15. LATE NEOGENE DIATOMS AND DIATOM OOZES IN THE CENTRAL SOUTH ATLANTIC[1]

A. M. Gombos, Jr., Exxon Production Research Company, Houston, Texas

ABSTRACT

The stratigraphic distribution of 31 late Miocene and Pliocene diatom species is documented for Hole 520 in the central South Atlantic. The diatom assemblage throughout the interval is dominated by fragments of the large, dissolution-resistant diatom *Ethmodiscus rex*, but it contains a minor component of other fairly dissolution-resistant tropical to subtropical planktonic diatoms. An *E. rex* ooze with a minor component of other robust diatoms is presumed to have formed by the selective dissolution of less resistant species as they settled through the 4200-m water column at Site 520. The protected nature of the depositional site (a depression on the Mid-Atlantic Ridge) prevented the further concentration of *Ethmodiscus rex* by winnowing. Species of *Nitzschia* used in zoning equatorial Pacific sediments are absent from the ooze at Site 520, so it was not possible to zone the sequence.

INTRODUCTION

Data on the stratigraphic distribution of Neogene diatoms in the subtropical South Atlantic Ocean are scarce. The stratigraphic ranges of diatoms in the upper Miocene and Pliocene sediments at Site 362 (which is on the Abutment Plateau at the eastern extremity of the Walvis Ridge) are described by Schrader (1979), and his data confirm that the late Miocene and Pliocene diatom zonal species used by Burckle (1972) to zone sediments of equivalent age in the eastern equatorial Pacific also occur in and can be used to zone the sediments of the eastern subtropical South Atlantic.

Neogene diatomaceous sediments in the western subtropical South Atlantic Ocean have been described by Gombos (1977) and Fenner (1979), who examined sediments from the northern Argentine Basin (Sites 331 and 358). Only displaced Antarctic Neogene diatoms and reworked Paleogene diatoms, presumably transported from the Paleogene sediments of the Falkland Plateau by bottom currents, were observed at those sites.

At Site 520, which is located in a depression on the Mid-Atlantic Ridge (25°31.40′S; 11°11.14′W), nearly 200 m of upper Miocene and Pliocene diatomaceous sediment were cored. Documentation of the floral assemblage at Site 520 therefore adds to our knowledge of subtropical South Atlantic Neogene diatoms.

MATERIALS AND METHODS

While on board the *Glomar Challenger*, the author collected 42 sediment samples. All samples collected were processed for shore-based investigation by using a standard acidizing technique to remove carbonate. Two slides were prepared of the residue. The residue was then passed through stacked 63-μm and 38-μm sieves, and two slides were prepared from each fraction. Estimates of relative abundance were made from the slides of the unsieved residue. Any species found concentrated in one of the sieved fraction slides but not observed in the unsieved fraction slides was considered rare. The abundances found on the basis of two traverses of the cover slip at 400× magnification are listed in Table 1. In some samples one species, *Ethmodiscus rex*, is classified as dominant. In those samples, specimens of this species (which occurred throughout only as fragments) were not counted but numbered in the tens or hundreds in each field of view.

Appendix A lists the species recorded in Table 1. Comments on a few significant or unusual species are given in Appendix B; for a taxonomic treatment of the other species the reader is referred to Gombos (1975), Kolbe (1954), Koizumi (1973, 1975), and Schrader (1974).

OBSERVATIONS

Shipboard sedimentologists distinguished three lithologic units in Hole 520. Unit 1 (0–256 m sub-bottom, Cores 1–8) consists of homogeneous nannofossil ooze with a calcium carbonate content of between 75 and 80%. The residual consists of clay and diatoms. Sporadic bioturbation was noted throughout the unit. Unit 2 (256.0–398.5 m sub-bottom, Cores 9–26) consists of interbedded clayey nannofossil diatomites, marls, and mudstones. The calcium carbonate content of the marl ranges between 60 and 90% and that of the mudstone between 30 and 50%; the carbonate content of the diatomaceous sediments ranges between 23 and 36%. Many of the diatomaceous sediments are laminated; burrows are less common. Unit 3 (398.5–446.5 m sub-bottom, Cores 27–30) consists of nannofossil marl and bioturbated claystone. Basalt was encountered below Core 30.

Diatoms occur in Lithologic Units 1 and 2 (Cores 4 through 26), although they are not ubiquitous; occasional intervals are barren (see Table 1). The diatom assemblage is composed predominantly of strongly silicified, solution-resistant species, fragments of *Ethmodiscus rex* being the most abundant species in all the samples that contain diatoms. The diversity of the assemblage is not great; only about 30 species were observed. The most diverse samples are from the lower part of Lithologic Unit 2 (see Table 1).

The ages assigned to the various samples are based on the calcareous nannofossil zonation developed by Percival (this vol.). Cores 4 to 6 are dated as Pliocene (NN15 and NN14), and Cores 8 to 26 are dated as late Miocene (NN12 and NN11). Cores 27 to 30 are barren of diatoms.

[1] Hsü, K. J., LaBrecque, J. L., et al., *Init. Repts. DSDP*, 73: Washington (U.S. Govt. Printing Office).

Table 1. Distribution of diatoms in Hole 520.

Age	Lithologic units	Calcareous nannofossil zones (Percival, this vol.)	Core-Section (interval in cm)	*Actinocyclus ehrenbergii*	*A. ellipticus*	*A. ellipticus* var. *elongatus*	*A. ellipticus* f. *lanceolatus*	*A. ellipticus* var. *moronensis*	*Asterolampra acutiloba*	*A. affinis*	*A. concinna*	*A. grevillei*	*A. marylandica*	*Asteromphalus arachne*	*A. heptactis*	*A. hiltonianus*	*Coscinodiscus curvatulus*	*C. excentricus*	*C. lineatus*	*C. nodulifer*	*C. vetustissimus* var. *javanica*	*C. tabularis*	*Ethmodiscus rex* (fragments)	*Hemidiscus cuneiformis*	*Neobrunia mirabilis*	*Nitzschia cylindrica*	*N. fossilis*	*N. marina*	*N. reinholdii*	*Pleurosigma* sp.	*Thalassionema nitzschioides*	*Thalassiothrix longissima*	*Triceratium cinnamomeum*	*T. cinnamomeum* var. *minor*
		NN15	4-1, 113–115																				F											
Pliocene			4-2, 77–79																				R											
	1		5-1, 90–92	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		NN14	6,CC																R	R			A					R						
		NN12	8-2, 63–65						R						R		R		R				D	F	R			F			F	F		R
			9-1, 20–22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			9-2, 20–22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			9-3, 20–22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			9-4, 21–23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			9-5, 20–22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			10-1, 30–32																R		R		D	R				R			R	R		
			11-1, 80–82						F								R	R					D	R			R				R	R		
			11-2, 80–82	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			11-3, 80–82														R						—											
			11-4, 25–27	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			12-1, 23–25																				A											
			12-1, 110–111		R				R			R							F	F			A	R			R	R						
late			12-2, 14–16		R	R			R	R		R					R	F			R		D	F	R	R	F	F	F		R	R	F	
Miocene	2	NN11	14-1, 40–42		F			F	R		R		R	R	R		F	F	F	F			D	F			F	R	F			C	F	
			14-2, 68–70		F			R	R				R				F	R	R	F			D	F			F	F	R	R			F	
			14-3, 36–38		R	R		R									R	R	R				D	R			F	R	F				F	
			15-1, 40–42					R			R							R		R			D					R						
			15-2, 45–47																	R			A											
			16-1, 129–131																				D					R						
			16-2, 44–46																				F											
			16-3, 44–46																R				D	R								R		
			16-4, 44–46					R				R					R		R	R			D	F								R		
			17-2, 71–73		R								R				R		R	F			D		R	R				R		R		
			18-1, 63–65					R		R										R	R		A		F							R	R	
			19-1, 3–5		R	R		F				F	C		R		R		F	F	R		A	F	A				R	R			R	
			20-1, 52–54	R	R		R		R			R	R					R	R	R	R		A	R	R			R					R	
			20-2, 52–54											R			R						A		R						R	R	R	R
			24-1, 47–48	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
			24-1, 116–117					F				R	C						F	R	R		A		A		F	R			R	R	F	
			24-2, 10–11		R			C				F	R						F	F	F	F	D	F					F			C	R	
			26-1, 10–12	R	R	R	R	R				F	R	R			F		R		F	R	D	R	F	R			R	R		C	R	
			26-1, 139–141		R			F				R	C			R		R	R		C	R	D	R	C				R			C	F	
			26-2, 30–32		F			C	R	R		R	C			R		R			F	C	D	R	R		R			R		C	R	
		NN11-10	27-1, 14–16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3		28-1, 16–18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
middle		NN10-9	29-1, 28–30	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Miocene		NN6	29-2, 50–52	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Note: R (rare) = 1 or 2 specimens; F (few) = 3 to 8 specimens; C (common) = 9 to 25 specimens; A (abundant) = 25 + specimens; D (dominant)—see text for explanation.

The sediments in Hole 520 cannot be zoned by using diatoms. The stratigraphic succession of Neogene diatoms in the central subtropical South Atlantic is not established, and even if it were the highly variable state of preservation of the diatoms would make any stratigraphic determinations (i.e., highest and lowest occurrences) dubious, at best.

Burckle (1972) proposed a diatom zonation for the tropical and subtropical sediments of the eastern equatorial Pacific that Schrader (1979) was able to apply, to some extent, to sediments recovered in the eastern South Atlantic (Site 362). Unfortunately, the zonal indicator species used by Burckle (1972) were not observed in the sediments from Hole 520. All the diatom species observed in Hole 520 are known to occur in sediments of the tropical and subtropical Pacific and Indian oceans, however (see Reinhold, 1937; Mukhina, 1969; Burckle, 1972; Gombos, 1975). The stratigraphic significance of selected species is given in more detail in Appendix B.

The discovery of nannofossil-diatom oozes and laminated diatomites at Site 520 was somewhat unexpected, because the site is situated in the South Atlantic gyre, which is a region of low diatom productivity today. Hendey (1937), in a study of modern planktonic diatoms in the central South Atlantic, found 23 oceanic diatom species to be typical of the warm waters of the region. The study also showed that large centric diatoms like *Hemidiscus* and *Asterolampra* are among the most common forms in the warm waters of the South Atlantic. As Table 1 shows, the late Neogene diatom flora preserved at Site 520 is dominated by fragments of *Ethmodiscus* (a very large centric diatom), but it also includes species of *Actinocyclus, Asterolampra, Asteromphalus, Coscinodiscus, Hemidiscus, Neobrunia,* and *Triceratium*. These are large centric diatoms that are somewhat resistant to dissolution.

The preservation of these and a few other robust forms at Site 520 is explained by the local topography. Site 520 is in a closed depression on the Mid-Atlantic Ridge that is protected from circulating bottom currents. The depression may have created a restricted environment in which decaying organic matter depleted oxygen and increased carbon dioxide. Restricted conditions (i.e., poor bottom circulation and reduced dissolved oxygen levels) are suggested not only by the preservation of a moderately diverse diatom assemblage (much of which would be dissolved by freely circulating bottom waters of higher pH) but also by the sparsity of burrowing in the laminated diatomites of Unit 2 and the significant concentrations of pyrite in that interval.

Two explanations for the relatively low diversity of the diatom assemblage preserved from the late Miocene and Pliocene at Site 520 are possible. First, the late Miocene and Pliocene flora may not have been more diverse. The planktonic diatom flora at Site 362 was somewhat more diverse (Schrader, 1979), but that site was near the west African coast during the late Miocene and Pliocene, a region of upwelling and high phytoplankton productivity. Those regional characteristics may also explain the presence there of a number of the zonal species used by Burckle (1972) for his late Miocene to Recent diatom zonation in the equatorial Pacific, which is also a region of high productivity. No other well preserved late Miocene and Pliocene diatom assemblages from the central South Atlantic are available for comparison with the assemblage preserved at Site 520, however, so it is not possible to formulate a reliable picture of the composition of the ancient plankton.

Another factor that must be considered in evaluating the diatom assemblage at Site 520 is water depth (Fig. 1). At Sites 331 (Gombos, 1977) and 358 (Fenner, 1979), which are west of Site 520 and lie at water depths of 5000 m or more, only Neogene Antarctic diatoms and displaced Paleogene diatoms were encountered in surface cores. Presumably the diatoms were moved to those sites by Antarctic Bottom Water. The absence from those sites of tropical and subtropical species, which would be expected to have lived in the overlying plankton, can be explained by dissolution as the valves passed downward through the water column. At Site 520, which was at a water depth of about 4200 m, only robust, solution-resistant tropical and subtropical diatoms are preserved (Site 520 is situated too high on the Mid-Atlantic Ridge for Antarctic diatoms to have been deposited there from Antarctic Bottom Water). At Site 362, which is at a water depth of about 1300 m, a more diverse assemblage is preserved because of the shallower depth of deposition.

At Site 519, which was at a water depth of about 3800 m, a short interval of moderately well preserved diatoms was encountered in Core 24 (see Site 519 chapter, this vol.) that is quite similar in composition to assemblages of equivalent age at Site 520. The similarity of these assemblages, both of which are made up of robust, solution-resistant forms, suggests that water depth

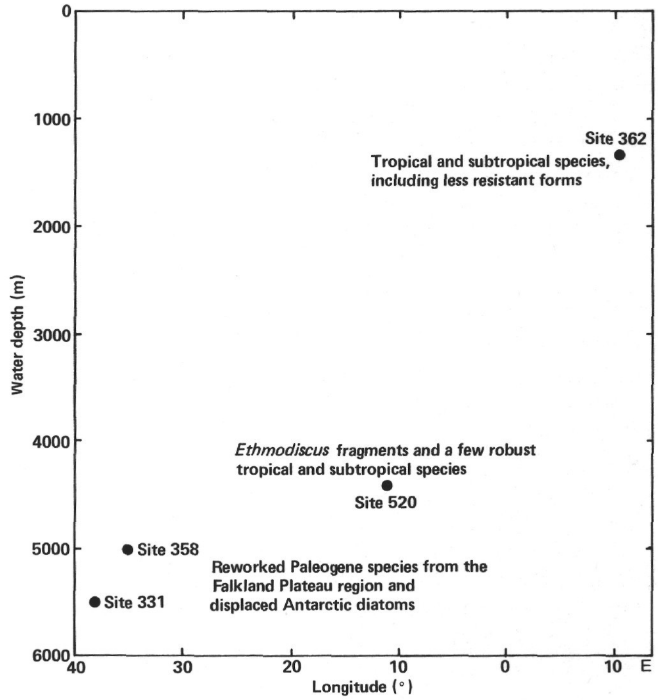

Figure 1. Preservation of diatoms in four South Atlantic DSDP holes.

is a controlling factor in determining the makeup of fossil diatom assemblages in the deeper parts of the central South Atlantic.

THE *ETHMODISCUS* PROBLEM REVISITED

Because *Ethmodiscus rex* is a relatively rare component of the modern plankton of tropical and subtropical waters, its relatively common occurrence as monospecific or nearly monospecific oozes up to several meters in thickness in the tropical and subtropical regions of the Indian, Pacific, and Atlantic oceans is somewhat paradoxical and has been dubbed the "*Ethmodiscus rex* problem" by Gardner and Burckle (1975).

The distribution of *E. rex* and *E. rex* oozes and the various hypotheses put forward to explain the origins of the oozes are thoroughly reviewed by Mikkelsen (1977). She also presents the results of laboratory experiments on the dissolution of *E. rex;* in controlled experiments on the dissolution of siliceous microfossil assemblages in seawater, *Ethmodiscus* reached concentrations similar to those observed in deep-sea oozes. Mikkelsen concludes that *Ethmodiscus* is a strongly solution-resistant diatom. She recognizes two general types of *Ethmodiscus* oozes: those composed of 99% *Ethmodiscus* and those that are dominated by *Ethmodiscus* but also include some other dissolution-resistant species. She suggests that the first type of ooze is the result of the differential dissolution of less resistant forms followed by the subsequent concentration of *Ethmodiscus* by winnowing or downslope transport. The second type is presumed to result from differential dissolution exclusively.

The *Ethmodiscus* ooze at Site 520 is of the second type. Almost every sample that contains diatoms is dominated by *Ethmodiscus* fragments, but in most samples a considerable number of other robust species are also present. It is concluded that the *Ethmodiscus* oozes at Site 520 originated in a tropical to subtropical planktonic diatom assemblage that was deposited in a closed depression and from which the less resistant forms were removed by dissolution. Topography prevented further concentration of the *Ethmodiscus* fragments by winnowing or the downslope movement of sediment.

SUMMARY

The late Miocene and Pliocene interval in Hole 520 contains an impure *Ethmodiscus rex* ooze with a minor component of robust tropical to subtropical planktonic diatoms. The formation of the ooze is explained by the great water depth at Site 520 (4200 m). As the dead diatoms of the overlying planktonic assemblage settled to the bottom, most of the less resistant species dissolved. The result was an accumulation of fragments of *E. rex* (which is perhaps the most resistant of diatoms) and a few examples of other fairly resistant diatoms. The depositional site, a depression on the Mid-Atlantic Ridge, prevented the removal of the minor diatom component from the ooze by winnowing. Key zonal species, mostly delicate *Nitzschia* spp., were presumably dissolved in transit to the bottom, making it impossible to assign zones to the section.

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APPENDIX A
Neogene Diatoms Found in Hole 520

Actinocyclus ehrenbergii Ralfs
A. ellipticus Grunow
A. ellipticus var. *elongatus* (Grunow) Kolbe
A. ellipticus f. *lanceolatus* Kolbe
A. ellipticus var. *moronensis* (Deby) Kolbe
Asterolampra acutiloba Forti
A. affinis Greville
A. concinna Greville
A. grevillei (Wallich) Greville
A. marylandica Ehrenberg
Asteromphalus arachne (Brebisson) Ralfs
A. heptactis (Brebisson) Greville
A. hiltonianus (Greville) Ralfs
Coscinodiscus curvatulus Grunow
C. lineatus Ehrenberg
C. nodulifer Schmidt
C. tabularis Grunow
C. vetustissimus var. *javanica* Reinhold
Ethmodiscus rex (Rattray) Hendey
Hemidiscus cuneiformis Wallich
Neobrunia mirabilis (Brun) Kuntze
Nitzschia cyclindrica Burckle
N. fossilis (Frenguelli) Kanaya
N. marina Grunow
N. reinholdii Kanaya
Pleurosigma sp.
Thalassionema nitzschioides Grunow
Thalassiosira excentrica (Ehrenberg) Cleve
Thalassiothrix longissima Cleve and Grunow
Triceratium cinnamomeum (Greville) Grunow
T. cinnamomeum var. *minor* Grunow

APPENDIX B
Notes on the Taxonomy and Stratigraphic Occurrence of Selected Diatoms

This appendix presents comments on the taxonomy and stratigraphic significance of three diatom species found in Hole 520. Information on other species referred to in this report is given in the papers mentioned in the Materials and Methods section of this report. Publications mentioned in this section appear in the preceding list of references.

Genus *ASTEROLAMPRA* Ehrenberg, 1844
Ehrenberg, 1844, p. 73

Asterolampra acutiloba* Forti *in Tempère and Peragallo, 1912, p. 337, no. 696–698; Forti, 1913, p. 1564, pl. 3, figs. 1, 5, 6, 9.

Remarks: This species is similar to *Asterolampra marylandica,* from which it apparently evolved, except for the acute termination of areolae on the inner margin of the areolated segments where the separating line joins the segment.

Burckle (1978) correlates the extinction of this species with the top of Magnetic Epoch 5 in the equatorial Pacific. In Hole 520, the last occurrence of *A. acutiloba* was observed in Core 8. Core 8 has been dated as late Miocene (Calcareous Nannofossil Zone NN12) by Percival (this vol.) and thus is in agreement with Burckle's (1978) observation.

Genus *COSCINODISCUS* Ehrenberg, 1838
Ehrenberg, 1838, p. 128

***Coscinodiscus vetustissimus* Pantocsek var. *javanica* Reinhold,** 1937, pp. 102–103, pl. 8, figs. 7, 8; Kolbe, 1954, pl. 1, fig. 10 (not *C. aeginensis*).

Remarks: This variety is characterized by a conspicuous central nodule, fasciculation like that found in *Coscinodiscus curvatulus*, and a coarsely striated margin.

The forms observed in the present material agree well with the illustration of Reinhold (1937), except that in the specimens from Hole 520 the central nodule is frequently larger, in proportion to the rest of the valve, than is apparent in Reinhold's one example.

Burckle (1972, p. 226) says that *C. vetustissimus* var. *javanica* "is apparently restricted to the earliest part of the Late Miocene" in equatorial Pacific sediments. In Hole 520, this variety is most common and consistent in occurrence in the early late Miocene (see Table 1), and thus is in agreement with Burckle's (1972) observation.

Genus *NEOBRUNIA* Kuntze, 1894
Kuntze, 1894, p. 477; *Brunia* Tempère, 1890, p. 21; *Bruniopsis* Karsten, 1928, pp. 217–218

Neobrunia mirabilis (Brun *in* Brun and Tempère 1889), Kuntze, 1894, p. 477.

Brunia mirabilis (Brun *in* Brun and Tempère, 1889) Tempère, 1890, p. 22.

Brightwellia? mirabilis Brun *in* Brun and Tempère, 1889, p. 27, pl. 8, fig. 1.

Bruniopsis mirabilis (Brun) Karsten, 1928, p. 218.

Brunia californica Terry, 1895, pp. 52–53, 88?

Remarks: As with *Ethmodiscus rex,* this species occurs only as fragments in the present material. The fragments are readily identifiable by regularly spaced hyaline fields that have one subtriangular areola in the center.

This species occurs consistently from Core 17 to Core 26. It reaches its greatest abundance in Cores 19 and 24, where tens to hundreds of fragments of *Neobrunia mirabilis* are observed in each field of view.

Because this species occurs in such great numbers in the lower part of Hole 520, it is presumed to be a relatively solution-resistant form that underwent relative enrichment much like *E. rex.* Because of its presumed resistance to dissolution and its absence from cores higher than Core 17 (except for rare occurrences in Cores 8 and 12), the last occurrence of this species in Core 17 represents a datum that may be useful in identifying early late Miocene sediment in the South Atlantic.

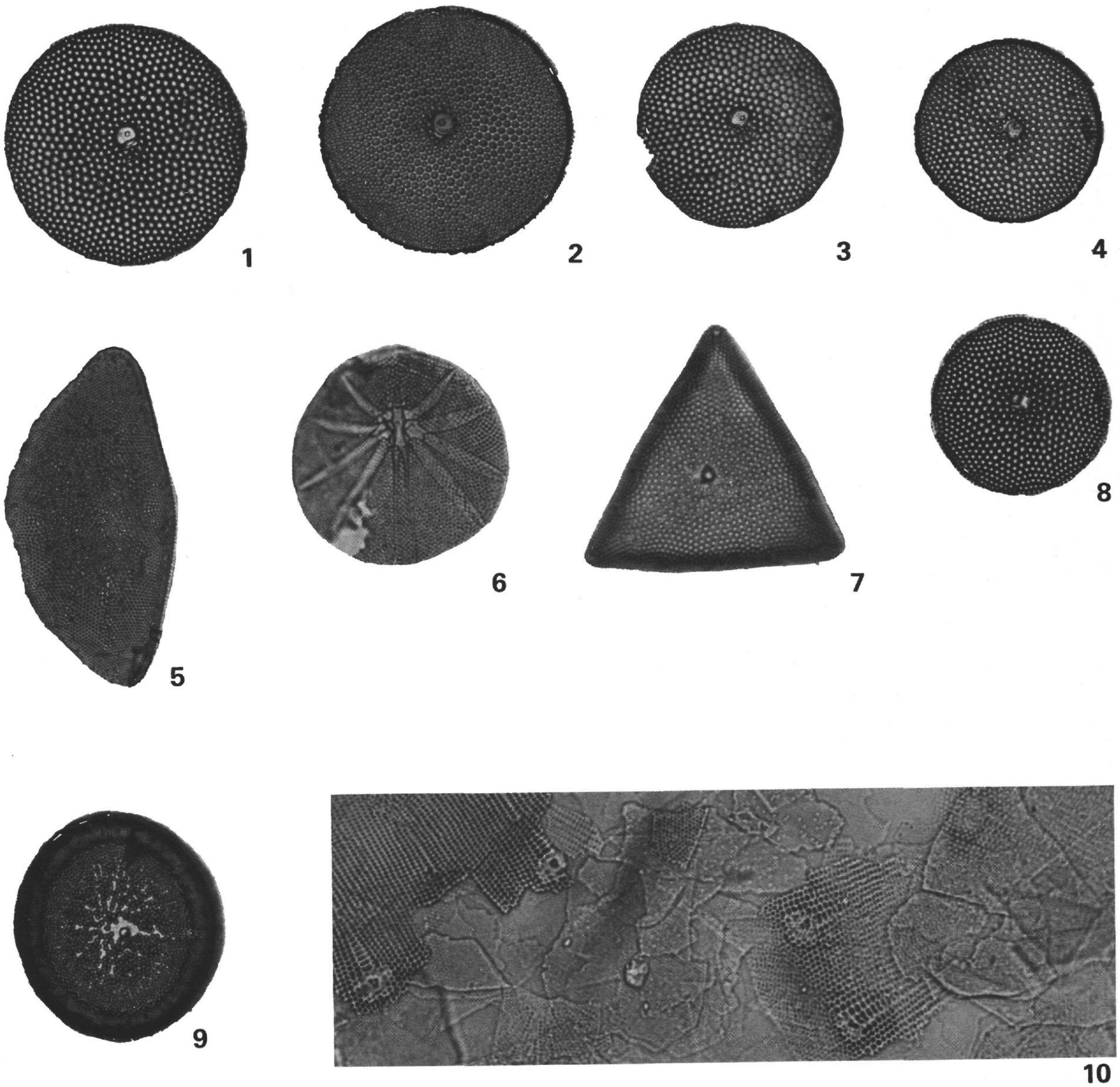

Plate 1 (all magnifications 500 ×). **1–4.** *Coscinodiscus vetustissimus* Pantocsek var. *javanica* Reinhold. Sample 520-26-1, 139–141 cm. Figures show different specimens. **5.** *Hemidiscus cuneiformis* Wallich. Sample 520-26-1, 139–141 cm. **6.** *Asteromphalus arachne* (Brebisson) Ralfs. Sample 520-26-1, 10–12 cm. **7.** *Triceratium cinnamomeum* Greville. Sample 520-26-1, 10–12 cm. **8.** *Coscinodiscus vetustissimus* Pantocsek var. *javanica* Reinhold. Sample 520-26-1, 139–141 cm. **9.** *Actinocyclus ellipticus* Grunow. Sample 520-26-1, 139–141 cm. **10.** *Neobrunia mirabilis* (Brun) Kuntze, fragments of valves. Sample 520-19-1, 3–5 cm.

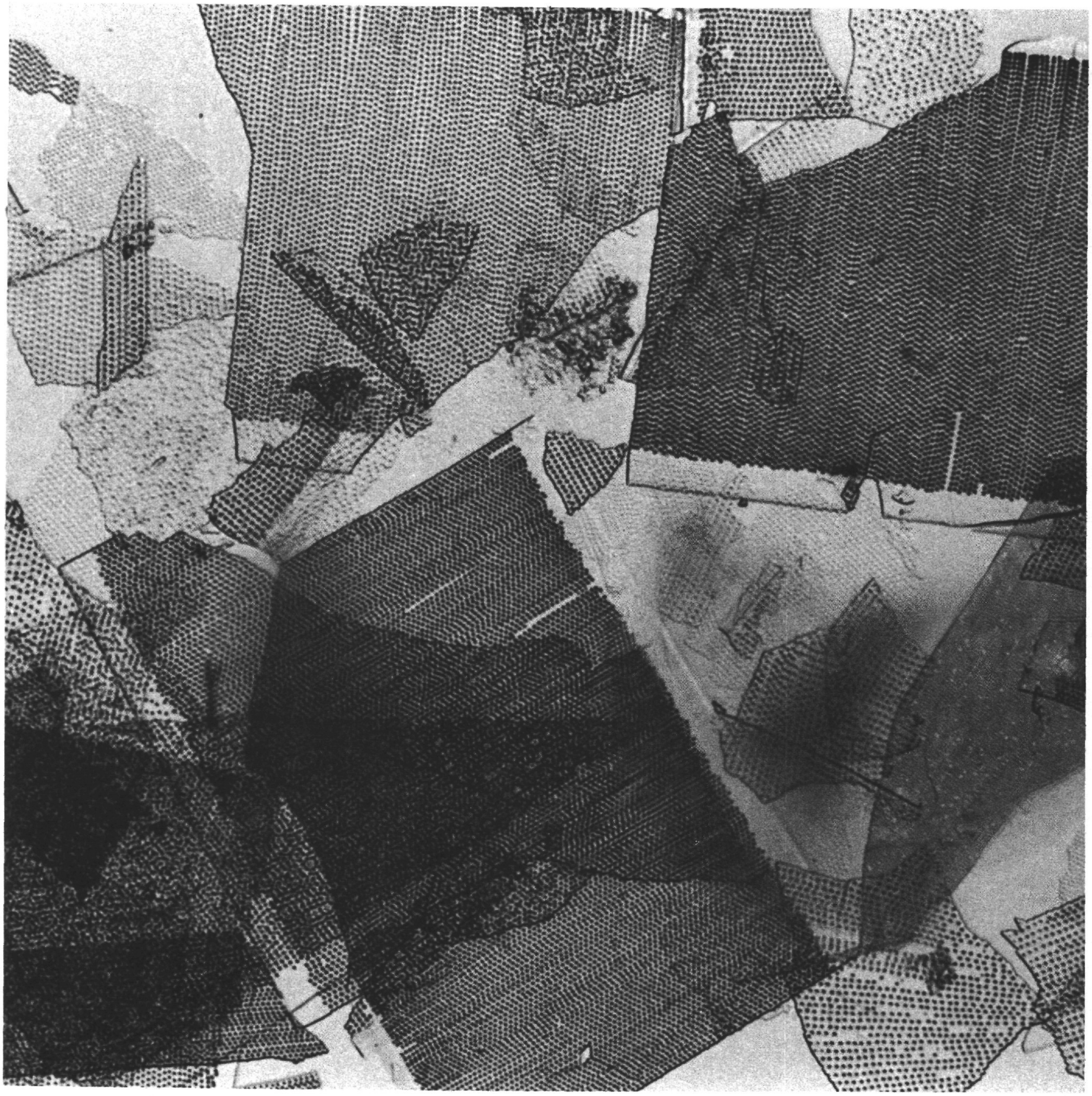

Plate 2 (magnification 320×). *Ethmodiscus rex* (Wallich) Hendey. Accumulation of valve fragments forms a nearly monospecific ooze. Sample 519-16-1, 125 cm.

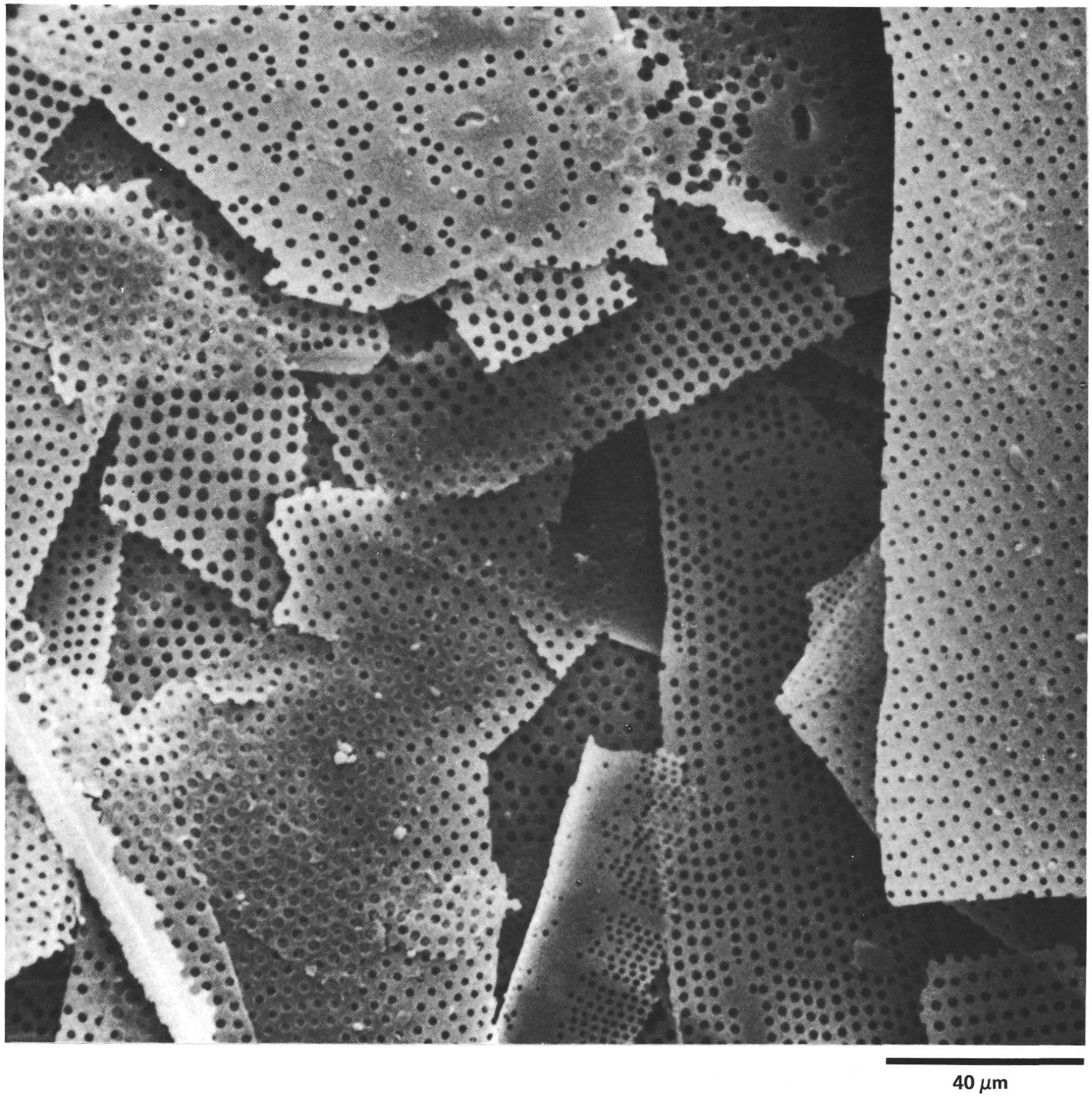

Plate 3. *Ethmodiscus rex* (Wallich) Hendey. Scanning electron micrograph of typical *Ethmodiscus* ooze.