarks. In both Holes 513A and 511 this species group occurs in great abundance in the upper lower Oligocene; it was not observed in the upper Oligocene. This abrupt demise is peculiar and may be attributed to changes in the oceanographic regime at the time. Though we have used the highest occurrence of this species to define the top of our *Coscinodiscus superbus* Zone, we caution against the use of that datum outside the region of the South Atlantic until future research more precisely defines its range and taxonomy.

Genus *CRASPEDODISCUS* Ehrenberg, 1844

Craspedodiscus moelleri Schmidt, 1893
(No illustration)

Reference. Schmidt, 1893, pl. 184, fig. 3; Benda, 1972, p. 255, pl. 1, fig. 1; Gombos, 1977, p. 593, pl. 27, fig. 6.
Remarks. This species is rare and sporadic in the upper Eocene and lower Oligocene of Hole 511. It is assumed that its presence in Hole 511 is due to reworking from older Eocene deposits in the region of the Falkland Plateau.

Genus *DENTICULOPSIS* (Kutzing) Simonsen, 1979

Denticulopsis dimorpha (Schrader) Simonsen, 1979
(No illustration)

References. Schrader, 1973, p. 704, pl. 1, figs. 37-46; Simonsen, 1979, p. 64.

Denticulopsis hustedtii (Simonsen and Kanaya) Simonsen, 1979
(No illustration)

References. Simonsen and Kanaya, 1961, p. 501, pl. 1, figs. 19-25; Simonsen, 1979, p. 64.

Denticulopsis lauta (Bailey) Simonsen, 1979
(No illustration)

References. Bailey, 1854, p. 9, figs. 1-2; Simonsen, 1979, p. 64.

Genus *DICLADIA* Ehrenberg, 1844
(No illustrations)

Remarks. This form-genus was observed rarely in the lower Oligocene of Hole 513A.

Genus *ENTOGONIA* Greville, 1863
(No illustrations)

Remarks. Only fragments of this Eocene genus were observed in the upper Eocene and lower Oligocene of Hole 511. Their presence is attributed to reworking.

Genus *ETHMODISCUS* Castracane, 1886

Ethmodiscus rex (Wallich) Hendey, 1953
(No illustration)

Reference. Hendey *in* Hendey and Wiseman, 1953, p. 51, pls. 1-2.
Synonym. *Coscinodiscus rex* Wallich *in* Rattray, 1890, p. 568.
Remarks. This species was observed throughout Holes 513A and 511. It occurs only as fragments.

Genus *GONIOTHECIUM* Ehrenberg, 1841

Goniothecium odontella Ehrenberg, 1844
(Plate 14, Figs. 6-8; Plate 22, Fig. 9)

References. Karsten, 1928, p. 301, fig. 419A; Schrader and Fenner, 1976, p. 983, pl. 6, figs. 1-2, 4; Fenner, 1979, p. 502, pl. 26, fig. 7; pl. 27, fig. 1.

Genus *GRAMMATOPHORA* Ehrenberg, 1839 (1841)

Grammatophora sp.
(Plate 21, Fig. 9)

Remarks. This species was observed only in the upper Eocene of Hole 511, where it is rare to frequent.

Genus *HEMIAULUS* Ehrenberg, 1844

Remarks. This large and complex genus is represented by a large number of species in the present material from Holes 511 and 513A. We have not attempted to differentiate all species; our emphasis has been on those which we consider to be of potential biostratigraphic utility.

Hemiaulus caracteristicus Hajós, 1976
(Plate 20, Figs. 1-5)

Reference. Hajós, 1976, pp. 828-829, pl. 15, fig. 10.
Synonyms. "New species" Schmidt, 1888, pl. 142, fig. 12; *Hemiaulus* "artifacts" Gombos, 1977, p. 594, pl. 15, figs. 4-6.
Remarks. This unusual species differs from all other *Hemiaulus* species by its hyaline valves. SEM photographs have revealed the presence of minute pores on the horns. This species has been reported by Gombos (1977) from the upper Paleocene of the Falkland Plateau and by Hajós (1976) from the upper Eocene of Hole 283 in the Tasman Sea; in the present study it was observed to be common to abundant from the upper Eocene through the lower Oligocene and rare to very rare in the upper lower Oligocene.

Hemiaulus incisus Hajós, 1976
(Plate 20, Fig. 6)

References. Hajós, 1976, p. 829, pl. 23, figs. 4-9; Gombos, 1977, p. 594, pl. 15, fig. 3; Fenner, 1979, p. 521, pl. 25, figs. 6, 8.
Synonyms. *Hemiaulus kittonii* Schmidt, 1888, pl. 142, fig. 11; *H.* sp. 1 McCollum, 1975, p. 535, pl. 9, fig. 2.
Remarks. In the present material this species was observed only in the upper Eocene and lower Oligocene.

Hemiaulus pacificus (Hajós) n. comb.
(Plate 8, Figs. 1-3)

Reference. Hajós, 1976, p. 828, pl. 22, figs. 1-6.
Synonym. *Biddulphia angulata*? Schmidt in McCollum, 1975, p. 525, pl. 3, figs. 3-5. *Cerataulus pacificus* Hajos, 1976, p. 828, pl. 22, figs. 1-6.
Remarks. The absence of ocelli eliminates this species from the genus *Cerataulus*, where it was placed by Hajós (1976).

Hemiaulus polycystinorum Ehrenberg, 1854
(No illustration)

References. Ehrenberg, 1854, pl. 36, figs. 43a-b; Fenner, 1979, p. 521, pl. 21, figs. 13-14; pl. 22, figs. 4-5, 7-10; pl. 23, figs. 1-4.
Remarks. In the present study the abundance of this species was recorded by Ciesielski for Hole 513A.

Hemiaulus polymorphus Grunow, 1884
(No illustration)

References. Grunow, 1884, p. 66; Schmidt, 1888, pl. 143, figs. 11-13; Kanaya, 1957, pp. 105-107, pl. 7, figs. 10-11; Fenner, 1979, p. 522, pl. 21, fig. 11; pl. 23, figs. 10-11; pl. 22, fig. 13.
Remarks. Most common in the lower Oligocene of Hole 513A.

Hemiaulus reflexispinosus Ross and Sims, 1977
(Plate 21, Figs. 1-3)

Reference. Ross and Sims *in* Ross et al., 1977, pp. 185-186, text-figure 2; pl. 3, figs. 17-19.
Remarks. Observed only in Hole 511, where it is rare and sporadic in occurrence from the upper Eocene through lower Oligocene.

Hemiaulus sp.
(Plate 20, Figs. 7-9)

Remarks. Rare through the lower Oligocene of Hole 511. The only consistent occurrence was noted in Hole 511 from Core 16, Section 2 to Core 17, Section 2. This species is characterized by outwardly directed horns and a central labiate process and prominent folds on each valve. We refrain from formally describing it until a detailed review of this type of *Hemiaulus* has been undertaken.

Genus *HYALODISCUS* Ehrenberg, 1845

Hyalodiscus sp.
(Plate 22, Fig. 2)

Remarks. Rare to very rare in the upper Eocene and lower lower Oligocene of Hole 511.

Genus *KOZLOVIELLA* Jousé, 1974

Kozloviella minor Jousé, 1974
(Plate 22, Fig. 1)

Reference. Jouse, 1974, p. 352, pl. 4, fig. 18.
Remarks. This species is very rare to common in the lower upper Oligocene of Hole 513A.

Genus *LISITZINIA* Jousé, 1978

Lisitzinia ornata Jousé, 1978
(Plate 18, Figs. 1-4)

Reference. Jouse, 1978, pp. 47-78, pl. 10, figs. 1-6.
Synonyms. *Triceratium cruciforme* Schmidt, 1887, pl. 77, fig. 41; Schrader and Fenner, 1976, pp. 1002-1003, pl. 27, fig. 2.
Remarks. Rare to abundant in the upper Oligocene of Hole 513A.

Genus *MELOSIRA* Agardh, 1824

Melosira architecturalis Brun, 1892
(No illustration)

References. Brun *in* Schmidt, 1892, pl. 177, figs. 49-50; Hajós 1976, p. 824, pl. 1, figs. 5-6; Schrader and Fenner, 1976, p. 989, pl. 14, fig. 13; pl. 29, figs. 7-8; pl. 35, figs. 1-4; Gombos, 1977, p. 595, pl. 26, figs. 5-7; Fenner, 1979, p. 524, pl. 16, figs. 7-12.
Synonym. *Cyclotella hannae* Kanaya, 1957, pp. 82-84, pl. 3, figs. 10-11, 14.
Remarks. With the recovery at Site 511 of a continuously cored upper Eocene and lower Oligocene section that is free of unconformities, we have been able to document, for the first time, the stratigraphic top of this species—at least for the region of the South Atlantic. Rare and sporadic occurrences of *Melosira architecturalis* were observed in Cores 2 through 12 of Hole 511. These occurrences are often in conjunction with reworked older species, suggesting that the occurrence of *M. architecturalis* in that interval is a result of reworking. Beginning in Core 13 and continuing to the bottom of Core 20 (lowest occurrence of siliceous microfossils), this species is common to abundant and consistent in occurrence. This suggests that the highest common and consistent occurrence of *M. architecturalis* in Core 13 (just above the Eocene/Oligocene boundary) represents the stratigraphic top of this species in the South Atlantic.

Genus *NAVICULA* Bory, 1822

Navicula bendaensis Schrader and Fenner, 1976
(No illustration)

Reference. Schrader and Fenner, 1976, p. 991, pl. 22, figs. 34-35; pl. 24, fig. 4.
Remarks. Schrader and Fenner (1976) report this species from the upper Eocene of the Norwegian Sea. In the present study it was observed in the lower Oligocene of Hole 513A.

Navicula udintsevii Schrader and Fenner, 1976
(Plate 21, Fig. 8)

Reference. Schrader and Fenner, 1976, p. 991, pl. 22, fig. 33; pl. 24, figs. 1(?), 2.
Remarks. Reported from the upper Eocene of the Norwegian Sea by Schrader and Fenner (1976). In this study it was observed in the lower Oligocene of Hole 513A.

Genus *NITZSCHIA* Hassall, 1845

Nitzschia maleinterpretaria Schrader, 1976
(No illustration)

Reference. Schrader, 1976, p. 634, pl. 2, figs. 9, 11-19, 21, 24.

Genus *PLEUROSIGMA* Smith, 1852
(Plate 24, Fig. 9)

Remarks. Very rare fragments of this genus were observed in Hole 513A.

Genus *PODOSIRA* Ehrenberg, 1840

***Podosira polita* Hanna and Grant, 1926**
(Plate 4, Fig. 11)

References. Hanna and Grant, 1926, p. 164, pl. 20, fig. 5; Fenner, 1979, p. 526, pl. 25, figs. 7–8.

Genus *PSEUDODIMEROGRAMMA* Schrader *in* Schrader and Fenner, 1976

***Pseudodimerogramma filiformis* Schrader and Fenner, 1976**
(No illustration)

Reference. Schrader and Fenner, 1976, p. 993, pl. 3, figs. 21–22.

Genus *PSEUDOPYXILLA* Forti, 1909

***Pseudopyxilla dubia* (Grunow) Forti, 1909**
(No illustration)

References. Forti, 1909, p. 12, pl. 1, figs. 1–3; Schrader and Fenner, 1976, p. 994, pl. 44, figs. 13–14; Fenner, 1979, p. 526, pl. 14, fig. 9; pl. 17, figs. 1–6.

Genus *PSEUDORUTILARIA* Grove and Sturt, 1886

***Pseudorutilaria monile* Grove and Sturt, 1886**
(No illustration)

References. Grove and Sturt, 1886, p. 324, pl. 18, fig. 7; Hajós, 1976, p. 829, pl. 14, figs. 10–12; Gombos, 1977, p. 595, pl. 40, fig. 7.
Remarks. One occurrence of this Eocene species was observed in the lower lower Oligocene of Hole 511.

Genus *PSEUDOTRICERATIUM* Grunow, 1884

***Pseudotriceratium chenevieri* (Meister) Gleser, 1975**
(Plate 17, Fig. 4)

References. Gleser, 1975, pl. 2, fig. 4; Schrader and Fenner, 1976, p. 994, pl. 11, figs 7–9; pl. 26, fig. 5; Strelnikova *in* Jousé et al., 1979, p. 51, figs. 152–153.
Synonym. *Triceratium chenevieri* Meister, 1937, p. 261, pl. 5, fig. 2.

***Pseudotriceratium radiosoreticulatum* Grunow, 1890**
(Plate 17, Figs. 1–3)

References. Grunow *in* Schmidt, 1890, pl. 151, figs. 35–36; Strelnikova *in* Jousé et al., 1979, p. 51, fig. 151.
Synonym. *Pseudotriceratium* aff. *chenevieri* (Meister) Gleser *in* Schrader and Fenner, 1976, p. 994, pl. 26, figs. 6, 8–9.

Genus *PTEROTHECA* (Grunow) Forti, 1909

Remarks. This form-genus was observed only in Hole 511. The affinities of *Pterotheca* are not known. The robust, hyaline valves of *Pterotheca* most closely resemble valves of *Pyxilla* in shape, being cylindrical with attenuated conical or subconical surfaces, and it is possible that *Pterotheca* represents resting-spores of *Pyxilla*. This speculation is based on the similarity in valve morphology of the two genera, the parallel stratigraphic range of the two genera (neither is known from post-Paleogene sediments), and the close association of their occurrence as discussed earlier. Because the family Pyxillaceae is the only extinct diatom family (Simonsen, 1979), it is not possible to determine the nature of resting spores in *Pyxilla*, and the proposal that *Pterotheca* represents such resting spores must be considered highly speculative.

***Pterotheca aculeifera* Grunow, 1881**
(No illustration)

References. Grunow *in* Van Heurck, 1881, pl. 83, fig. 5; Kanaya, 1975, pp. 109–110, pl. 8, figs. 1–2; Schrader and Fenner, 1976, p. 994, pl. 43, figs. 1–4; Gombos, 1977, p. 596, pl. 23, figs. 1–2; Fenner, 1979, p. 527, pl. 17, figs. 8–21.

Remarks. Very rare in the upper Eocene and lower Oligocene of Hole 511.

***Pterotheca danica* (Grunow) Forti, 1909**
(Plate 13, Figs. 1–3, 9)

References. Forti, 1909, p. 13; Hanna, 1927, p. 119, pl. 20, fig. 11; Proschkina-Lavrenko, 1949, p. 203, pl. 75, fig. 9.
Synonyms. *Stephanogonia* (*Pterotheca*?) *danica* Grunow, 1866, p. 146; Kitton, 1871, p. 1969, pl. 13, figs. 4–5; *Pyxilla* (*P.*) *danica* Grunow in Van Heurck, 1881, pl. 83, figs. 7–8; Kanaya, 1957, pp. 112–113, pl. 8, fig. 5–8.
Remarks. A variety of *Pterotheca danica* in which the cylindrical part, below the conical prolongation, accounts for about two-thirds the valve height was noted in Hole 511. It is recorded on the range chart for that hole (Fig. 4) as *P. danica* (elongate variety).

***Pterotheca major* Jousé, 1955**
(Plate 13, Figs. 6–8)

Reference. Jousé, 1955, p. 101, pl. 6, fig. 2; text-figure 1.
Remarks. All forms with broadly expanded bases (i.e., large-diameter valves) are included in this taxon. Jouse (1955) reports this species from the upper Eocene of western Siberia and the Urals. In this study this species was observed in the upper Eocene and lower Oligocene of Hole 511.

***Pterotheca spada* Tempère and Brun, 1889**
(Plate 13, Figs. 4–5)

References. Tempère and Brun *in* Brun and Tempère, 1889, p. 50, pl. 1, fig. 17; Forti, 1909, p. 13; Proschkina-Lavrenko, 1949–1951, p. 203, pl. 75, fig. 8; Cleve-Euler, 1951, p. 93, fig. VI/t.
Remarks. Forms with greatly attenuated valve surfaces were included in this taxon. Observed only in the lower Oligocene of Hole 511.

Genus *PYRGUPYXIS* Hendey, 1969

***Pyrgupyxis eocena* Hendey, 1969**
(Plate 12, Figs. 6–7)

References. Hendey, 1969, pp. 3–4, figs. 1–4; Hajós 1976, p. 829, pl. 24, figs. 3–5, 8–9; Gombos, 1977, p. 596, pl. 22, figs. 6–7.
Remarks. Observed only in lower Oligocene of Hole 511.

Genus *PYXILLA* Greville, 1865

Remarks. Hendey (1969) erected the genus *Pyrgupyxis* to include those forms which are similar to *Pyxilla* but which possess attachment spurs (or attachment "scars") on the hornlike extension or apiculus of the upper part of the frustule and which do not have an apiculus on the lower part of the valve. Hendey (1969, p. 5) placed all *Pyxilla* species, except *P. johnsoniana* Greville and *P. barbadensis* Greville, in synonomy with *Pyrgupyxis*. Simonsen (1979, p. 22) states that he has observed an attachment "scar" on the type specimen of *Pyxilla barbadensis* Greville (British Museum slide No. 3037). This would seem to indicate that the species transferred to *Pyrgupyxis* by Hendey (1969) should in fact remains in *Pyxilla* since the attachment "scar" (this "scar" is actually a small spurlike process) is a characteristic feature of *Pyxilla*, even though it was not observed by Greville. The genus *Pyrgupyxis* therefore includes only *P. eocena* Hendey, which has a lower part with a flat surface (i.e., no apiculus).

In this study I have observed only what appear to be the upper parts of *P. eocena* frustules; no complete frustules were observed. Until more research is done to confirm the true nature of the lower parts of *P. eocena*, forms similar to those illustrated on Plate 12, Figs. 6–7 are excluded from *Pyxilla* sensu Greville (1865).

The taxonomic relationship of the various species of *Pyxilla* is not clear. There exists a great degree of variation between species, particularly in the degree of inflation of the basal parts of the valves, the position of the attachment spur on the apiculus, and the coarseness of areolation (see Fenner, 1978a, pp. 527, 528). In the present material most of the valves are broken, making specific assignations difficult. Most of the complete valves could be assigned to *P. prolongata* Brun or, rarely, *P. johnsoniana* Forti. For the purpose of this report we have included all *Pyxilla* specimens, broken or complete, in the *P. prolongata* group. We believe that the most important aspect of the occurrence of this genus in Holes 513A and 511 is the determination of the stratigraphic top, or extinction, of the genus at about the early/late Oligocene boundary.

Pyxilla prolongata **Brun, 1893**
(Plate 12, Figs. 1-5)

References. Brun, 1893, p. 176, pl. 24, fig. 7.

Genus *RAPHIDODISCUS* Smith *in* Christian, 1887

Raphidodiscus marylandicus **Christian, 1887**
(No illustration)

Reference. Christian, 1887, pp. 66-68; Andrews, 1974, pp. 233-235, pl. 1-5.

Genus *RHIZOSOLENIA* Ehrenberg, 1841

Rhizosolenia praebarboi **Schrader, 1973**
(Plate 24, Fig. 10)

References. Schrader, 1973, pp. 709-710, pl. 24, figs. 1-3; Schrader and Fenner, 1976, p. 997, pl. 7, fig. 10; pl. 24, figs. 1-3.
Synonyms. *Rhizosolenia* sp. B. Gombos, 1977, p. 596, pl. 23, fig. 7; *R. interposita* Hajós, 1976, p. 827, pl. 21, fig. 8; *R.* sp. 1 Strelnikova *in* Dzinoridze et al., 1978, pl. 5, figs. 4, 6.

Rhizosolenia styliformis **Brightwell, 1858**
(No illustration)

References. Brightwell, 1858, p. 95, pl. 5, figs. 5a-b, d; Hustedt, 1930, pp. 584-588, figs. 333-335.

Genus *ROCELLA* Hanna, 1930

Rocella gelida **(Mann) Bukry, 1978**
(Plate 6, Figs. 1-6; Plate 26, Fig. 1)

Reference. Bukry, 1978, p. 788, pl. 5, figs. 1-13.
Remarks. See Bukry (1978) for discussion of the synonomy and taxonomy of this species. The stratigraphic record of this species in the material from Holes 511 and 513A is discussed earlier in this chapter.

Rocella schraderi **Bukry, 1978**
(Plate 22, Fig. 6)

Reference. Bukry, 1978, p. 788, pl. 6, figs. 1-10; pl. 7, fig. 1.
Remarks. Differs from *Rocella gelida* by having a ring of central pores which are much larger than those adjacent to them. The range and abundance of this species is illustrated in Figure 3.

Rocella vigilans **(Kolbe) Fenner, 1982**
(Plate 6, Figs. 7-10; Plate 26, Fig. 2)

Reference. Kolbe, 1954, p. 36, pl. 1, figs. 13-14.
Remarks. This species differs from *Rocella gelida* by the uniform size and distribution of pores on the valve surface. One central labiate process is located in the center of the valve as in *R. gelida*. The stratigraphic occurrence of *R. vigilans* (see Fig. 3) suggests that it is the evolutionary precursor of *R. gelida*.

Genus *ROSSIELLA* Desikachary and Maheshwari, 1958

Rossiella **sp.**
(Plate 24, Figs. 1-2)

Synonym. *Bogorovia veniamini* Jousé *in* Gombos, 1977, p. 593, pl. 1, figs. 6-7; pl. 12, figs. 1-2, 4.
Remarks. Differs from *Rossiella* (*Bogorovia*) *veniamini* Jousé (1974) by the absence of a prominent apical thickening with alternating transapical thickenings on the valve face. A detailed review of the genus is necessary before this species is defined.

Genus *ROUXIA* Brun and Heribaud, 1893

Rouxia granda **Schrader, 1976**
(Plate 21, Fig. 11)

Reference. Schrader *in* Schrader and Fenner, 1976, p. 997, pl. 7, fig. 17.
Remarks. Observed in the lower Oligocene of Holes 513A and 511.

Rouxia hannae **Jousé, 1974**
(Plate 21, Fig. 13)

Reference. Jousé, 1974, pp. 349-350, pl. 2, fig. 13.
Remarks. Jousé (1974) reports this species from the middle Oligocene of the tropical Pacific. In Hole 511 it was observed in the lower Oligocene and is very rare to frequent in abundance.

Rouxia obesa **Schrader, 1976**
(Plate 21, Fig. 12)

Reference. Schrader *in* Schrader and Fenner, 1976, p. 997, pl. 24, figs. 5-6.
Remarks. Observed in the lower Oligocene of Hole 513A.

Genus *RYLANDSIA* Greville, 1861

Rylandsia biradiata **Greville, 1861**
(No illustration)

References. Greville, 1861, p. 67, pl. 8, fig. 1; Gombos, 1980, p. 242, pl. 6, figs. 32-36; pl. 13, fig. 54; pl. 14, figs. 55-56; pl. 15, figs. 57-58.
Remarks. One specimen of this species was observed in the lower Oligocene of Hole 511, suggesting reworking.

Rylandsia inaequiradiata **Barker and Meakin, 1944/45**
(Plate 7, Figs. 7-9)

References. Barker and Meakin 1944/45, p. 21, pl. 4, fig. 9; Gombos, 1980, p. 242, pl. 15, fig. 59.
Remarks. Fenner (1978b) indicated that in Holes 366 and 369A, off the coast of Spanish Sahara, this species ranges across the Eocene/Oligocene boundary and becomes extinct in the lower Oligocene. Data from Hole 511 confirm Fenner's (1978) observation that the species ranges across the boundary and becomes extinct in the lower Oligocene.

Genus *SCEPTRONEIS* Ehrenberg, 1844

Sceptroneis facialis **Fenner, 1976**
(No illustration)

Reference. Fenner *in* Schrader and Fenner, 1976, p. 998, pl. 24, figs. 19-20.

Sceptroneis grunowii **Anissimova, 1937**
(No illustration)

References. Hajós and Stradner, 1975, p. 936, pl. 11, figs. 14-15; Schrader and Fenner, 1976, p. 998, pl. 22, figs. 26-28; pl. 23, fig. 8; pl. 25, figs. 7, 9.

Sceptroneis ligulatus **Fenner, 1979**
(Plate 24, Fig. 8)

Reference. Fenner, 1979, p. 531, pl. 31, figs. 8-10.
Synonym. Genus and species indeterminate (C) Gombos 1977, p. 599, pl. 12, fig. 8.
Remarks. Fenner (1979) says that two types of valves were found, those with structure on the surface and those with well-developed margins, but with no apparent structure on the surface; she includes both in this species. In material from Holes 513A and 511 both types of valves were observed; those having no apparent structure were the more common of the two.

Sceptroneis pesplanus **Fenner and Schrader, 1976**
(Plate 21, Fig. 10)

Reference. Fenner and Schrader *in* Schrader and Fenner, 1976, p. 998, pl. 22, figs. 30-31; pl. 25, figs. 10-11.

Sceptroneis pupa **Schrader and Fenner, 1976**
(No illustration)

Reference. Schrader and Fenner, 1976, p. 999, pl. 22, figs. 17-21; pl. 24, figs. 11-13.

Sceptroneis tenue **Schrader and Fenner, 1976**
(No illustration)

Reference. Schrader and Fenner, 1976, p. 999, pl. 3, figs. 1-4; pl. 24, figs. 14?, 15?, 16?; pl. 25, figs. 12, 22, 24.

Genus *SKELETONEMA* Greville, 1865

***Skeletonema barbadenis* Greville, 1865**
(Plate 5, Figs. 1–4; Plate 21, Fig. 4)

Reference. Greville, 1865, p. 43, pl. 5, fig. 1.
Remarks. This species is rare to common in the lower Oligocene of Hole 513A. It was not observed in the correlative interval of Hole 511.

Genus *STEPHANOPYXIS* Ehrenberg, 1844

Remarks. This genus is represented by numerous species and individuals in some parts of the sections examined for this study. We have recorded the occurrence of only three species which may have stratigraphic value.

***Stephanopyxis eocaenica* Hajós, 1976**
(Plate 10, Figs. 8–11)

Reference. Hajós, 1976, p. 824, pl. 4, figs. 3–4; Gombos, 1977, p. 597, pl. 31, figs. 3–4.
Remarks. Rare to common in the lower Oligocene of Hole 511.

***Stephanopyxis halomarginata* Hajós, 1976**
(Plate 10, Figs. 1–6)

References. Hajós, 1976, p. 824, pl. 19, figs. 11–12; Schrader and Fenner, 1976, p. 1000, pl. 19, figs. 6, 9; Gombos, 1977, p. 597, pl 30, fig. 7; pl. 31, fig. 4.

***Stephanopyxis superba* (Greville) Grunow, 1884**
(Plate 10, Fig. 7)

References. Grunow, 1884, p. 91; Greville, 1865, p. 68, pl. 8, figs. 3–5 (as *Creswellia superba*); Schmidt, 1888, pl. 123, figs. 3–8; Hajós, 1976, p. 926, pl. 2, figs. 11, 12; Gombos, 1977, p. 597, pl. 29, figs. 1–4.

Genus *STICTODISCUS* Greville, 1861

***Stictodiscus novaezealandica* Grunow, 1888**
(Plate 22, Fig. 3)

Reference. Grunow *in* Schmidt, 1888, pl. 443, figs. 7–12.
Remarks. A solitary occurrence in Hole 511, lower Oligocene.

***Stictodiscus* sp.**
(Plate 22, Figs. 7–8)

Remarks. Very rare to common in the upper Oligocene and lower Miocene of Hole 513A.

Genus *SYNEDRA* Ehrenberg, 1830

***Synedra jouseana* Sheshukova-Poretzkaya, 1962**
(Plate 24, Figs. 3–7)

References. Sheshukova-Poretzkaya, 1962, p. 208, fig. 4, Schrader, 1973 p. 710, pl. 23, figs. 21–23, 25, 28; Gombos, 1977, p. 598, pl. 12, fig. 7.
Remarks. Frequent to dominant in the upper Oligocene and lower Miocene of Hole 513A.

***Synedra miocenica* Schrader, 1976**
(No illustration)

Reference. Schrader, 1976, p. 636, pl. 1, fig. 1.
Remarks. Range concurrent with *Synedra jouseana* in Hole 513A.

Genus *TRICERATIUM* Ehrenberg, 1841

***Triceratium groningensis* Reinhold, 1937**
(Plate 15, Figs. 1–3)

References. Reinhold, 1937, p. 126, pl. 20, fig. 9; Fenner, 1979, p. 534, pl. 30, figs. 21–22.
Remarks. Very rare to common in the upper Oligocene and lower Miocene of Hole 513A. Reinhold reports this species from the middle Miocene of Java; Fenner reports it as common in the lower Oligocene of Hole 354 on the Ceara Rise and also from the middle Eocene of Hole 356 on the São Paulo Plateau. A quadrate form of this species was observed in Core 15 of Hole 513A. It is described in the new species as *Triceratium groningensis* f. *quadrata*. The restricted occurrence of this form may have stratigraphic significance.

***Triceratium macroporum* Hajós, 1968**
(Plate 17, Figs. 5–6)

References. Hajós, 1968, pl. 35, figs. 1–10; Jousé, 1974, p. 349, pl. 2, fig. 12.
Remarks. The specimen illustrated by Jousé (1974) differs from those illustrated by Hajós (1968) by having nearly straight sides. Jousé (1974) also states that the characteristic features of this species include the large and sparse areolae with smaller intermediate pores. Hajós (1968) reports this species from the middle Miocene of Hungary. Jousé found it in the middle Oligocene of the tropical Pacific; in this study it was observed from upper Eocene to lower Oligocene in Hole 511 and in the lower Oligocene of Hole 513A.

The specimens observed in the present material most closely resemble that illustrated by Jouse (1974); however, there seems to be a good deal of variation in this species. Often forms with nearly straight sides are found in the same sample with those with slightly concave sides.

A form of this species, which possesses the characteristics of *Triceratium macroporum* except for strongly concave sides, was observed in the lower Oligocene of Hole 511. It is recorded on the range chart for Hole 511 (Fig. 4) as *T. macroporum* (concave form).

***Triceratium unguiculatum* Greville, 1864**
(Plate 14, Figs. 9–12; Plate 16, Figs. 1–4)

References. Greville 1864, p. 85, pl. 11, fig. 9; Gombos, 1977, pp. 598–599, p. 33, figs. 1, 3; pl. 34, figs. 1–6.
Remarks. Ross and Sims (pers. comm.) and Ross (pers. comm.) informed Gombos that amongst the forms we have included in this species are three distinct taxa: *Triceratium unguiculatum, T. pulvinar* and *T.* sp., which differ on the basis of the arrangement of pseudoloculi and sizes of elevations and ocelli. These taxa were not differentiated in this study and are all included in *T. unguiculatum* group.

Genus *TRINACRIA* Heiberg, 1863

***Trinacria excavata* Heiberg, 1863**
(Plate 17, Fig. 8)

References. Hustedt, 1930, pp. 887, 888, fig. 352; Gombos, 1977, p. 599, pl. 37, fig. 6.

***Trinacria excavata* Heiberg f. *tetragona* Schmidt, 1888**
(No illustration)

References. Schmidt, 1888, pl. 152, figs 24–25; Fenner, 1979, pp. 535–536, pl. 27, figs. 9–11.
Remarks. Fenner (1978a) indicates this form as characteristic of the upper Eocene of the Norwegian Sea. Its presence in the lower Oligocene of Hole 511 may result from reworking.

***Trinacria simulacrum* Grove and Sturt, 1887**
(Plate 17, Fig. 7)

References. Grove and Sturt, 1886–1887, p. 144, pl. 13, fig. 46; Schmidt, 1888, pl. 127, fig. 14; Hajos, 1975, p. 829, pl. 15, figs. 1–4; Gombos, 1977, p. 599, pl. 35, figs. 1–2, 4; pl. 36, figs. 1–4; Fenner, 1979, p. 536, pl. 29, fig. 2; pl. 31, fig. 2.
Remarks. Rare to common in the upper Eocene and lower lower Oligocene and rare to very rare in the upper lower Oligocene of Hole 511; not observed in Hole 513A.

INCERTAE SEDIS
Genus and species uncertain #1
(Plate 25, Figs. 1–4)

Remarks. No complete example of this species was observed in the present material, though several slides of each size fraction were examined in their entirety. The fragments characteristically carry a long spine adjacent to an ocellus which is situated on a prominent elevation.

Genus and species uncertain #2
(Plate 25, Figs. 5–7)

Remarks. This species is characterized by circular valves which have a subcircular, elevated ridge situated in about a midradial position. Several large, irregularly arranged puncta are situated near the valve center; several large puncta are also situated near the inner margin of the ridge. Numerous, small, irregular, radially aligned plications cover the valve face. Diameter is commonly 65–75 μm. This species may have affinities to *Acanthodiscus.*

Genus and species uncertain #3
(Plate 25, Figs. 8–9)

Remarks. This species is triangular with a flat, flangelike margin; the inner portion of the valve is raised into a triangular hump. The surface is covered with numerous pores. No similar species could be found in the literature.

Descriptions of New Taxa

The following section includes descriptions of seven new taxa discovered in material from Holes 511 and 513A. The new species are listed alphabetically by genus. All holotypes have been deposited in the Hustedt Collection in Bremerhaven, Federal Republic of Germany. Collections of type material are retained by Gombos.

Asterolampra gradiata **Gombos n. sp.**
(Plate 1, Figs. 4–6)

Description. Valves circular, central portion commonly nonaerolated; number of rays variable, but commonly six or seven, with a labiate process at the marginal end of each; areolated segments fasciculate, with 6 areolae in 10 μm measured radially; areolae at inner margin of areolated segments arranged in steplike pattern. Diameter of holotype 71 μm.

Holotype. Author's slide 511-11CC; holotype is circumscribed on slide and is illustrated in Plate 1, Figure 5.

Repository. Hustedt Collection, Bremerhaven, Federal Republic of Germany, catalog number Zu2/65.

Type locality. Deep Sea Drilling Project Site 511 (51°00.28′S; 46°58.30′W), on Maurice Ewing Bank of Falkland Plateau in Southwest Atlantic Ocean.

Type stratum. Sample 511-11,CC; 99 meters below sediment surface.

Age. Early Oligocene.

Asterolampra vulgaris **(Greville) var.** ***hyalina*** **Gombos n.f.**
(Plate 1, Figs. 3 and 9)

Description. An *Asterolampra vulgaris* Greville in which one-half to two-thirds of the inner portion of the areolated segments are hyaline; 3–4 rows of areolae are present on the outer or marginal portions of the segments; diameter of holotype 38 μm.

Holotype. Author's slide D278AS4; holotype is circumscribed on slide and is illustrated in Plate 1, Figure 3.

Repository. Hustedt Collection, Bremerhaven, Federal Republic of Germany, catalog number Zu2/67.

Type locality. Deep Sea Drilling Project Site 511 (51°00.28′S; 46°58.30′W), on Maurice Ewing Bank of Falkland Plateau in Southwest Atlantic Ocean.

Type stratum. Sample 511-6-1, 23–25 cm; 52.75 meters below sediment surface.

Age. Early Oligocene.

Hemiaulus taurus **Gombos n. sp.**
(Plate 19, Figs. 1–8)

Description. Valves subconical with a bulbous, subspherical upper part separated by a constricted zone from the lower part; two opposite, tapering horns arise from the bulbous upper part and form a broad U-shaped pattern. Valve surface covered with relatively large pores more or less randomly arranged on bulbous upper part and arranged in parallel rows on lower part and along horns; pore rows separated by ridges near constricted zone and along length of horns; three pores in 10 μm measured along pervalvar axis on lower part, 6 in 10 μm along middle part of horns. Diameter of holotype 27 μm; length of horns (measured in a straight line from point of departure from bulbous upper part to tips) 55 μm; distance between tips of horns 49 μm.

Remarks. No valves were observed with complete lower parts, so the nature of the margin could not be determined. Specimens with complete horns are rare.

Holotype. Author's slide D287L3; specimen is circumscribed on slide and is illustrated in Plate 19, Figs. 1–2.

Repository. Hustedt Collection, Bremerhaven, Federal Republic of Germany, catalog number Zu2/68.

Type locality. Deep Sea Drilling Project Site 513 (47°34.99′S; 24°38.40′W), on lower flank of Mid-Atlantic Ridge east of the Argentine Basin in Southwest Atlantic Ocean.

Type stratum. Sample 513A-15-2, 46–48 cm; 201 meters below sediment surface.

Age. Late Oligocene.

Rhizosolenia gravida **Gombos and Ciesielski n. sp.**
(Plate 11, Figs. 1–7)

Description. Valves subconical, flexed near base so that in girdle view one side appears slightly concave and the other somewhat convex. Height of valve including spine 147 μm, spine 49 μm long or about one-third the height of the valve; valve surface minutely punctate with puncta arranged in subparallel, often discontinuous rows. No complete frustules were observed so the number and nature of connecting bands could not be determined.

Remarks. This species is characterized by the flexed nature of the valve.

Holotype. Author's slide 511-4CC; holotype is circumscribed on slide and is illustrated in Plate 11, Fig. 1.

Repository. Hustedt Collection, Bremerhaven, Federal Republic of Germany, catalog number Zu2/69.

Type locality. Deep Sea Drilling Project Site 511 (51°00.28′S; 46°58.30′W), on Maurice Ewing Bank of Falkland Plateau in the Southwest Atlantic Ocean.

Type stratum. 511-4,CC; 33.5 meters below sediment surface.

Age. Early Oligocene.

Thalassiosira hydra **Gombos n. sp.**
(Plate 7, Figs. 1–6)

Description. Valves circular, concave, areolate in tangential rows with secondary, inwardly curved rows; 4 areolae in 10 μm measured tangentially, 5 in 10 μm measured radially; prominent external tubes of internal labiate processes arranged more or less symmetrically on valve face, usually closer to the margin than to the center, number variable though commonly 2–3; margin hyaline. Diameter of holotype 71 μm.

Holotype. Author's slide DSDP 511-5CC; holotype is circumscribed on slide and is illustrated in Plate 7, Figures 1–2.

Repository. Hustedt Collection, Bremerhaven, Federal Republic of Germany, catalog number Zu2/70.

Type locality. Deep Sea Drilling Project Site 511 (51°00.28′S; 46°58.30′W) on Maurice Ewing Bank of Falkland Plateau in Southwest Atlantic Ocean.

Type stratum. Sample 511-5,CC; 43 meters below sediment surface.

Age. Early Oligocene.

Thalassiosira primalabiata **Gombos n. sp.**
(Plate 9, Figs. 1–8)

Description. Valves circular, slightly concave; areolae in tangential rows with secondary marginally concave rows; areolae uniform in size, 7 in 10 μm measured radially, 8 in 10 μm measured tangentially; a single, prominent labiate process situated at center of valve. Diameter of holotype 63 μm, average diameter of 40 measured specimens 66 μm.

Holotype. Author's slide D287N3; holotype is circumscribed on slide and is illustrated in Plate 9, Figures 7–8.

Repository. Hustedt Collection, Bremerhaven, Federal Republic of Germany, catalog number Zu2/71.

Type locality. Deep Sea Drilling Project Site 513 (47°34.99′S; 24°38.40′W) on lower flank of Mid-Atlantic Ridge east of the Argentine Basin in Southwest Atlantic Ocean.

Type stratum. Sample 513A-15-4, 131–132 cm; 204.82 meters below sediment surface.

Age. Late Oligocene.

Triceratium groningensis Reinhold f. *quadrata* Gombos and Ciesielski n.f.
(Plate 15, Figs. 4-6)

Description. Like the species, but with a quadrate outline; length of diagonal of holotype is 103 μm.

Remarks. The restricted range of this form in Hole 513A, Core 15 (latest late Oligocene) suggests that it may be of stratigraphic value.

Holotype. Author's slide D287J5(2); holotype is circumscribed on slide and is illustrated in Plate 15, Figure 6.

Repository. Hustedt Collection, Bremerhaven, Federal Republic of Germany, catalog number Zu2/72.

Type locality. Deep Sea Drilling Project Site 513 (47°34.99′S; 24°38.40′W) on lower flank of Mid-Atlantic Ridge east of the Argentine Basin in Southwest Atlantic Ocean.

Type stratum. Sample 513A-15-1, 21-23 cm; 199.23 meters below sediment surface.

Age. Late Oligocene.

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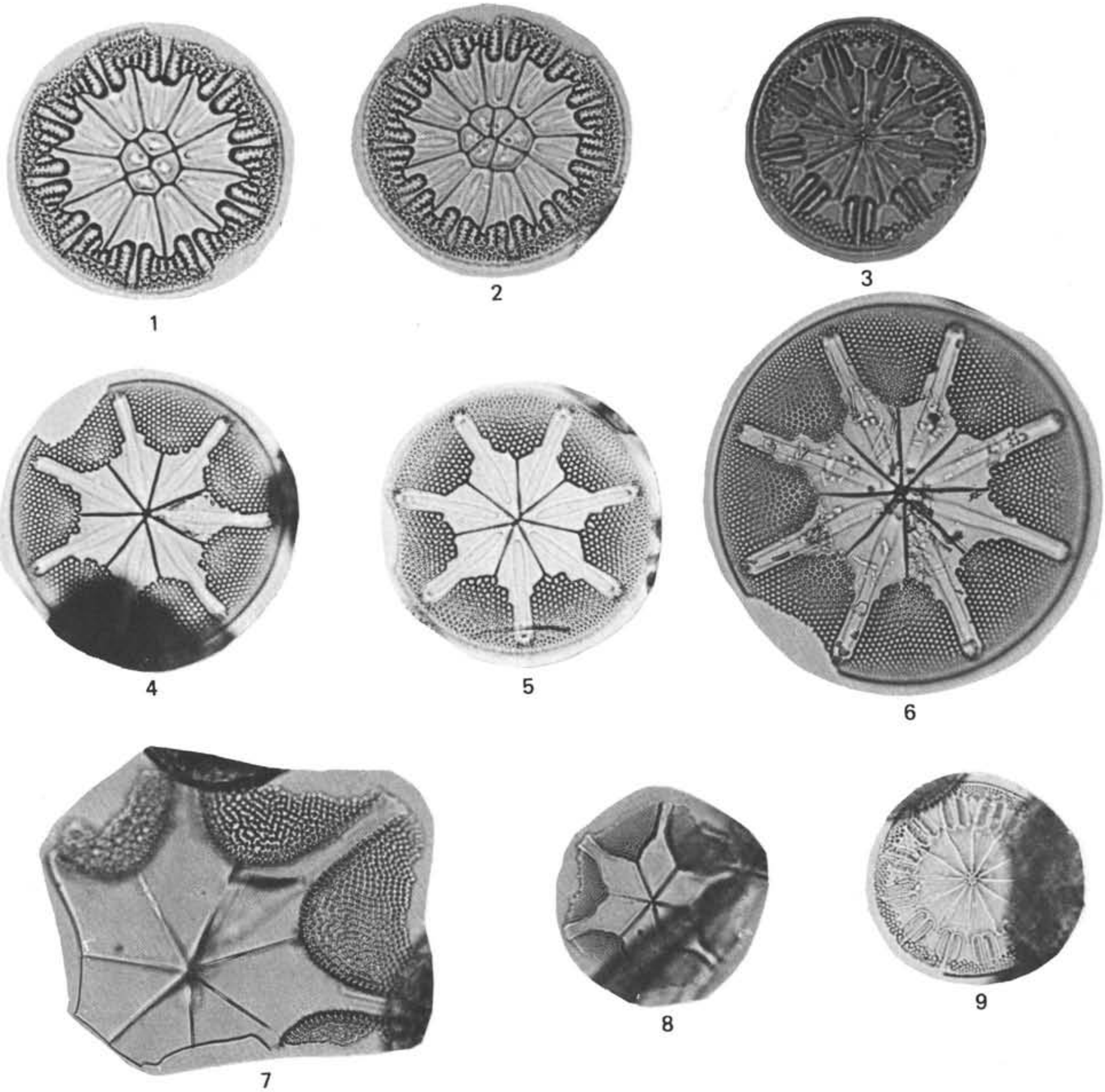


Plate 1. (All magnifications ×500 unless otherwise noted.) 1–3. *Asterolampra vulgaris* Greville (1–2) Sample 511-16,CC (3) v. *hyalina* n.v., holotype. Sample 511-6-1, 23–25 cm. ×800. 4–6. *Asterolampra gradiata* n. sp. (4) Sample 511-11,CC (5) Holotype. Sample 511-11,CC (6) Sample 511-12-1, 11–13 cm. 7. *Asterolampra marylandica* Ehrenberg. Sample 511-2,CC. 8. *Asterolampra acutiloba* Forti. Sample 511-3-3, 67–69 cm. 9. *Asterolampra vulgaris* Greville v. *hyalina* n.v. Sample 513A-29-1, 80–82 cm.

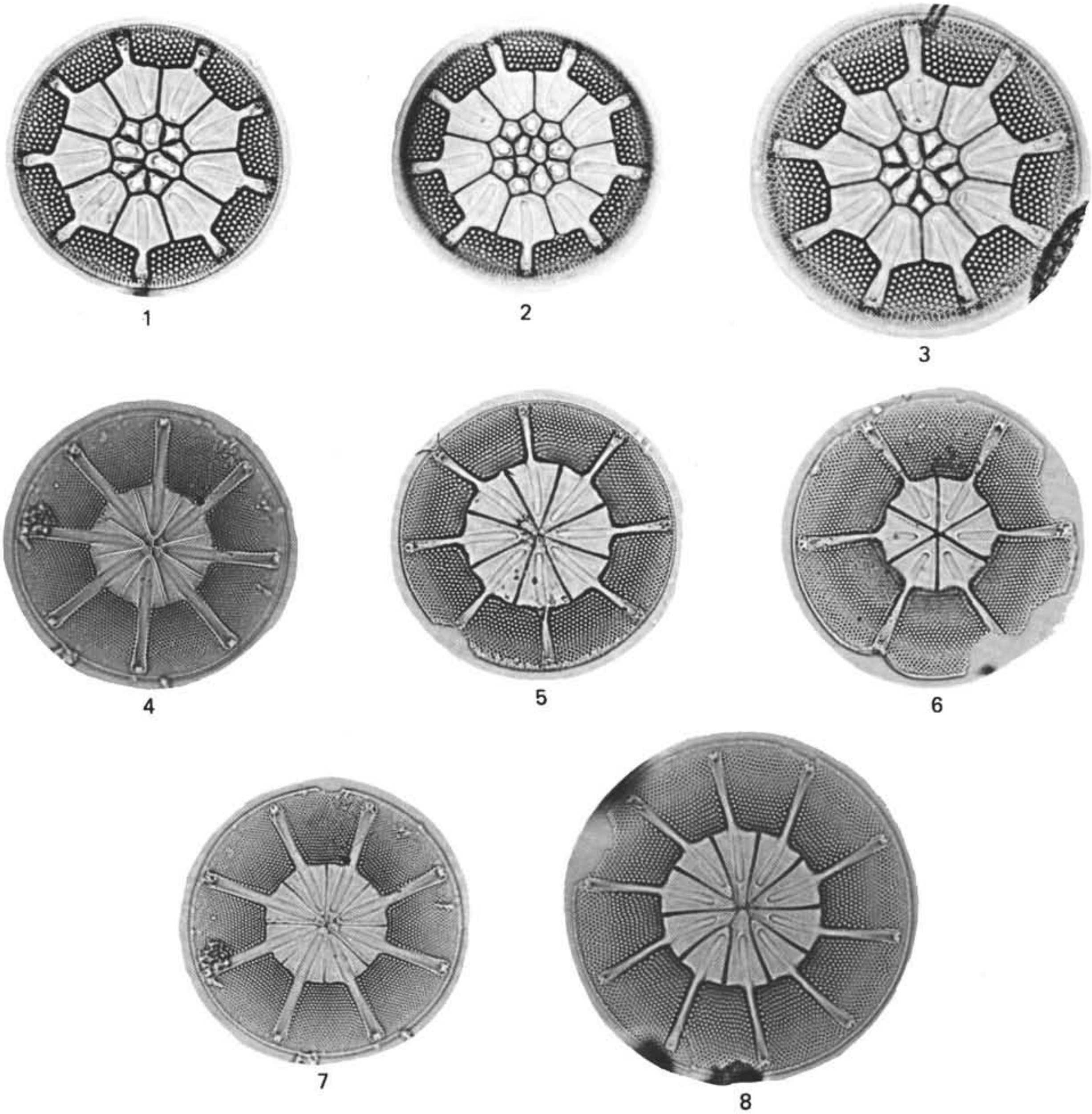


Plate 2. (All magnifications ×500.) 1–3. *Asterolampra schmidtii* Hajós (1) Sample 511-5,CC (2) Sample 511-8,CC (3) Sample 511-1,CC. 4–8. *Asterolampra punctifera* (Grove) Hanna (4) Sample 511-13,CC (5) Sample 511-5,CC (6) Sample 511-1,CC (7) Sample 511-13,CC (8) Sample 511-5,CC.

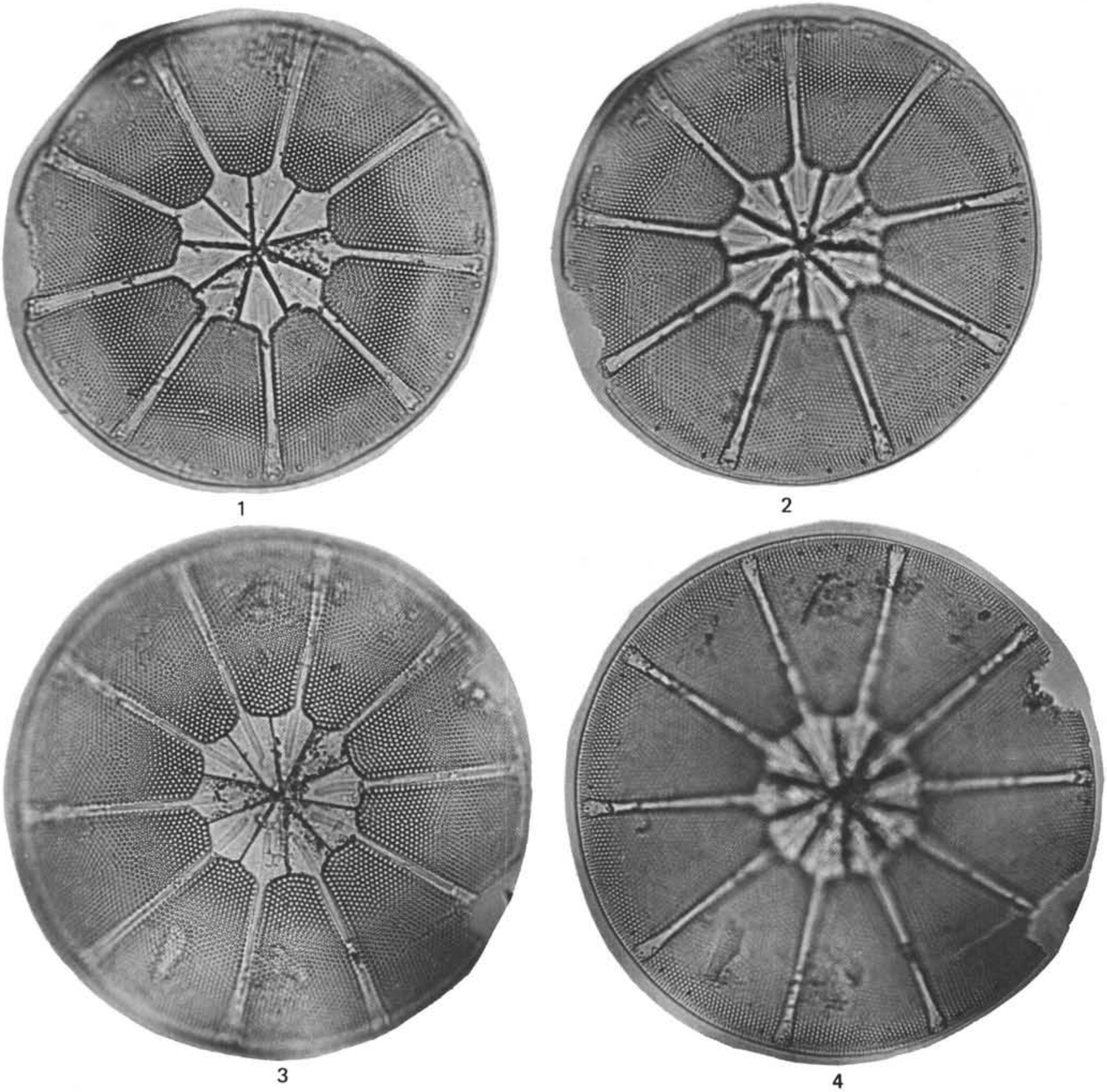


Plate 3. (All magnifications ×500.) 1–4. *Asterolampra tela* n. sp. (1–2) Holotype. Sample 513A-15-1, 21–23 cm (3–4) Sample 513A-15-1, 21–23 cm.

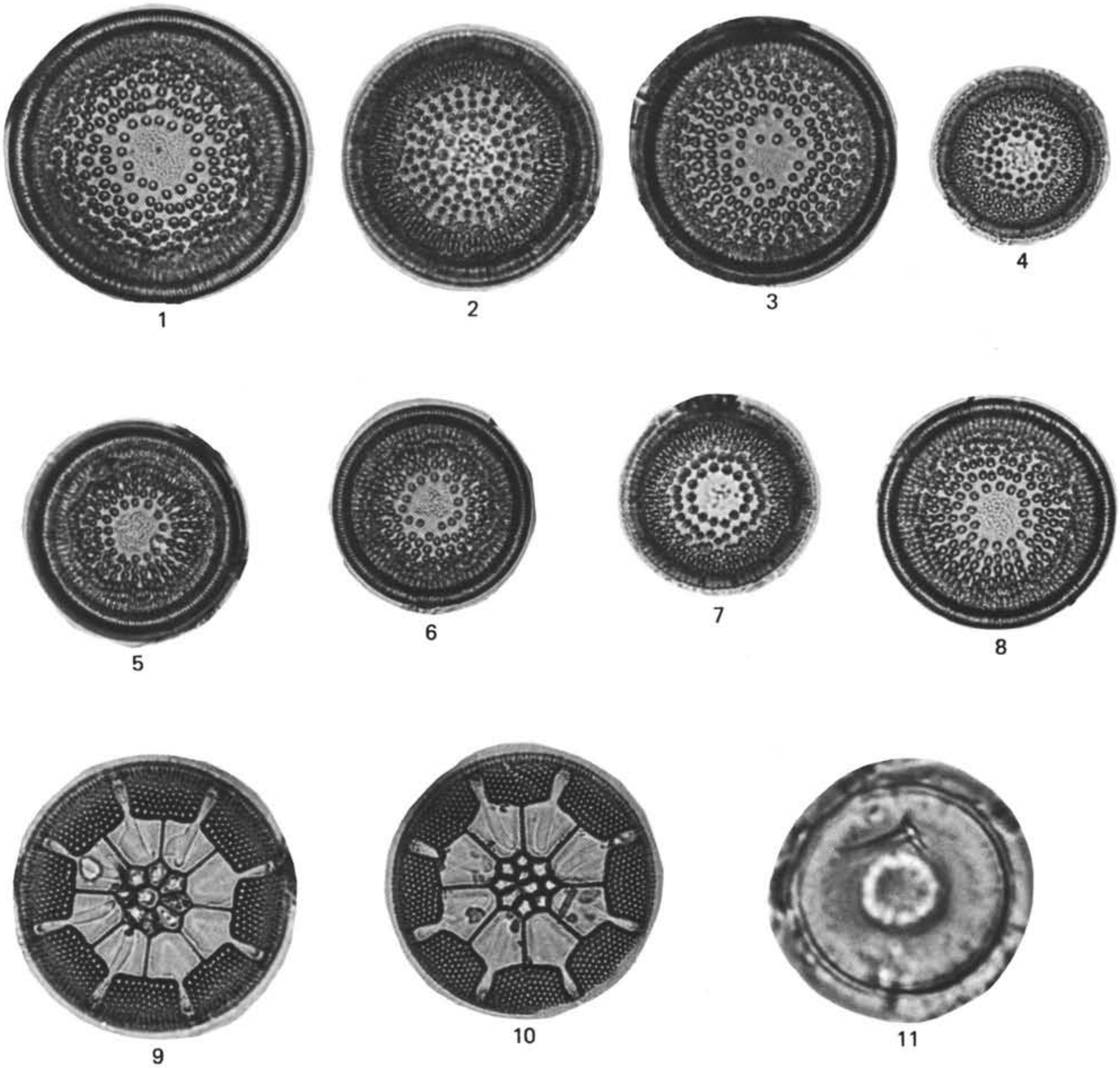


Plate 4. (All magnifications ×500 unless otherwise noted.) 1–8. *Coscinodiscus superbus* Hardman s.l. (1–2) Sample 511-3-1, 67–69 cm (3–8) Sample 511-3-1, 67–69 cm. 9–10. *Asterolampra schmidtii* Hajós. Sample 511-3-1, 67–69 cm. 11. *Podosira polita* Hanna and Grant. Sample 512-11-1, 74–76 cm. ×2000.

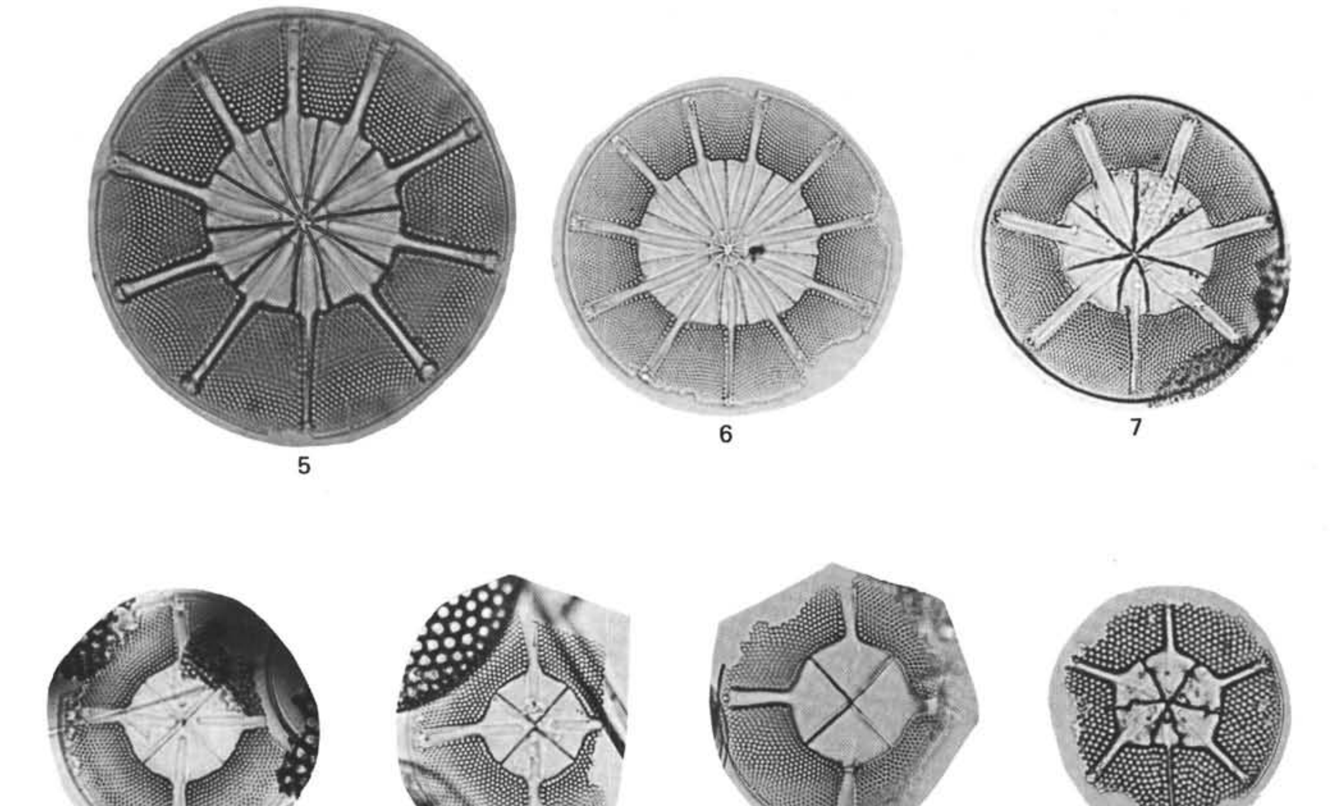


Plate 5. (All magnifications ×500 unless otherwise noted.) 1–4. *Skeletonema barbadensis* Greville. Sample 513A-33-6, 138–140 cm. ×800. 5–7. *Asteromphalus oligocenicus* Schrader and Fenner (5) Sample 511-5,CC. ×750 (6) Sample 511-1,CC (7) Sample 511-6-1, 23–25 cm. 8–10. Asterolampra punctifera (Grove) Hanna. Sample 511-3-3, 67–69 cm. 11. *Asteromphalus symmetricus* Schrader and Fenner. Sample 513A-14-2, 94–96 cm.

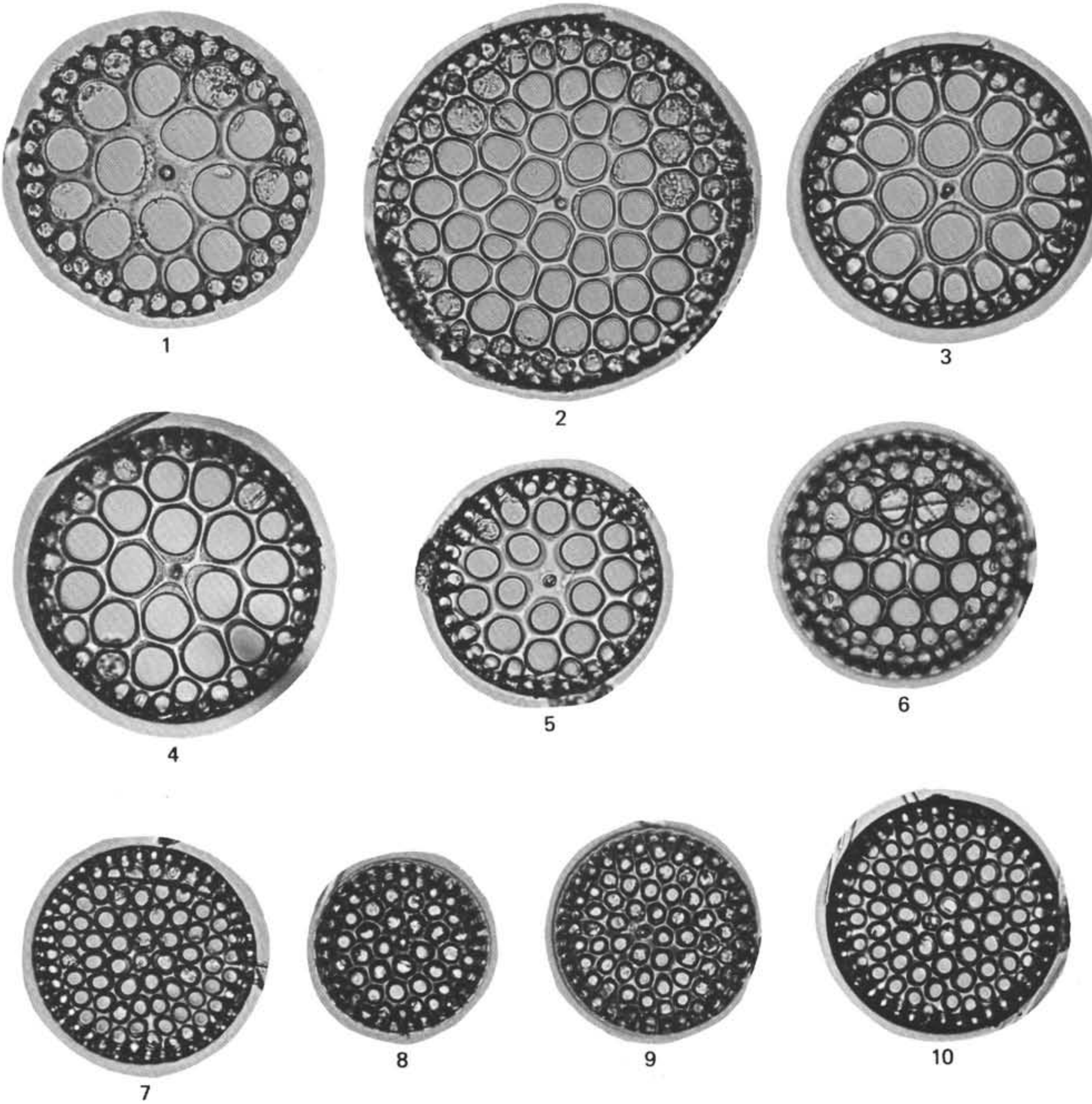


Plate 6. (All magnifications ×500.) 1–6. *Rocella gelida* (Mann) Bukry (1–4) Sample 513A-15-1, 21–23 cm (5–6) Sample 513A-15-6, 106–108 cm. 7–10. *Rocella vigilans* (Schmidt) Fenner. Sample 513A-17-5, 115–117 cm.

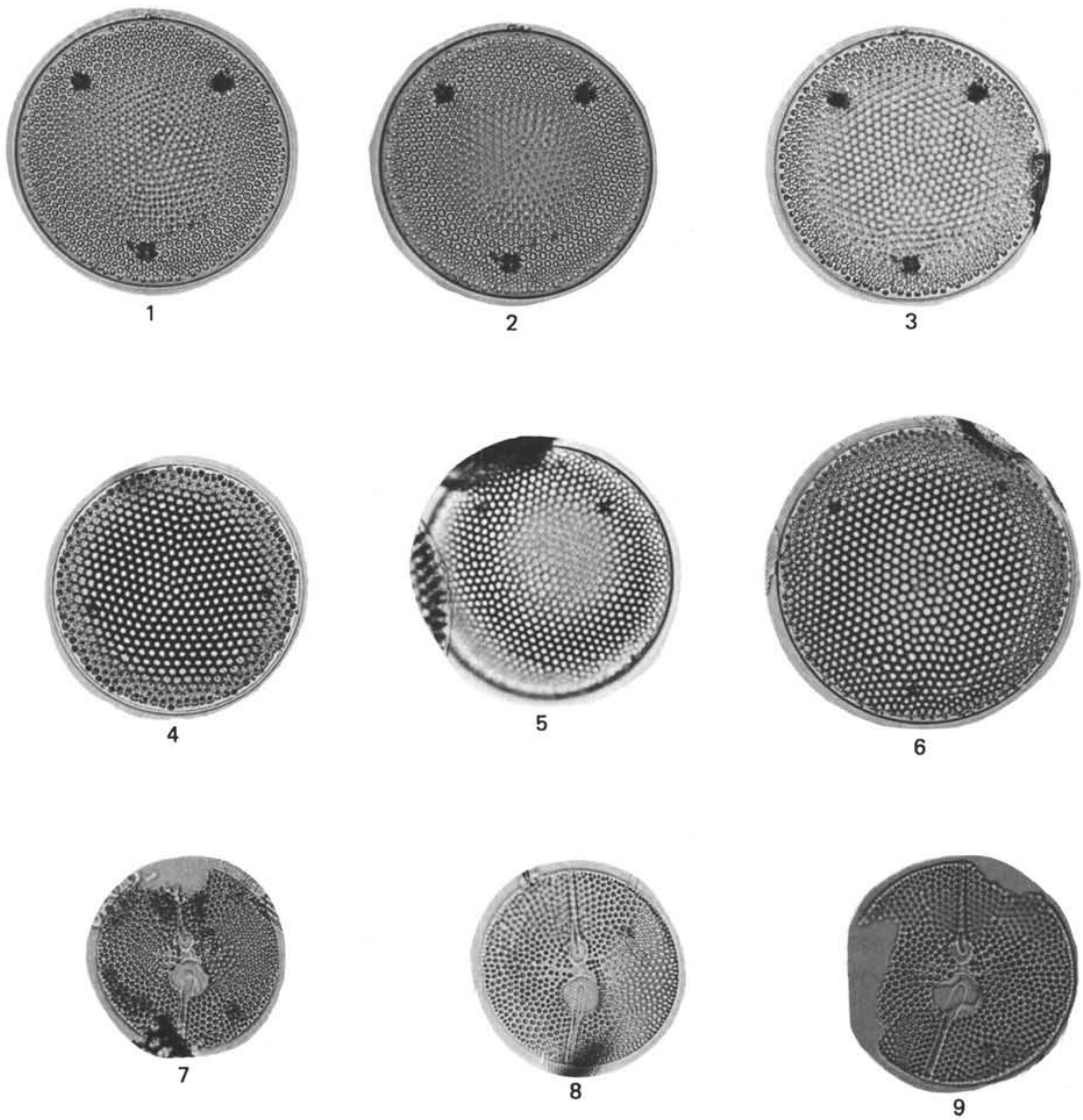


Plate 7. (All magnifications ×500.) 1–6. *Thalassiosira hydra* n. sp. (1–2) Holotype. Sample 511-5,CC (3–4) Sample 511-5,CC (5) Sample 511-8,CC (6) Sample 511-3-2, 67–69 cm. 7–9. *Rylandsia inaequiradiata* Barker and Meakin (7) Sample 511-17-1, 83–85 cm (8) Sample 511-18-2, 21–23 cm (9) Sample 511-17-1, 83–85 cm.

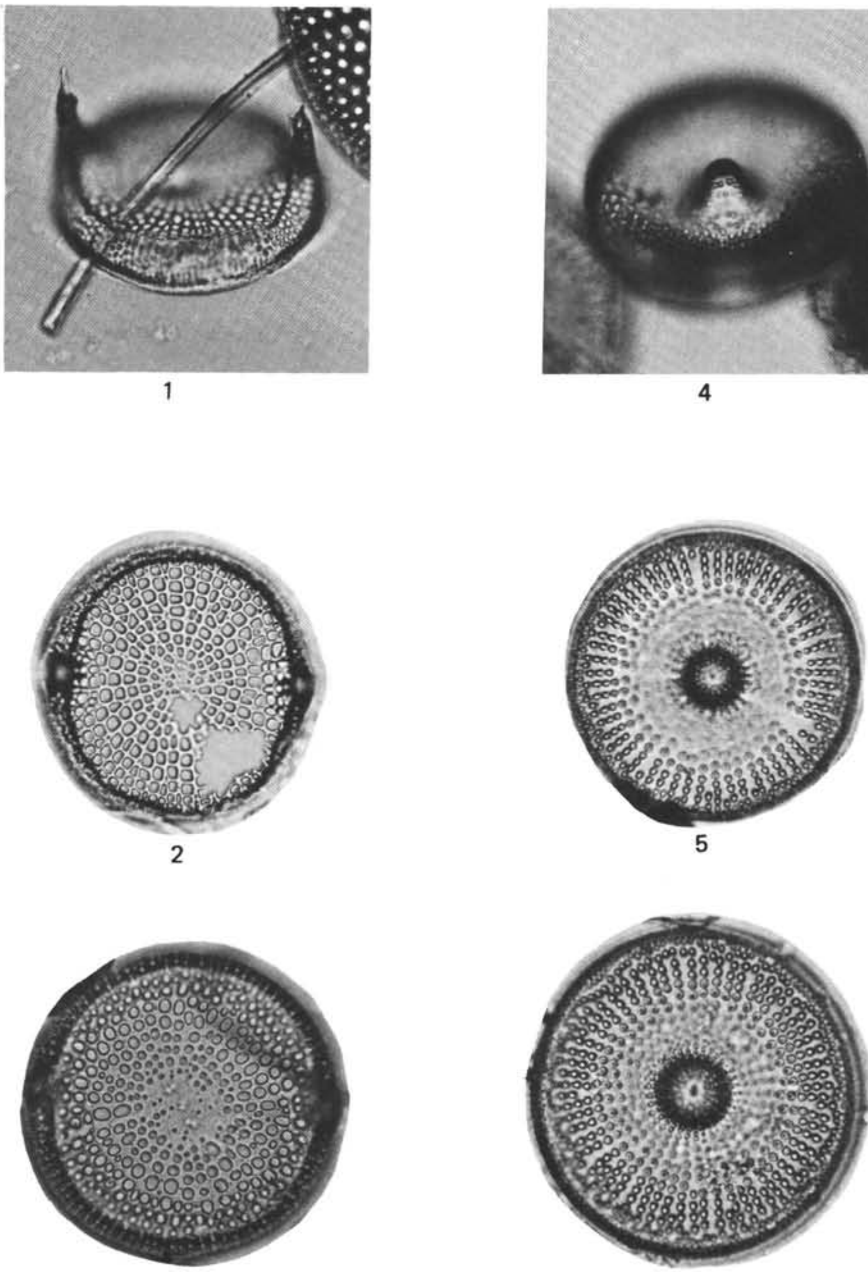


Plate 8. (All magnifications ×500.) 1–3. *Hemiaulus pacificus* (Hajós) n. comb. (1) Sample 511-8,CC (2) Sample 511-13,CC (3) Sample 511-2-2, 101–103 cm. 4–6. *Cestodiscus* sp. Sample 511-16,CC.

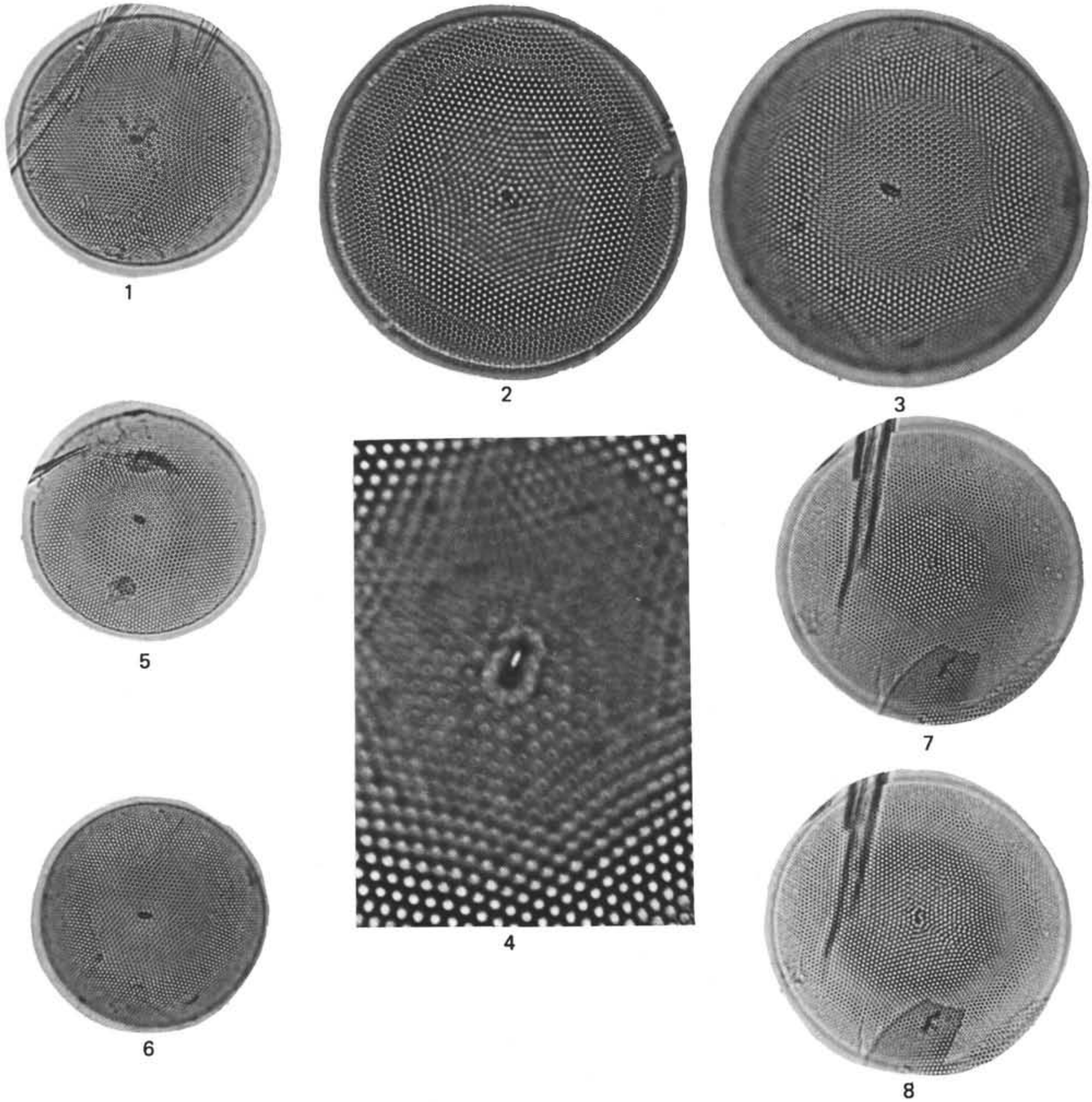


Plate 9. (All magnifications ×500 unless otherwise noted.) 1–8. *Thalassiosira primalabiata* n. sp. (1) Sample 513A-15-4, 131–133 cm (2) Sample 513A-15-4, 131–133 cm. ×800 (3) Sample 513A-15-6, 106–108 cm. ×800 (4) Sample 513A-15-4, 131–133 cm. ×2000 (5) Sample 513A-15-4, 131–133 cm. (6) Sample 513A-15-6, 106–108 cm (7) Holotype. Sample 513A-15-4, 131–133 cm (8) Sample 513A-15-4, 131–133 cm.

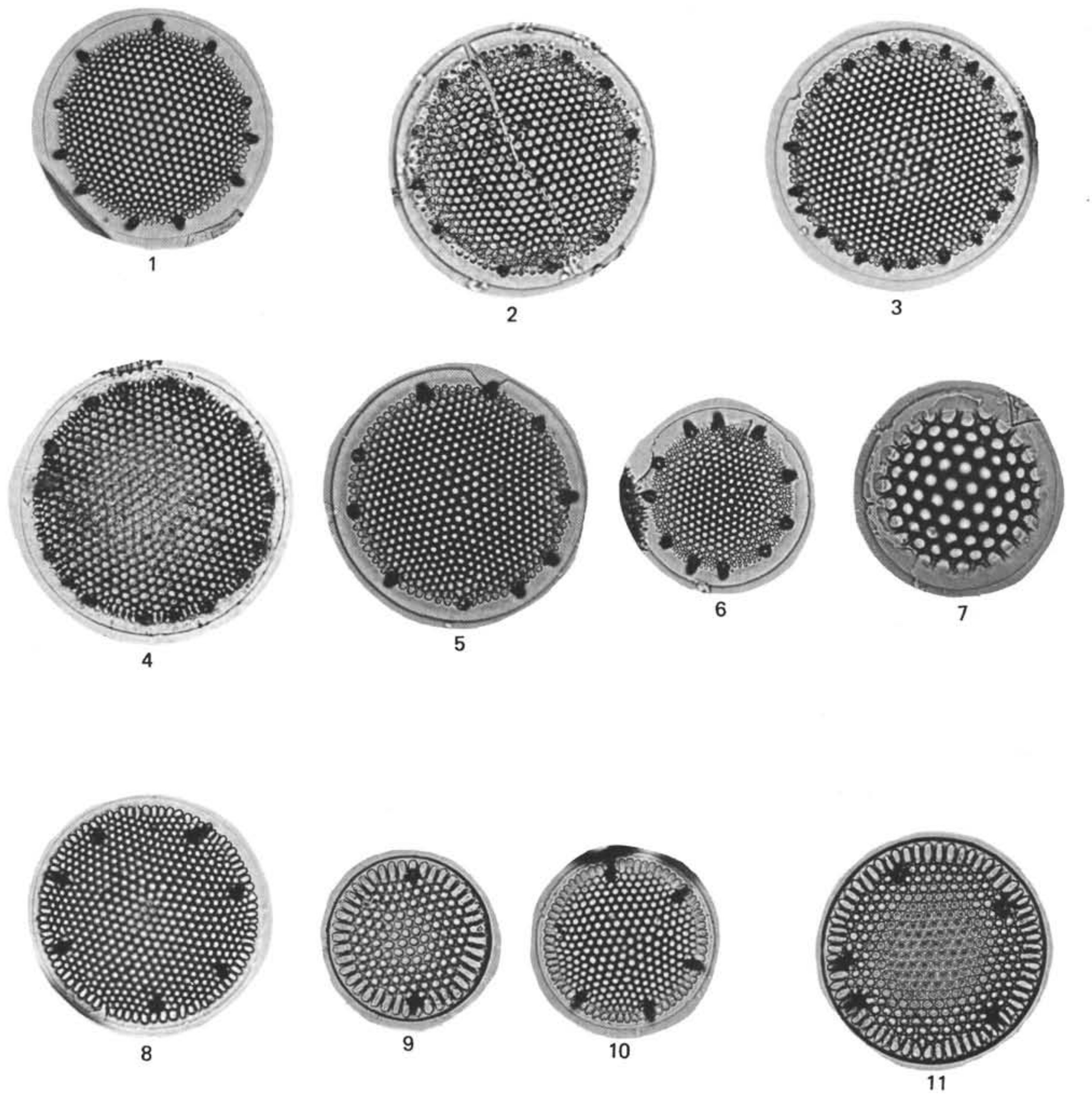


Plate 10. (All magnifications ×500.) 1–6. *Stephanopyxis hyalomarginata* Hajós (1) Sample 511-3-2, 67–69 cm (2) Sample 511-2,CC (3) Sample 511-2-2, 101–103 cm (4) Sample 511-2,CC (5) Sample 511-2-2, 101–103 cm (6) Sample 511-1-4, 16–18 cm. 7. *Stephanopyxis superba* (Greville) Grunow. Sample 511-16-1, 22–24 cm. 8–11. *Stephanopyxis eocaenica* Hajós (8) Sample 511-2,CC (9) Sample 511-16-1, 22–24 cm (10) Sample 511-1-4, 16–18 cm (11) Sample 511-16-1, 22–24 cm.

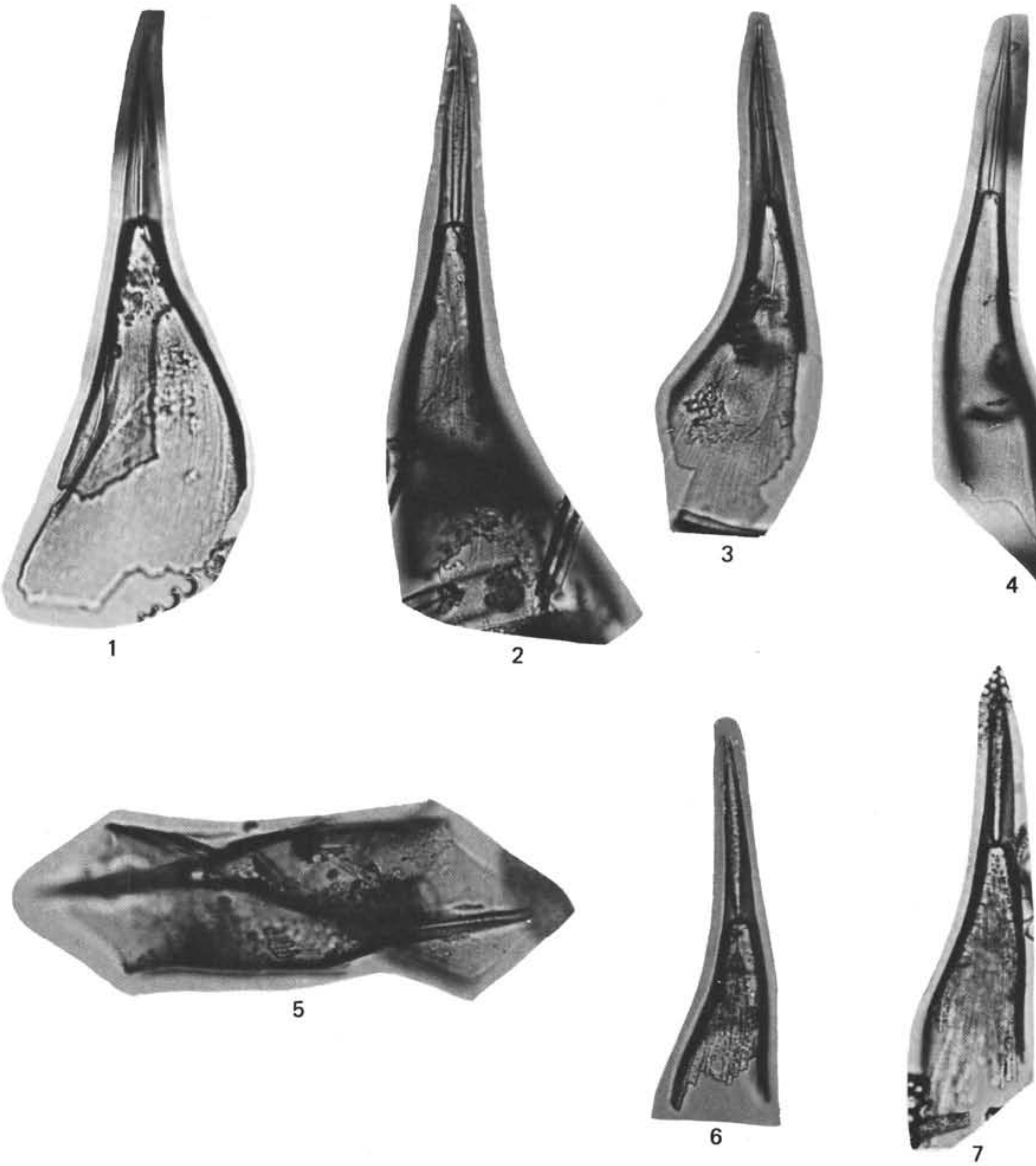


Plate 11. (All magnifications ×500.) 1–7. *Rhizosolenia gravida* n. sp. (1) Holotype. Sample 511-4,CC (2–3) Sample 511-9-5, 82–84 cm (4) Sample 511-9-6, 82–84 cm (5) Sample 511-4,CC (6–7) Sample 511-9-5, 82–84 cm.

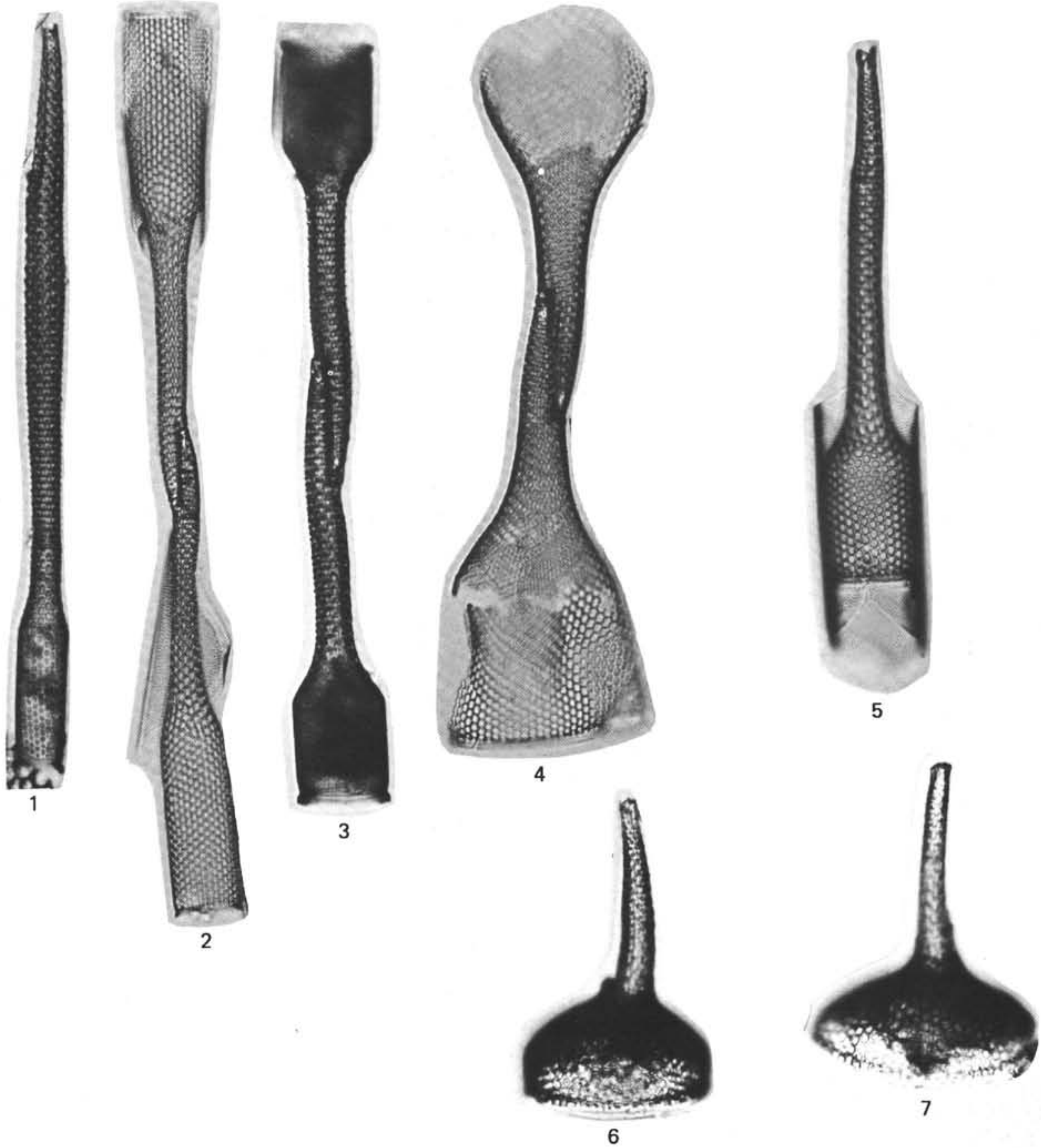


Plate 12. (All magnifications ×500.) 1–5. *Pyxilla prolongata* Brun s.l. (1) Sample 511-13,CC (2) Sample 511-12-1, 11–13 cm (3) Sample 511-2,CC (4–5) Sample 511-12-1, 11–13 cm 6–7. *Pyrgupyxis eocena* Hendey. Sample 511-13,CC.

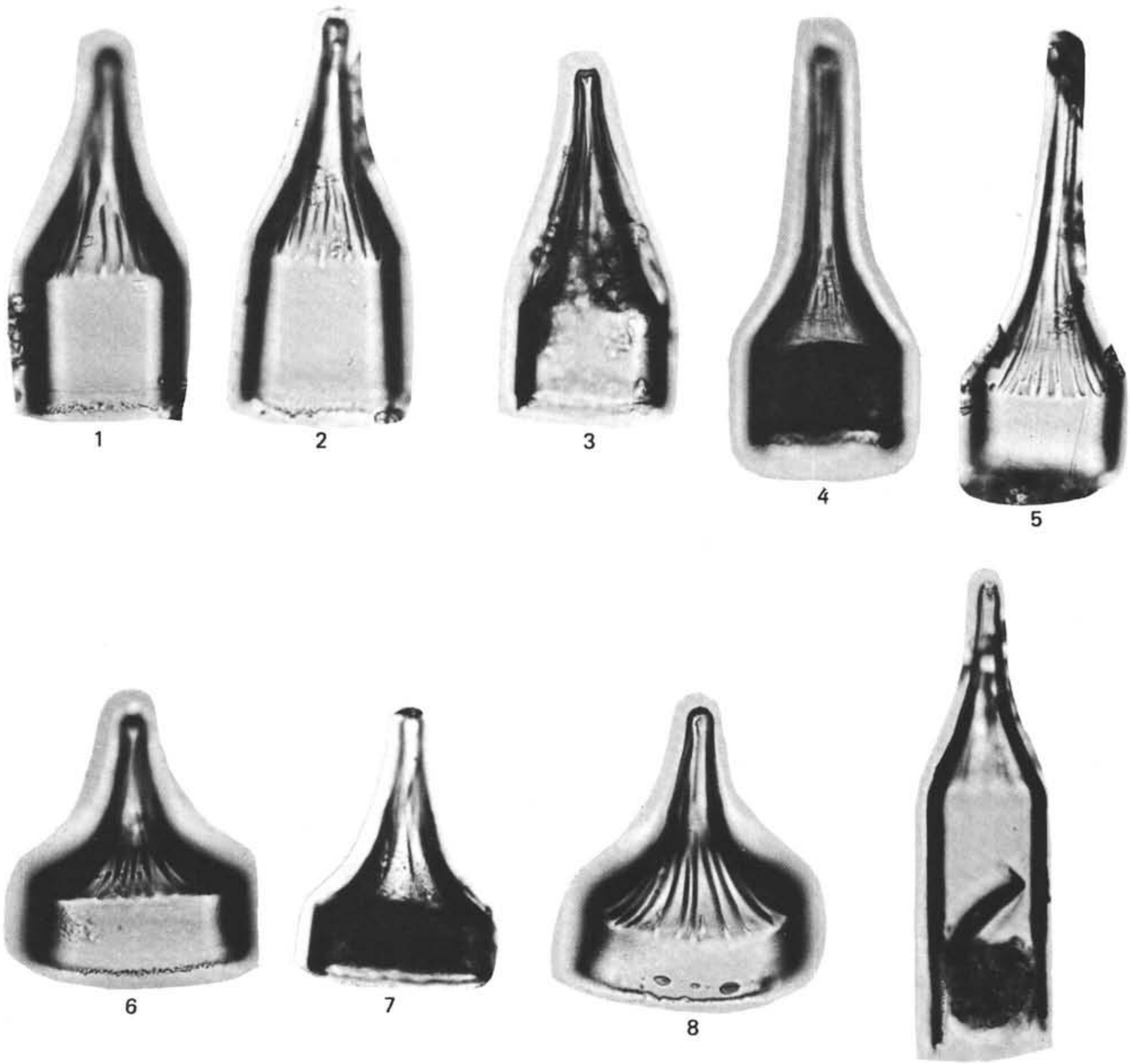


Plate 13. (All magnifications ×500). 1–3. *Pterotheca danica* (Grunow) Forti (1–2) Sample 511-2,CC (3) Sample 511-13,CC. 4–5. *Pterotheca spada* Tempère and Brun (4) Sample 511-2,CC (5) Sample 511-1,CC. 6–8. *Pterotheca major* Jousé (6–7) Sample 511-2,CC (8) Sample 511-13, CC. 9. *Pterotheca danica* (elongate variety). Sample 511-13,CC.

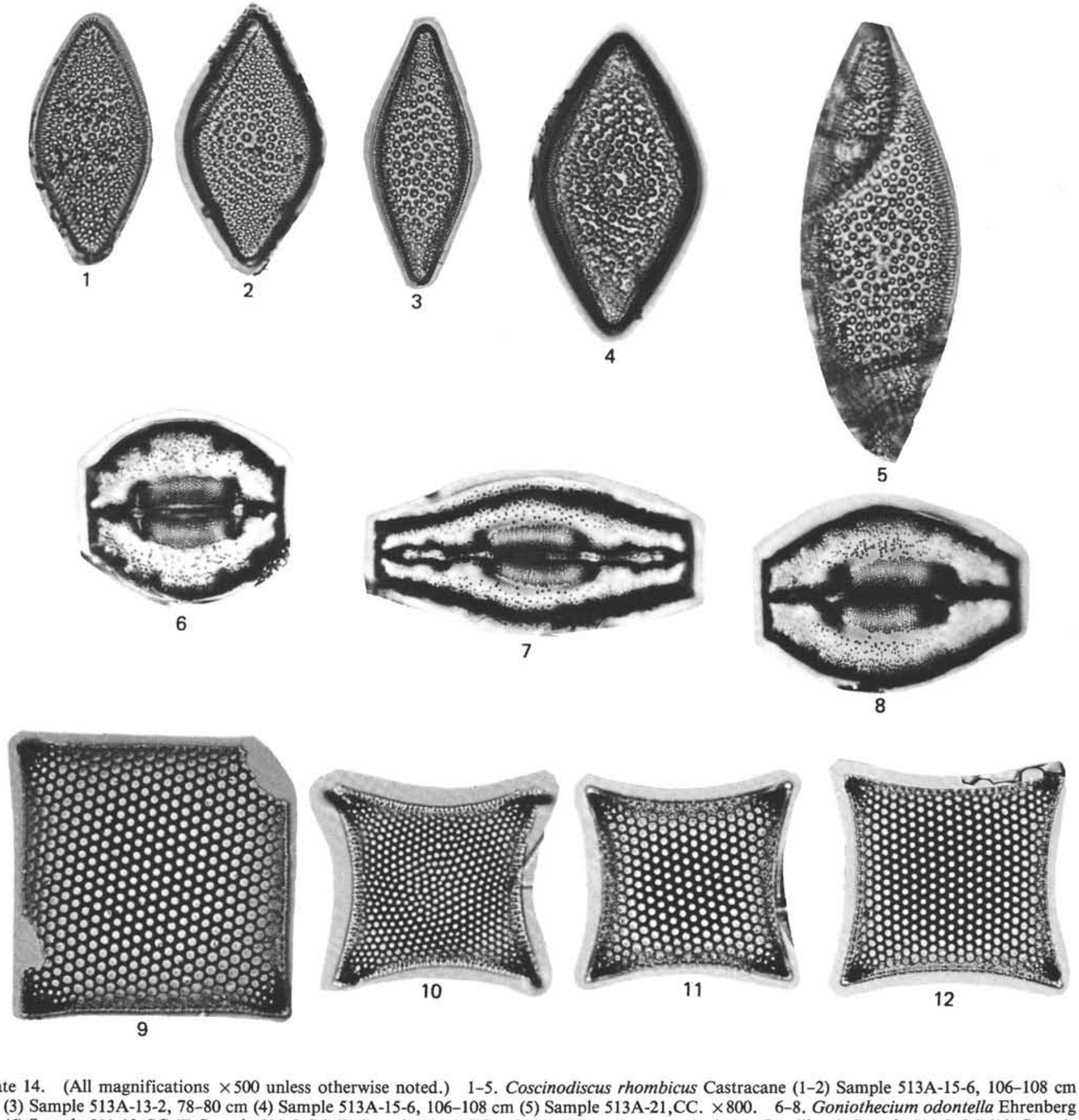


Plate 14. (All magnifications ×500 unless otherwise noted.) 1–5. *Coscinodiscus rhombicus* Castracane (1–2) Sample 513A-15-6, 106–108 cm (3) Sample 513A-13-2, 78–80 cm (4) Sample 513A-15-6, 106–108 cm (5) Sample 513A-21,CC. ×800. 6–8. *Goniothecium odontella* Ehrenberg (6) Sample 511-13,CC (7) Sample 511-5,CC (8) Sample 511-2,CC. 9–11. *Triceratium unguiculatum* Greville s.l. Sample 511-2,CC (10) Sample 511-5,CC (11) Sample 511-5,CC (12) Sample 511-5,CC.

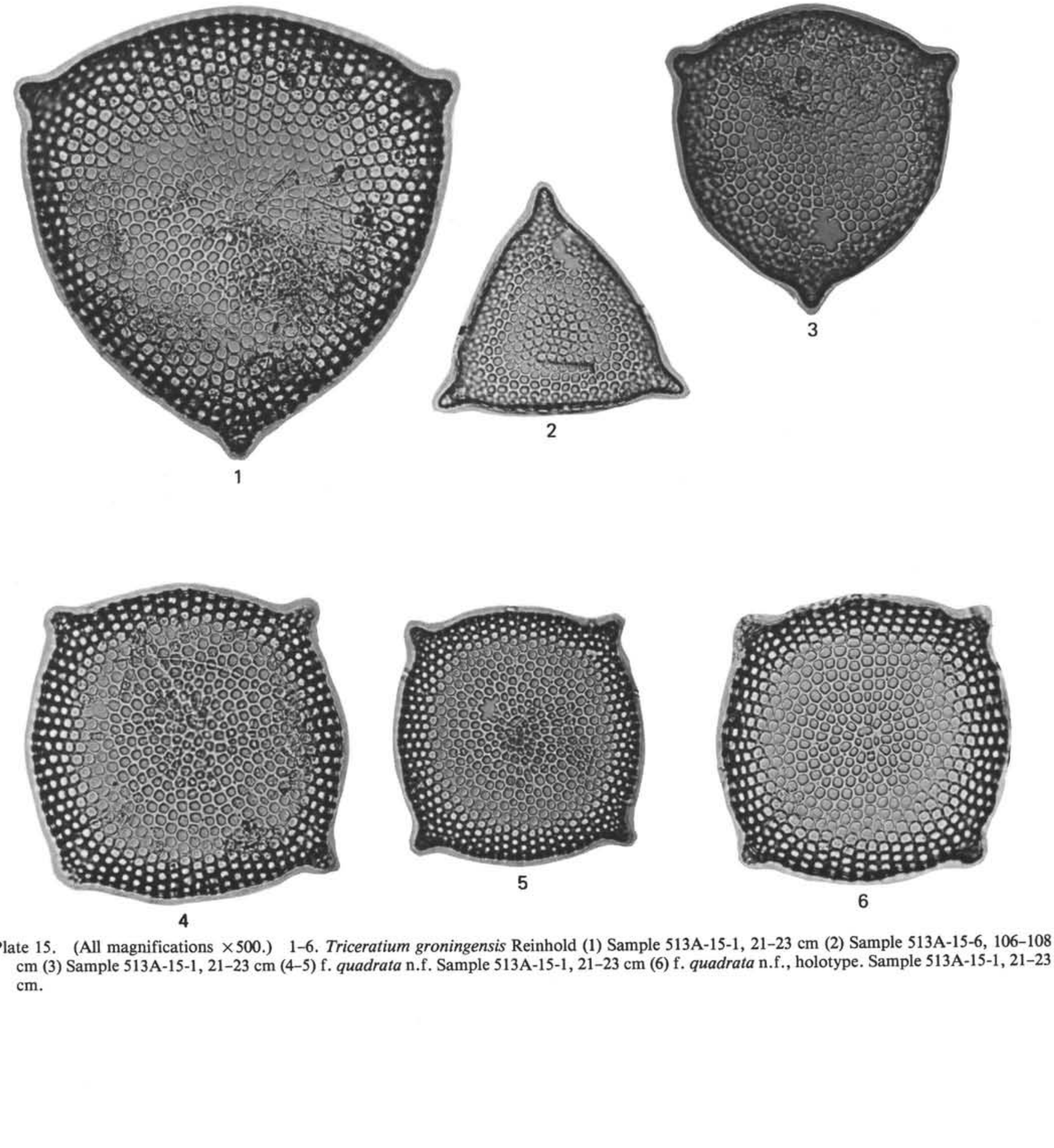


Plate 15. (All magnifications ×500.) 1–6. *Triceratium groningensis* Reinhold (1) Sample 513A-15-1, 21–23 cm (2) Sample 513A-15-6, 106–108 cm (3) Sample 513A-15-1, 21–23 cm (4–5) f. *quadrata* n.f. Sample 513A-15-1, 21–23 cm (6) f. *quadrata* n.f., holotype. Sample 513A-15-1, 21–23 cm.

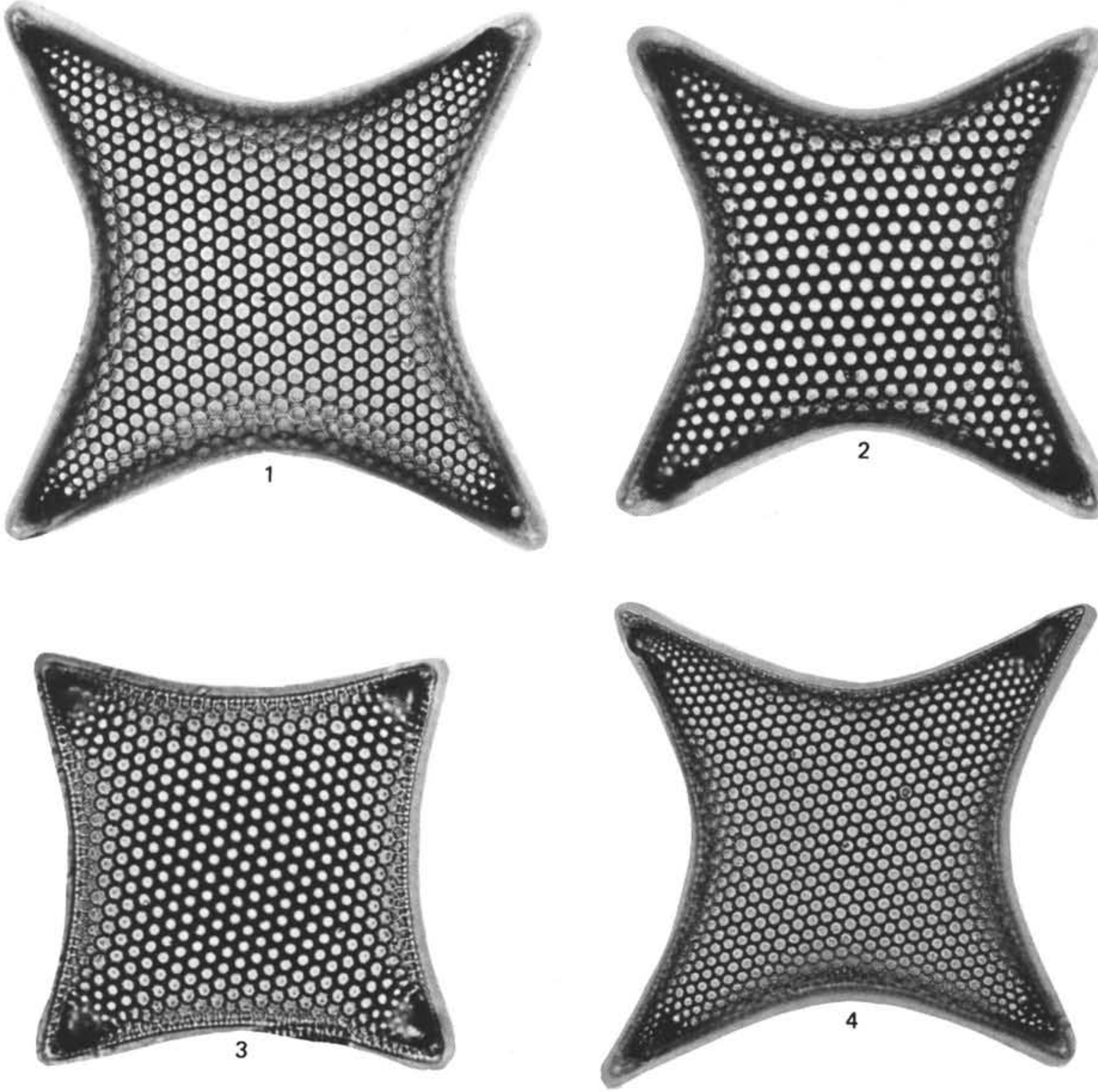


Plate 16. (All magnifications ×500.) 1–4. *Triceratium unguiculatum* Greville s.l. (1–2) Sample 511-12-1, 11–13 cm, (3) Sample 511-4-1, 10–12 cm (4) Sample 511-12-1, 11–13 cm.

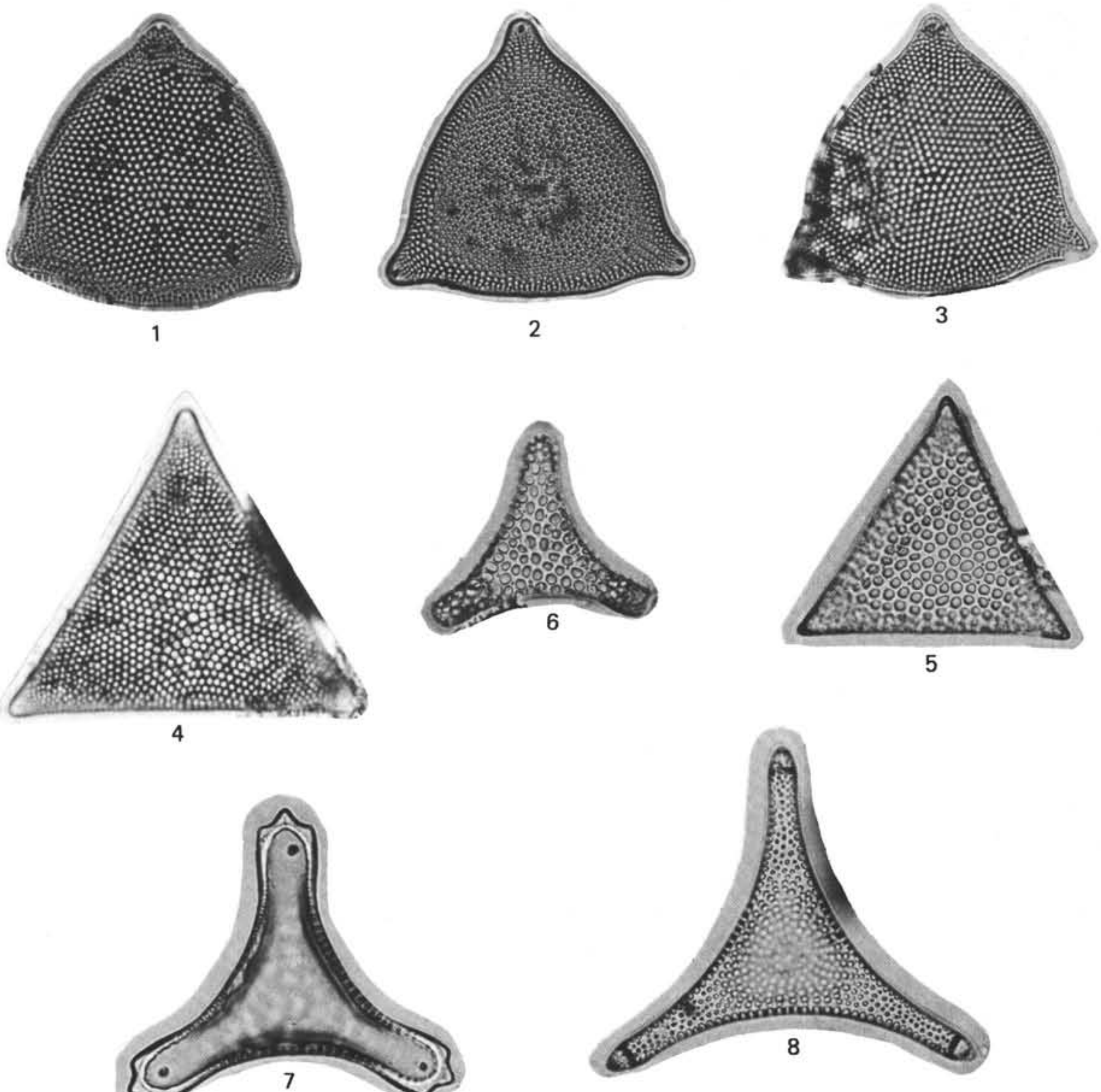


Plate 17. (All magnifications ×500.) 1–3. *Pseudotriceratium radiosoreticulatum* Grunow (1–2) Sample 511-12-2, 11–13 cm (3) Sample 511-13,CC. 4. *Pseudotriceratium chenevieri* (Meister) Gleser. Sample 5-1-1,CC. 5–6. *Triceratium macroporum* Hajós (5) Sample 511-17-2, 83–85 cm (6) (Concave form.) Sample 511-10-1, 11–13 cm. 7. *Trinacria simulacrum* Grove and Sturt. Sample 511-5,CC. 8. *Trinacria excavata* Heiberg. Sample 511-5,CC.

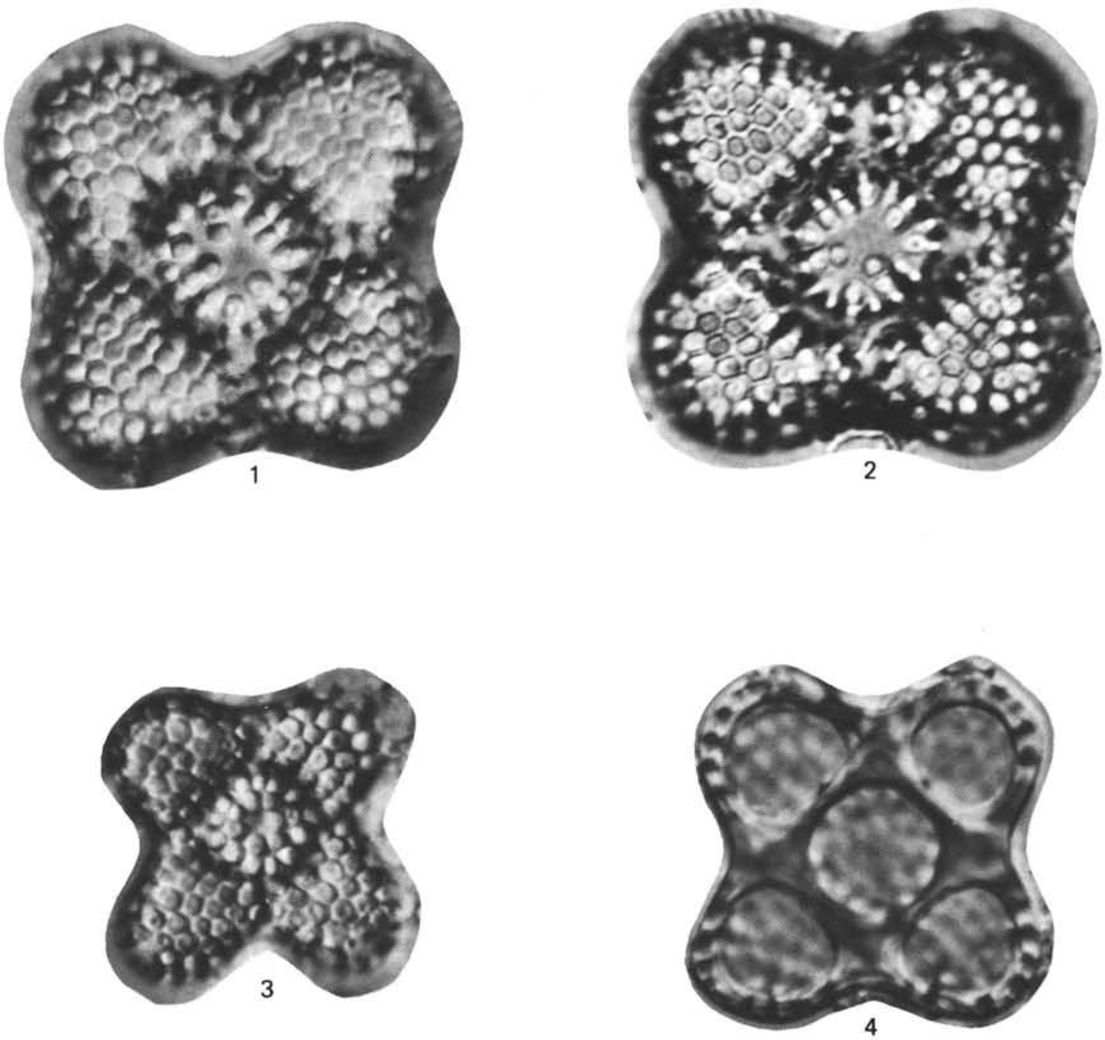


Plate 18. (All magnifications ×2000.) 1–4. *Lisitzinia ornata* Jousé. Sample 513A-18-2, 143–145 cm.

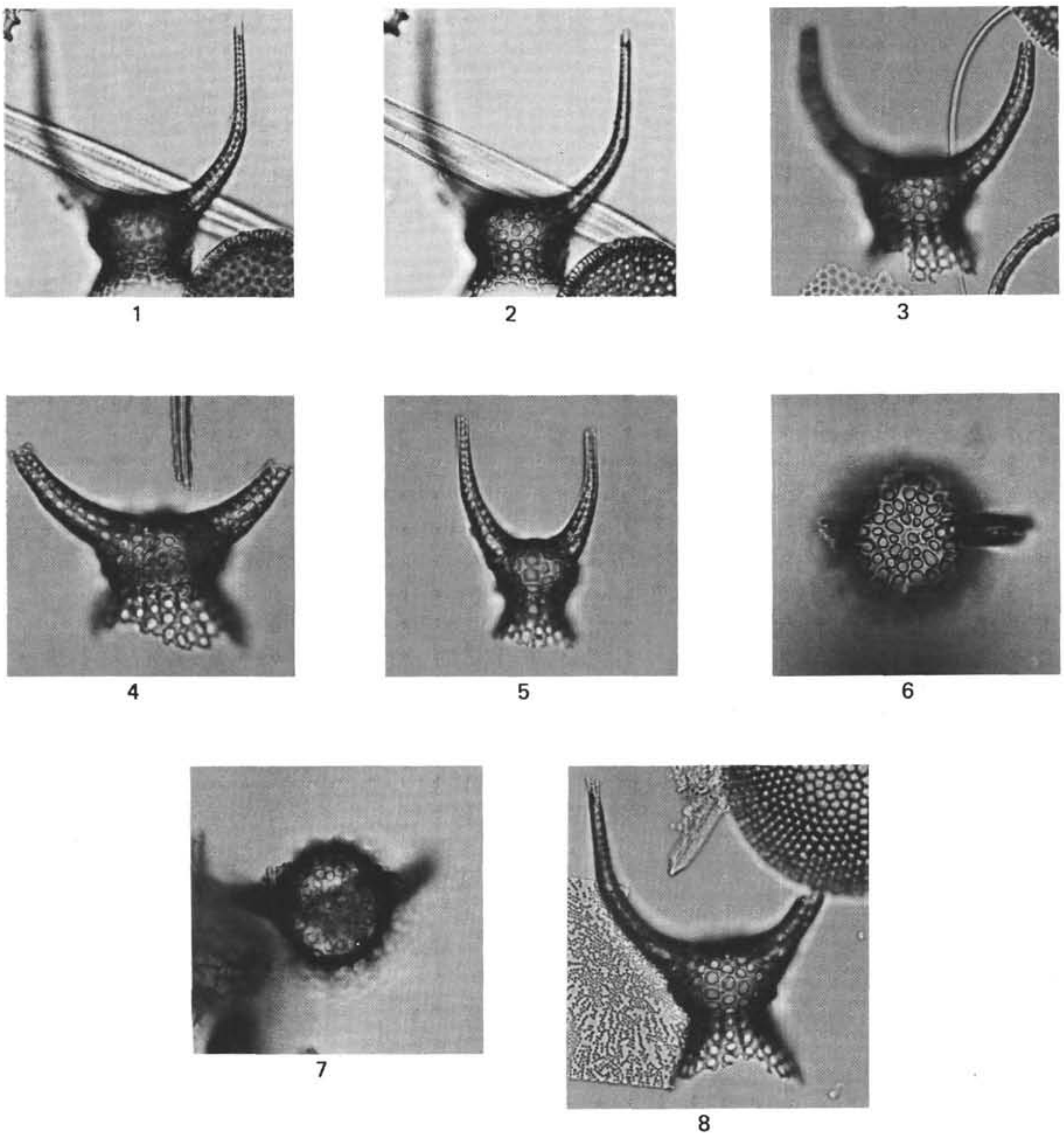


Plate 19. (All magnifications ×500.) 1–8. *Hemiaulus taurus* n. sp. (1–2) Holotype. Sample 513A-15-2, 46–48 cm (3–4) Sample 513A-15-2, 46–48 cm (5) Sample 513A-15-4, 131–133 cm (6) Sample 513A-15-2, 46–48 cm (7) Sample 513A-15-4, 131–133 cm (8) Sample 513A-15-2, 46–48 cm.

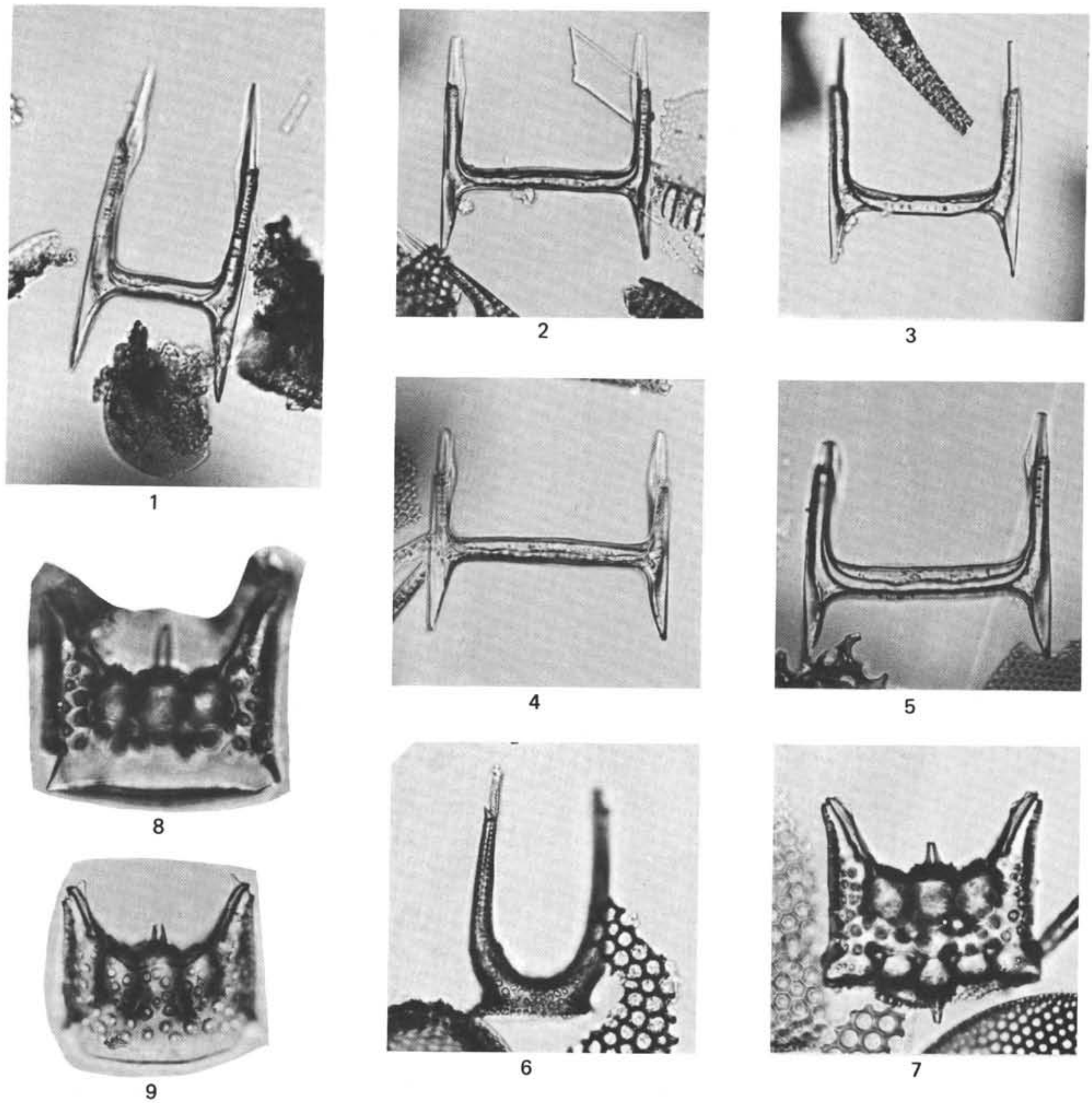


Plate 20. (All magnifications ×500.) 1–5. *Hemiaulus caracteristicus* Hajós. Sample 511-10-1, 11–13 cm. 6. *Hemiaulus incisus* Hajós. Sample 511-13,CC. 7–9. *Hemiaulus* sp. (7) Sample 511-13,CC (8) Sample 511-16,CC (9) Sample 511-13,CC.

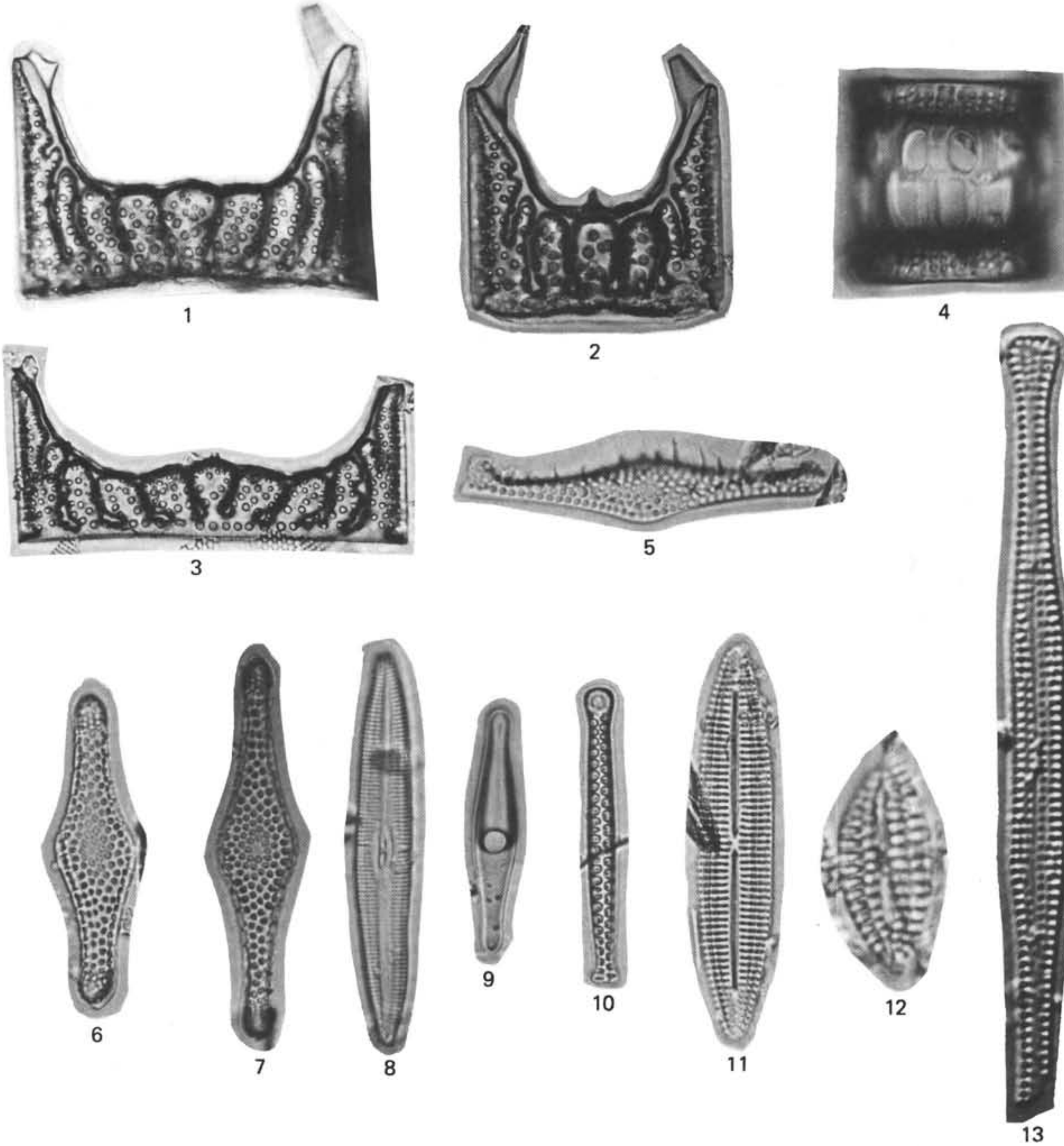


Plate 21. (All magnifications ×500 unless otherwise noted.) 1–3. *Hemiaulus reflexispinosus* Ross and Sims (1) Sample 511-17,CC (2) Sample 511-5-5, 15–17 cm (3) Sample 511-17-2, 83–85 cm. 4. *Skeletonema barbadensis* Greville. Sample 513A-33-6, 73–75 cm. ×1800. 5–7. *Baxteria brunii* Van Heurck. Sample 511-20-2, 23–25 cm. ×800. 8. *Navicula udintsevii* Schrader and Fenner. Sample 513A-33-6, 73–75 cm. ×1000. 9. *Grammatophora* sp. Sample 511-20-2, 23–25 cm. ×800. 10. *Sceptroneis pesplanus* Fenner and Schrader. Sample 511-6-1, 23–25 cm. ×800. 11. *Rouxia granda* Schrader. Sample 511-1-4, 16–18 cm. ×800. 12. *Rouxia obesa* Schrader. Sample 513A-31-3, 21–23 cm. ×2000. 13. *Rouxia hannae* Jousé. Sample 511-11-2, 30–32 cm. ×2000.

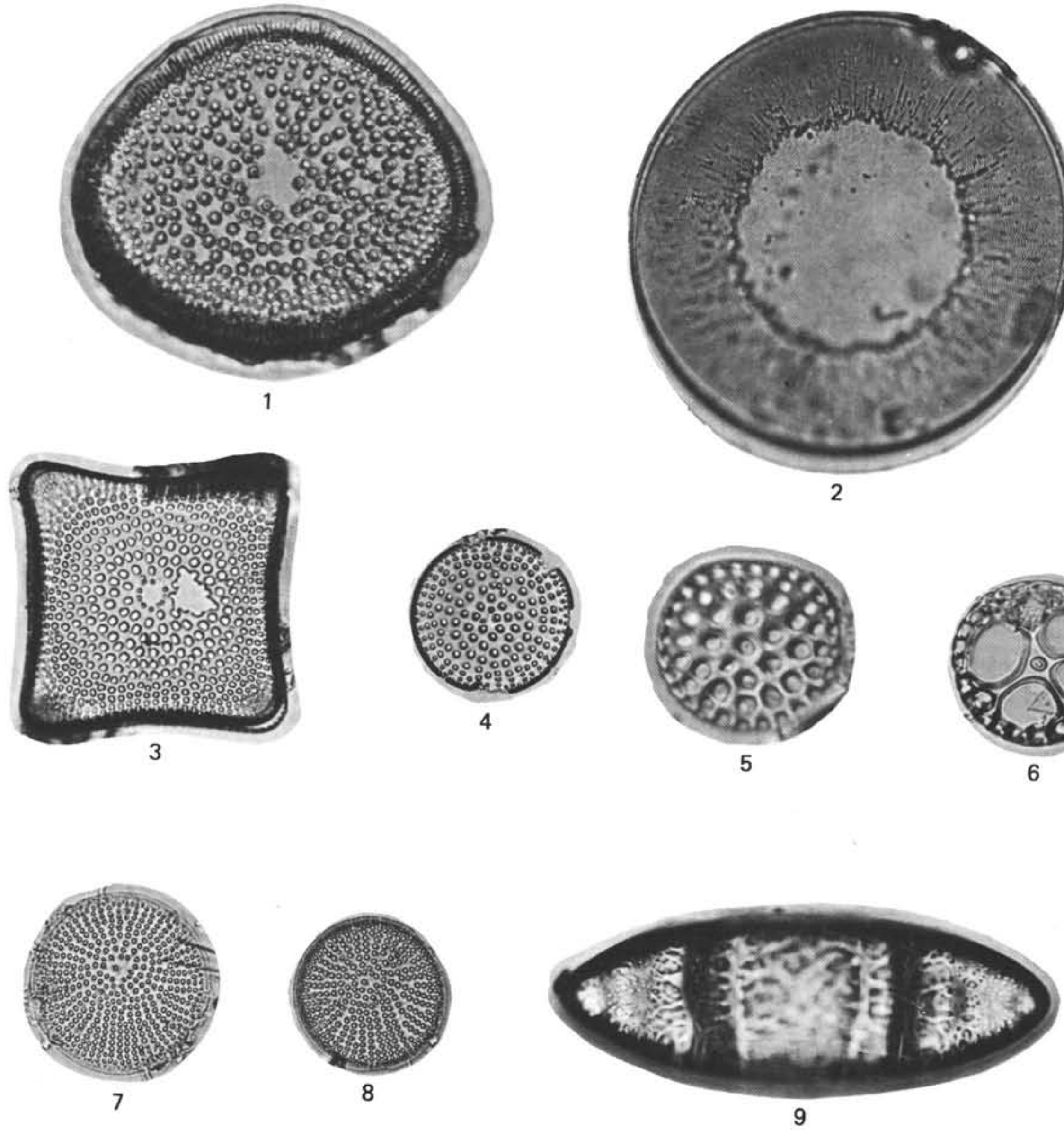


Plate 22. (All magnifications ×500 unless otherwise noted.) 1. *Kozloviella minor* Jousé. Sample 513A-21-6, 41–43 cm. ×800. 2. *Hyalodiscus* sp. Sample 511-16,CC. ×750. 3. *Stictodiscus novaezealandica* Grunow. Sample 511-16,CC. 4–5. *Coscinodiscus praenitidus* Fenner (4) Sample 511-17-2, 83–85 cm (5) Sample 513A-25,CC. ×1500. 6. *Rocella schraderi* Bukry. Sample 513A-15-4, 131–133 cm. 7–8. *Stictodiscus* sp. Sample 513A-18-4, 143–145 cm. 9. *Goniothecium odontella* Ehrenberg. Sample 511-18,CC. ×750.

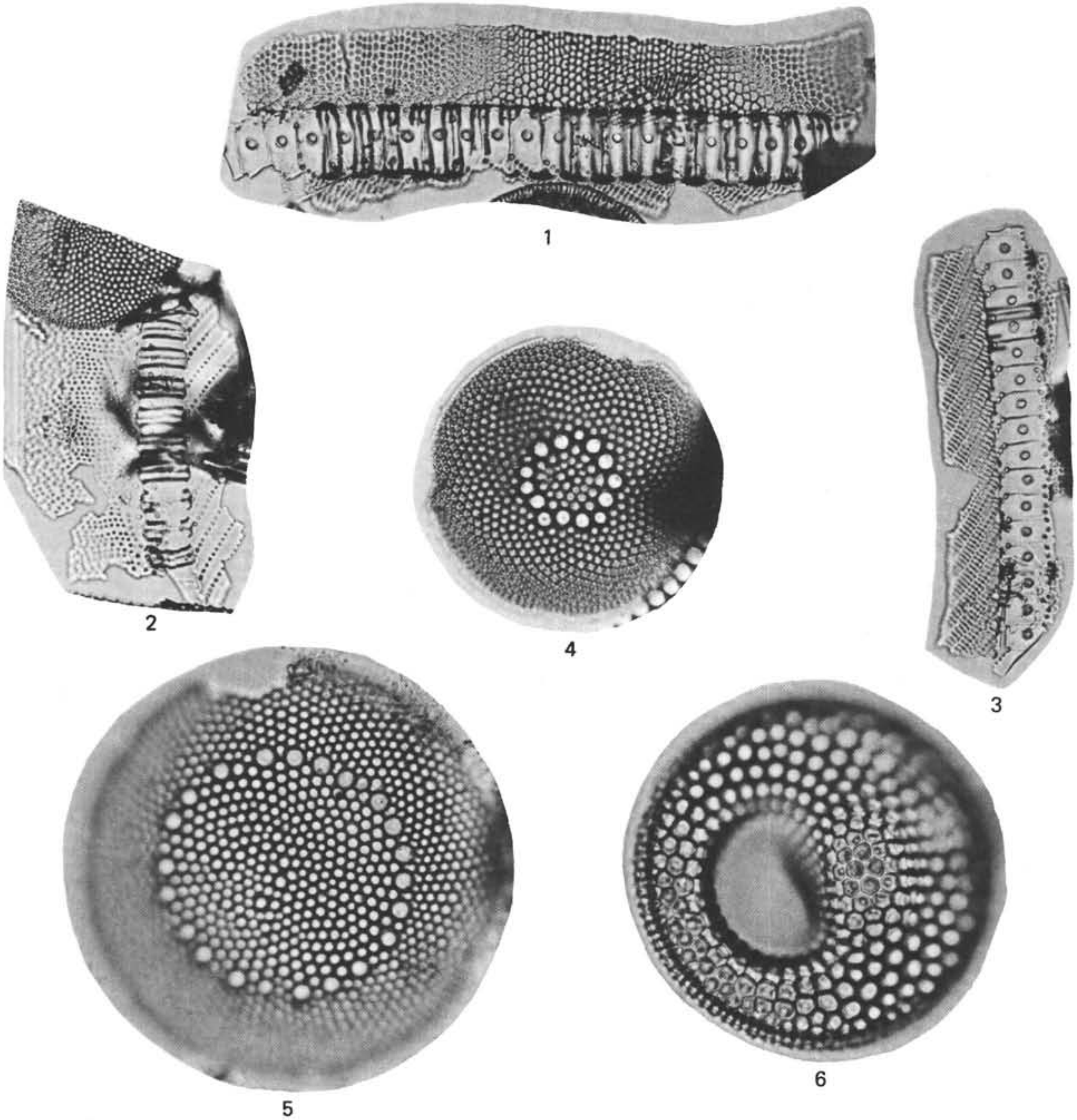


Plate 23. (All magnifications ×500.) 1–3. *Brightwellia spiralis* Gleser (1) Sample 511-18-2, 21–23 cm (2) Sample 511-13,CC (3) Sample 511-20,CC. 4–5. *Coscinodiscus bulliens* Schmidt (4) Sample 511-16,CC (5) v. l. Sample 511-2-2, 101–103 cm. 6. *Coscinodiscus excavatus* Greville v. *tuberosa* Fenner. Sample 511-1-4, 16–18 cm.

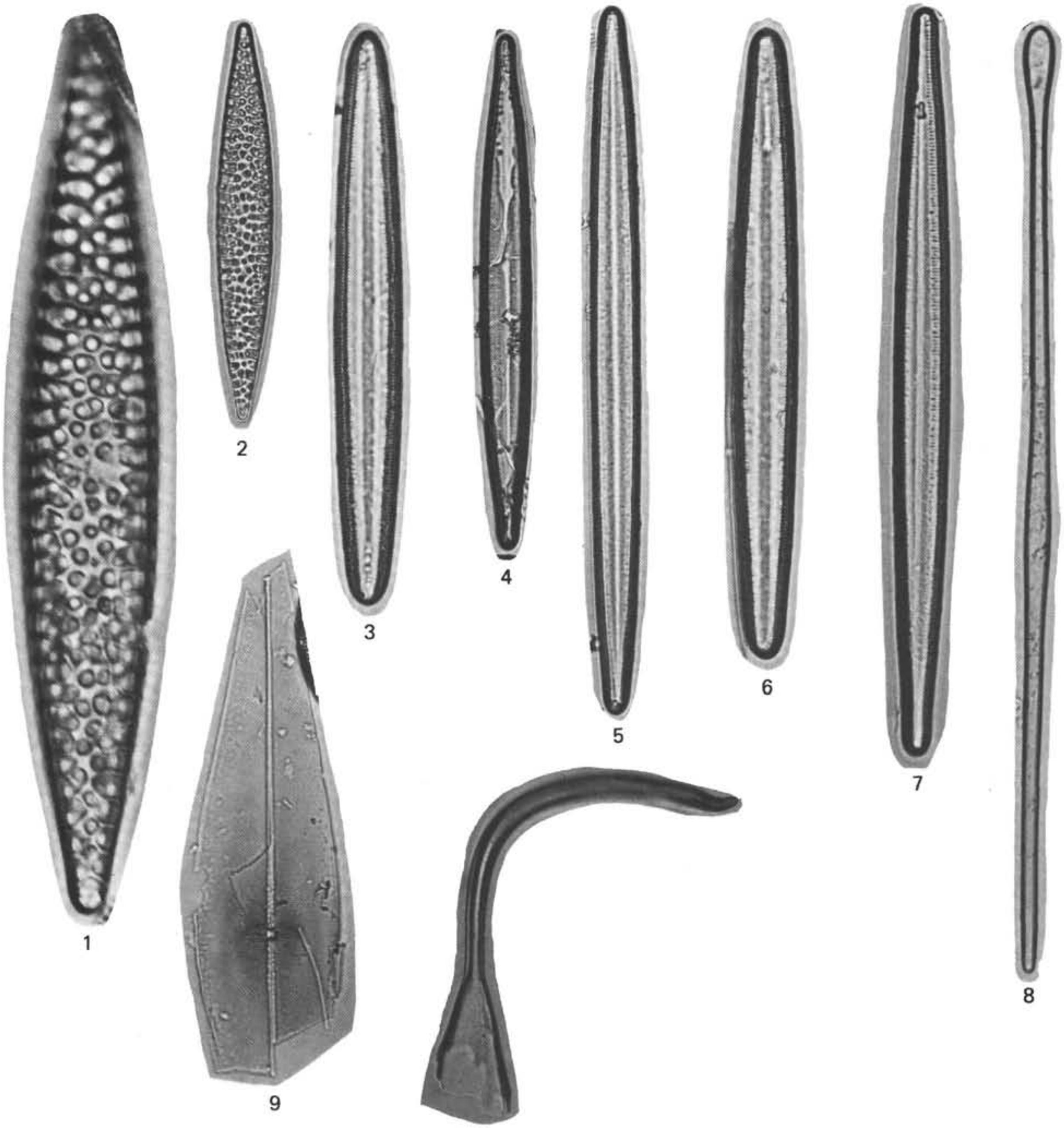


Plate 24. (All magnifications ×500 unless otherwise noted.) 1–2. *Rossiella* sp. (1) Sample 513A-13-1, 67–69 cm. ×2000 (2) Sample 513A-14-2, 92–94 cm. ×800. 3–7. *Synedra jouseana* Sheshukova-Poretzkaya (3) Sample 513A-14-2, 92–94 cm. ×800 (4) Sample 513A-17-5, 115–117 cm (5) Sample 513A-15-1, 21–23 cm (6–7) Sample 513A-14-2, 92–94 cm. ×800. 8. *Sceptroneis ligulatus* Fenner. Sample 511-18-1, 40–42 cm. 9. *Pleurosigma* sp. (fragment). Sample 513A-15-1, 21–23 cm. 10. *Rhizosolenia praebarboi* Schrader. Sample 511-11-1, 30–32 cm.

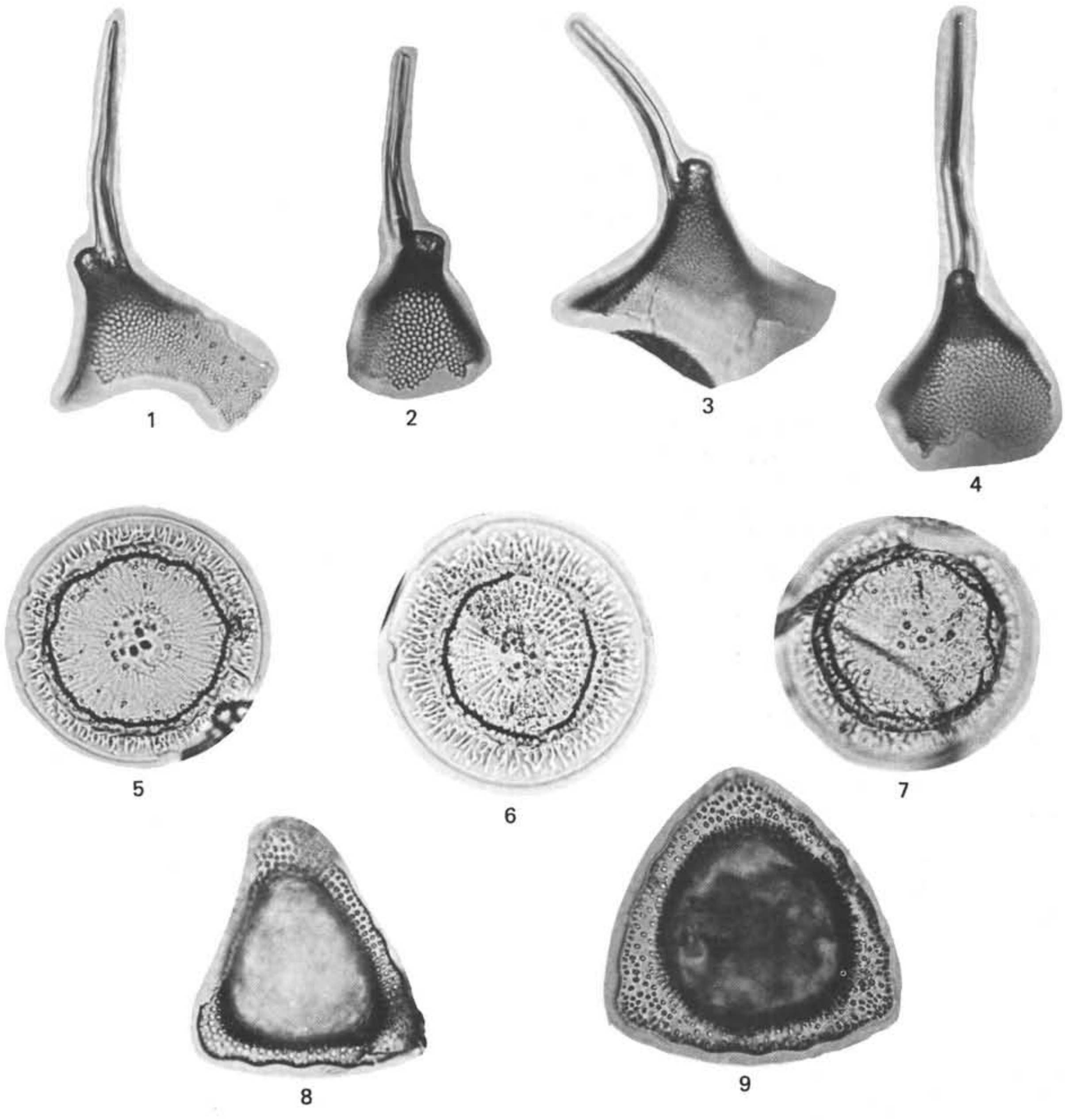
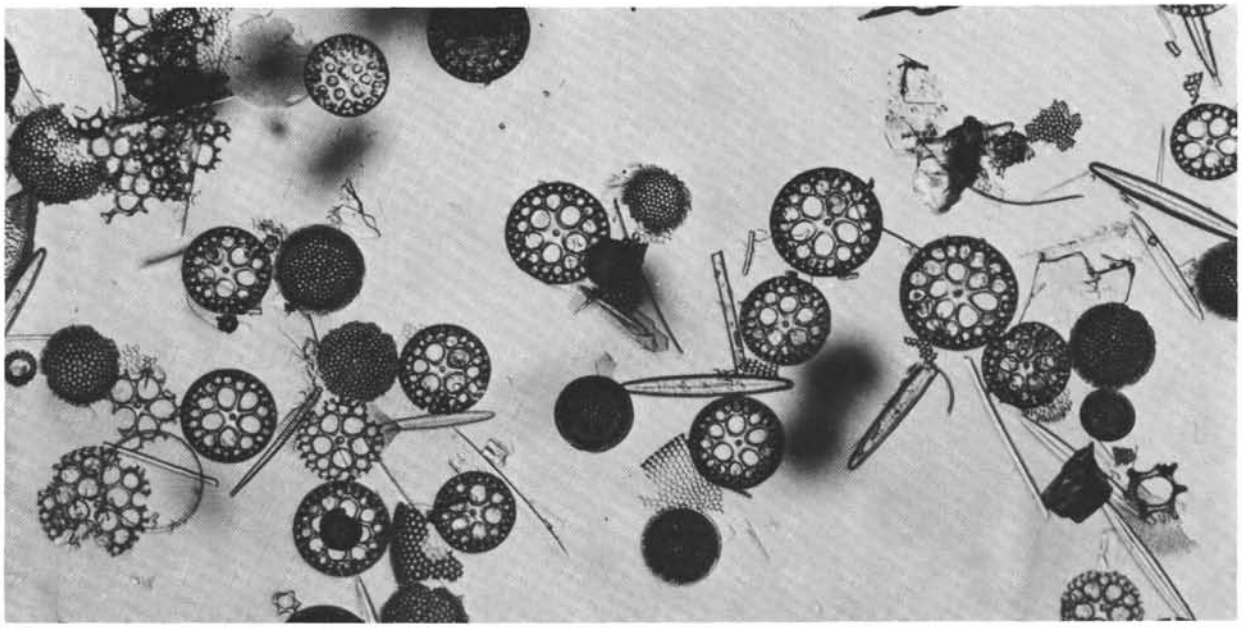


Plate 25. (All magnifications ×500.) 1–4. Genus and species uncertain #1. Sample 511-16-2, 22–24 cm. 5–7. Genus and species uncertain #2 (5) Sample 511-16,CC (6) Sample 511-13,CC (7) Sample 511-16,CC. 8–9. Genus and species uncertain #3 (8) Sample 511-16,CC (9) Sample 511-12-1, 11–13 cm.



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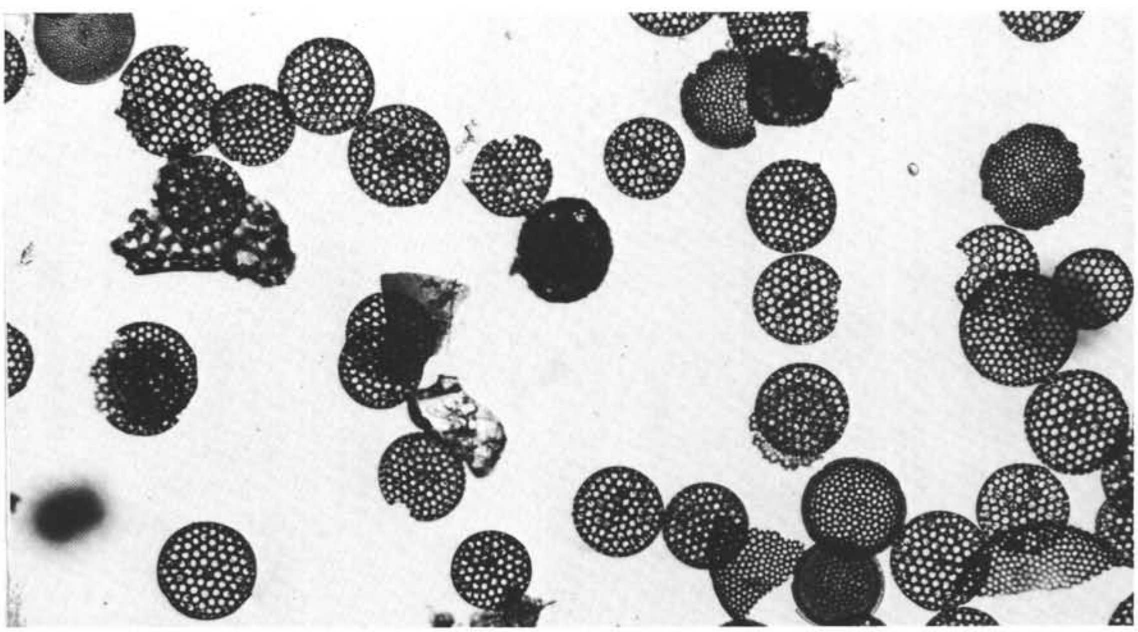

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Plate 26. 1. Concentration of *Rocella gelida* (Mann) Bukry. Sample 513A-15-5, 125–127 cm. ×200. 2. Concentration of *Rocella vigilans* (Schmidt) Fenner. Sample 513A-18-2, 143–145 cm. ×200.