

17. UPPER PLIOCENE AND QUATERNARY DIATOM BIOSTRATIGRAPHY OF DEEP SEA DRILLING PROJECT LEG 54, TROPICAL EASTERN PACIFIC

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INTRODUCTION

Burckle (1972, 1977) proposed a diatom zonation for the late Cenozoic of the equatorial eastern Pacific that was tied directly to paleomagnetic stratigraphy in several piston cores (Figure 1). This zonation can also be recognized in tropical sediments of the Indian and Atlantic oceans (Schrader, 1974, 1977). Recently, Burckle et al. (in press) have presented additional correlations of Pliocene and Pleistocene diatom extinction and first-appearance levels with the paleomagnetic record. For example, they report that *Rhizosolenia matuyamai* has a restricted range from just below the Jaramillo polarity event into the lower part of the Jaramillo (Figure 1) in the North Pacific.

DSDP Leg 54 (April to June 1977) recovered sediments containing moderately to well preserved upper Pliocene and Quaternary diatoms from the East Pacific Rise and the Galapagos Spreading Center (Figure 2, Table 1). The diatom datum levels of Burckle (1972, 1977) and Burckle et al. (in press) are easily recognizable in Leg 54 sediments and thus provide reliable absolute age estimates.

METHODS

Strewn slides of acid-cleaned material were prepared following the procedures outlined in Barron (1976). An entire microscope slide (22 × 40 mm cover glass size) was examined under the light microscope at ×500, and the occurrences of stratigraphically diagnostic diatoms and the silicoflagellate *Mesocena quadrangula* were recorded. Because it contains the longest and most comprehensive record, an occurrence chart was prepared for Site 420 (Table 2) in which the relative abundances of all diatom taxa encountered were recorded. Taxa were listed as "abundant" if two or more specimens were observed in one field of view at ×500 (446 μm diameter); "common," if at least one specimen was present in two fields of view at ×500; "few," if at least one specimen was seen during each vertical traverse (22 mm length); and "rare," if occurrences were less consistent.

DIATOM BIOSTRATIGRAPHY

In the summary of diatom zonal determinations for the nine sites drilled on Leg 54 (Figure 3), the Pliocene/Pleistocene boundary is placed near the top of the Olduvai polarity event according to Haq et al. (1977) and therefore is near the top of Subzone A of the *Nitzschia reinholdii* Zone (Figure 1).

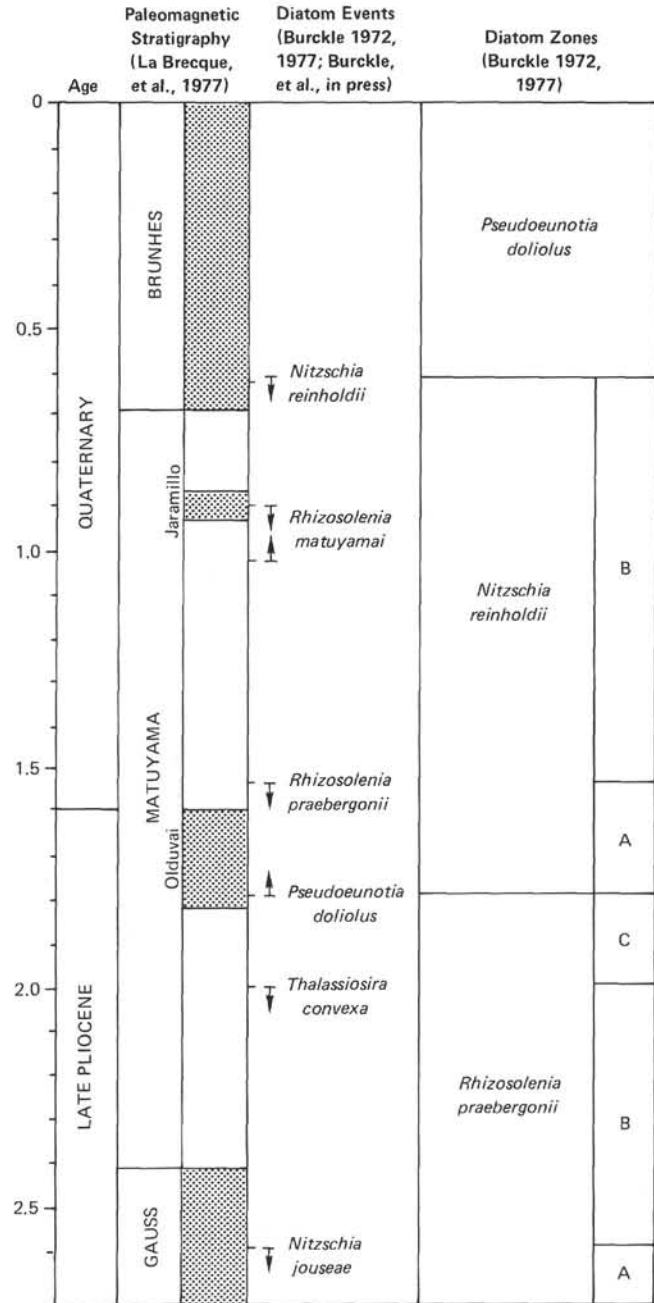


Figure 1. Correlation of the diatom zonation of Burckle (1972, 1977) to paleomagnetic stratigraphy for the late Pliocene/Quaternary. (↑ = first occurrence of taxon; ↓ = last occurrence.)

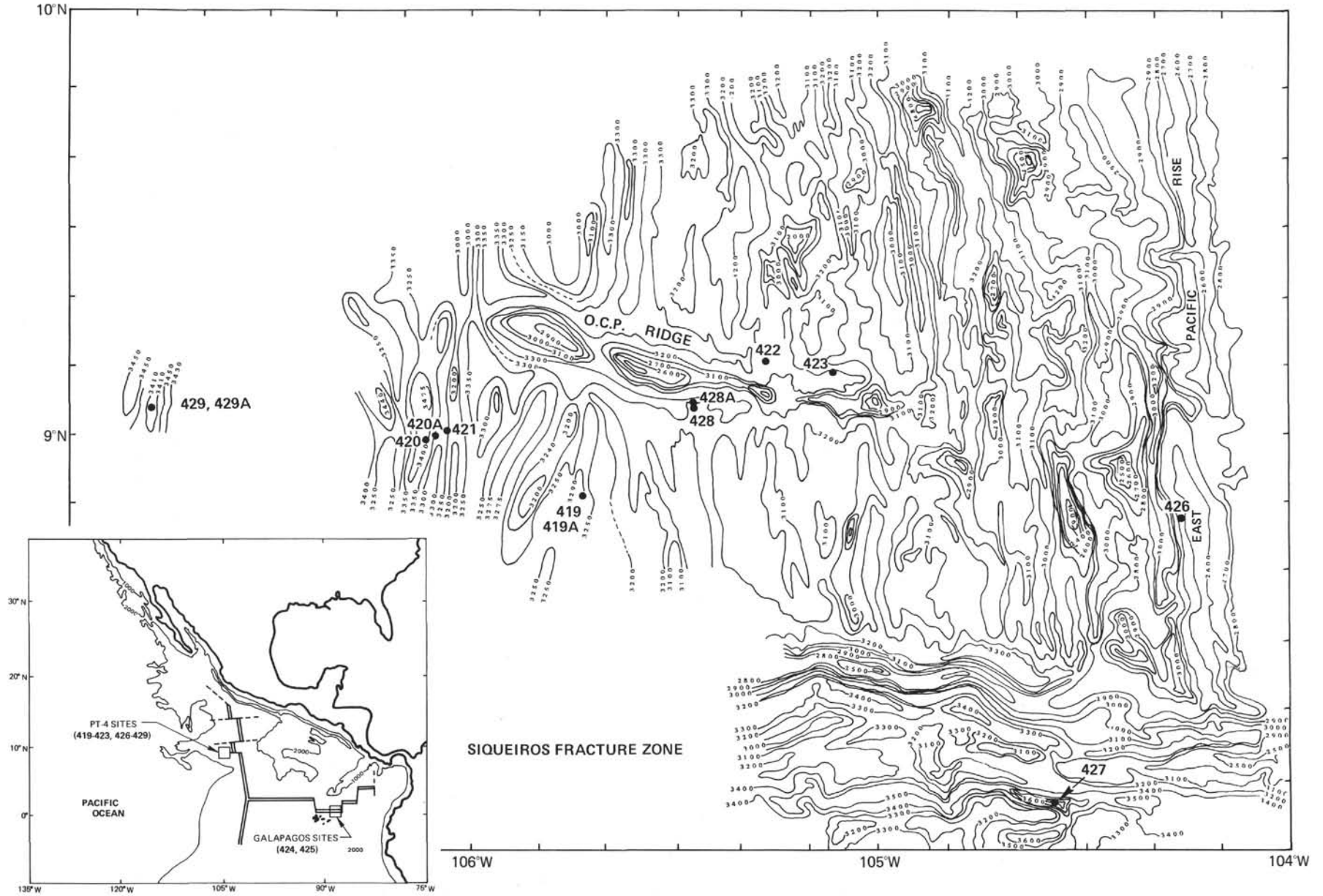


Figure 2. Location of DSDP Leg 54 sites in the equatorial Eastern Pacific; bathymetry in meters. Inset: bathymetry in fathoms.

TABLE 1
Location and Water Depth of Leg 54 Cores Studied for Diatoms

Site	Hole	Latitude	Longitude	Water Depth (m)
419	—	08°55.96'N	105°41.17'W	3274
420	—	09°00.10'N	106°06.77'W	3381
421	—	09°01.41'N	106°03.68'W	3339
422	—	09°10.59'N	105°16.27'W	3247
423	—	09°08.81'N	105°06.57'W	3161
424	424B	00°35.82'N	86°07.82'W	2705
425	—	01°23.68'N	86°04.22'W	2850
427	—	08°06.79'N	104°36.35'W	3834
428	—	09°02.77'N	105°26.14'W	3295

I assign most of the diatom-bearing sediments recovered during Leg 54 to the Quaternary *Pseudoenotia doliolus* Zone and Subzone B of the *Nitzschia reinholdii* Zone. Samples 425-6-2, 99-101 cm and 428-5-3, 37-39 cm are placed in Subzone A of the *Nitzschia reinholdii* Zone and probably lie near the Pliocene/Pleistocene boundary of Haq et al. (1977).

Hole 420 is the only hole drilled that penetrates well into the Pliocene. The oldest sediments (Sample 420-13-4, 66-68 cm) are assigned to Subzone B of the *Rhizosolenia praebergonii* Zone (late Pliocene) (2.0 to about 2.6 m.y. ago).

Figure 4 gives the stratigraphic occurrences of diatom datum levels in six of the Leg 54 sites. The last occurrence of the silicoflagellate *Mesocena quadrangula*, which Burckle (1977) estimates to be about 0.79 m.y. old, in the central Pacific, is also included. Taken as a sequence, the datum levels are mutually supportive, although poor preservation in Core 3 of Site 419 and discontinuous coring at Sites 425, 427, and 428 should be taken into consideration when attempting correlations.

Except at Site 427, the datum levels of the Leg 54 sites occur at about the same sediment depths and suggest similar sediment accumulation rates (about 40 to 60 m/m.y.). Site 427 was drilled in the deepest known trough in the Siqueiros fracture zone, and the greater rate of sediment accumulation (about 130 m/m.y.) probably reflects sediment ponding.

In all six of these Leg 54 holes, the last occurrence of the diatom *Nitzschia fossilis* lies very close to the last occurrence of *M. quadrangula* and thus supports Koizumi and Kanaya's (1976) placement of the last occurrence of *N. fossilis* between the Jaramillo polarity event and the earliest part of the Brunhes polarity epoch in the central North Pacific.

The diatom assemblage in Hole 420 (Table 2) is very similar to low-latitude Pliocene and Pleistocene assemblages recorded by Schrader (1974) and Jousé and Kazarina (1974) from the tropical Indian Ocean. Many of the diatom taxa figured in Plates 1 through 11 were also documented by these authors.

Diatoms are generally abundant to few throughout Site 420, with rare or barren intervals in Cores 3 and 13. Preservation varies considerably from sample to sample. Diatoms are generally moderately to well preserved, but intervals of poor preservation occur in almost every core.

The stratigraphic ranges of selected diatoms and the silicoflagellate *Mesocena quadrangula* at Site 420 are shown in Figure 5. The datum levels of Burckle (1972, 1977) and Burckle et al. (in press) provide correlation with paleomagnetic stratigraphy (Figure 1) and estimates of absolute ages. As in other Leg 54 holes (Figure 4), the last occurrence of *Nitzschia fossilis* falls near the last occurrence of *Mesocena quadrangula* and presumably between the Jaramillo polarity event and the base of the Brunhes polarity epoch.

Burckle et al. (1978) report the last occurrence of *Rhizosolenia praebergonii* var. *praebergonii* in the central Pacific during the earliest part of the Olduvai event, immediately before the first occurrence of *Pseudoenotia doliolus*. The last occurrence of *R. praebergonii* var. *praebergonii* in Sample 420-11-4, 19-21 cm and the first occurrence of *P. doliolus* in Sample 420-11-1, 32-34 cm provide correlation with the earliest part of the Olduvai polarity event (Table 2, Figure 5).

Similarly, Burckle et al. (1978) note that *Coscinodiscus nodulifer* var. *cyclopus* recurs in two intervals during the earlier reversed event of the Matuyama epoch. The later occurrence is reported just before the Olduvai polarity event; however, the range of *C. nodulifer* var. *cyclopus* at Site 420 (Figure 5) suggests a slightly younger age when compared with the ranges of *P. doliolus* and *R. praebergonii*. The earlier restricted occurrence of *C. nodulifer* var. *cyclopus* during the oldest part of the Matuyama polarity epoch was not observed in Hole 420, possibly because sediments in Core 13 are poorly preserved (Table 2).

Likewise, the first occurrence of *R. praebergonii* var. *robusta* in Sample 420-13-1, 70-72 cm probably does not correspond with its reported first occurrence in the earliest part of the Matuyama epoch (Burckle et al., 1978) owing to poor preservation in Core 13. In fact, calcareous nannofossils (Bukry, this volume) suggest that the oldest sediments cored at Site 420 are about 2.1 million years old (near the *Discoaster pentaradiatus/D. surculus* zonal boundary).

The ranges of *C. nodulifer* var. *apiculata*, *C. nodulifer* (multinodule form), and *Thalassiosira plicata* at Site 420 are included in Figure 5, because similar ranges were found for these taxa at other Leg 54 sites. However, more detailed stratigraphic studies are needed to establish the biostratigraphic utility of these ranges over a larger area.

TAXONOMIC NOTES

The reader is referred to Schrader (1974), Jousé and Kazarina (1974), Kolbe (1954), Lohman (1941), Hasle and Fryxell (1977), Burckle et al. (in press), and Jousé (1977) for taxonomic references and illustrations of the taxa recorded during this study. Selected notes follow.

Coscinodiscus nodulifer Schmidt, 1978 (multinodule form) (Plate 4, Figures 2, 5; Plate 11, Figures 2-4)

Included here are specimens possessing two or more central nodules (central papillae).

Specimens of this form are large (>60 μ m in diameter) and, except for the numerous central nodules, are identical to typical *C. nodulifer*. Kolbe (1954) argues against the significance of the number of central papillae, stating that "individuals with single and (rarely) several

Age	Diatom Zone (Burckle, 1972, 1977)	Subzone	Site, Hole Sample (Interval in cm)								
			419	420	421	422	423	424B	425	427	428
Quaternary	<i>Pseudoemotia doliolus</i>		1, CC/ 3-1, 59-61 (3-3, 59-61?)	1-1, 55-57/ 3-5, 29-31	1-5, 80-82	1-1, 69-71/ 1-2, 68-70	2-1, 86-88/ 2-2, 70-72		1-1, 70-72/ 2-4, 99-101	1-1, 60-62/ 4-4, 70-72	
	<i>Nitzschia reinholdii</i>	B	4-1, 69-71/ 5-2, 69-71 (5-3, 73-75?)	4-1, 66-68/ 8-5, 65-67		3-3, 66-68/ 8-3, 50-52		1-1, 140-142? 2-3, 140-142 4-3, 30-32?	3-1, 99-101/ 5-2, 99-101	6-1, 123-125/ 8-6, 49-51	2-2, 49-51/ 5-2, 29-31
Late Pliocene		A		9-1, 64-66/ 11-1, 32-34					6-2, 99-101		5-3, 37-39
		C		11-2, 75-77/ 12-3, 50-52							
	<i>Rhizosolenia praebergonii</i>	B		12-4, 50-52 13-4, 66-68							
		A									

Figure 3. Diatom zonation of samples from Leg 54 based on Burckle (1972, 1977). Samples are listed by core number, section number, and interval in centimeters. Where a zone is represented in more than two samples, the highest and lowest are listed separated by a slash.

nodules may be found in the same level of a core." Burckle and McLaughlin (1977), however, note that increases in the abundance of large-diameter *C. nodulifer* may reflect climatic change and be useful for high-resolution biostratigraphy. Specimens of *C. nodulifer* with numerous central nodules tend to be large relative to typical *C. nodulifer*, and future studies may determine their possible ecological significance.

At Site 420, *C. nodulifer* (multinodule forms) occurs within Subzone B of the *Nitzschia reinholdii* Zone (lower Quaternary) (Table 2, Figure 5).

Coscinodiscus nodulifer var. *apiculata* Rattray, 1890
(Plate 4, Figures 6-8; Plate 11, Figures 5, 6)

Coscinodiscus nodulifer Schmidt, in Schmidt et al. (1874), pl. 59, fig. 20.

Coscinodiscus nodulifer Schmidt, Jousé, 1977, pl. 40, fig. 1, 4-6 (not 2, 3).

Rattray (1890) described this form from one of Schmidt's (1874) original illustrations which displayed prominent marginal apiculi. This variety has subsequently been included with the species by various authors (Lohman, 1941; Kolbe, 1954).

In addition to the marginal apiculi present on the variety (Plate 11, Figure 5), the areolations of *C. nodulifer* and *C. nodulifer* var. *apiculata* are distinct. Whereas the former has radial fasciculate areolation of the curvatus type (Plate 4, Figures 1-5), *C. nodulifer* var. *apiculata* displays near-tangential areolation with rows concave towards the margin (eccentric type) (Plate 4, Figures 6, 7).

Under the scanning electron microscope (Plate 11), the distinction of the two areolar patterns and the presence or absence of marginal apiculi is distinct. One could argue for separation at the species level; however, a conservative approach is retained for purposes of this initial report.

At Site 420 (Figure 5), *C. nodulifer* var. *apiculata* is restricted to the Quaternary.

Coscinodiscus tabularis var. *egregius* (Rattray) Hustedt, 1930

Included here are specimens referred to *C. endoi* Kanaya by Schrader (1974).

Nitzschia fossilis (Frenguelli) Kanaya, in Kanaya and Koizumi, 1970

Coarsely silicified forms were separated from the more typical specimens (Plate 6, Table 2). Whether these two forms have ecologic or preservation significance is uncertain.

Rhizosolenia bergonii Peragallo, 1890

Coarsely silicified forms are treated separately from finely silicified forms (Plate 7, Table 2).

Thalassiosira leptopus var. *elliptica* (Kolbe) Barron, n. comb.
(Plate 9, Figure 10)

Coscinodiscus lineatus var. *ellipticus* Kolbe, 1954, p. 32, pl. 2, fig. 15.
Coscinodiscus lineatus var. *ellipticus* Kolbe, Schrader, 1974, p. 913, pl. 10, figs. 5-8.

Coscinodiscus lineatus var. *ellipticus* Kolbe, Jousé, 1977, pl. 43, fig. 4; pl. 45, fig. 34, 35; pl. 46, fig. 7.

Hasle and Fryxell (1977) recently have transferred *Coscinodiscus lineatus* Ehrenberg (1854) to the genus *Thalassiosira*. Because the name *T. lineata* was already occupied, the oldest legitimate synonym, *C. (lineatus* var. ?) *leptopus* Grun. in van Heurck (1883) became the basionym, and the species was named *T. leptopus* (Grun.) Hasle and Fryxell (1977).

Specimens referred to *C. lineatus* var. *ellipticus* Kolbe (1954) are virtually identical to *T. leptopus* under the light microscope and the scanning electron microscope (see Jouse, 1977, pl. 46, fig. 7), except for their elliptical valve outline. Fryxell (personal communication, 1978) has also noted the close resemblance.

In Hole 420, *T. leptopus* and *T. leptopus* var. *elliptica* generally are not present in the same samples (Table 2). *Thalassiosira leptopus* var. *elliptica* occurs in the Quaternary and is concentrated below the last occurrence of *Nitzschia reinholdii*, whereas *T. leptopus* is present in the upper Pliocene and in two samples from the upper part of the Quaternary. Similarly, Bukry and Foster (1973) and Bukry (this volume) also note the restriction of elliptical forms of this species to the Quaternary in the equatorial eastern Pacific. The distribution of *T. leptopus* and its variety may therefore be ecologically controlled; however, further studies are needed to substantiate this.

Thalassiosira spp.

Thalassiosira sp. 1, *T.* sp. 2, and *T.* sp. 3 in Table 2 could not be identified from the literature. Brief descriptions of these forms follow.

Thalassiosira sp. 1
(Plate 8, Figure 2)

This slightly domed form is small (figured specimen 26 μ m diameter) and displays areolation of the eccentric type. Hexagonal areolae vary from six in 10 μ m near the center to eight in 10 μ m near the margin. The margin itself is undifferentiated. At least four mucus pores are dispersed around the center with no more than three areolae separating them.

Thalassiosira sp. 2
(Plate 8, Figure 5)

This strongly domed diatom possesses areolation very similar to that of *T. convexa* Mukhina. Hexagonal areolae decrease notably in size from the center (five to six in 10 μ m) toward the margin (10 to 11

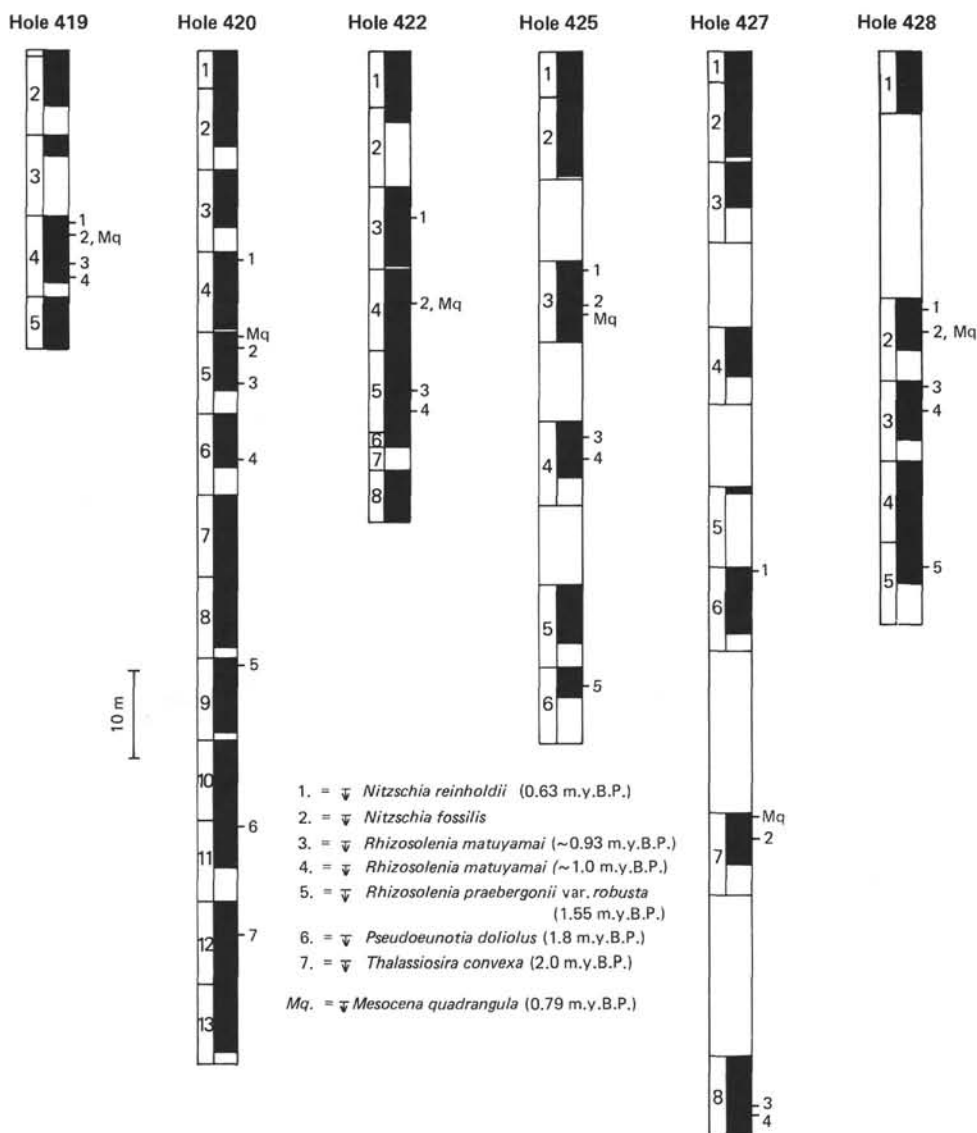


Figure 4. Stratigraphic occurrence of diatom and silicoflagellate datum levels in six of the Leg 54 holes. (↑ = first occurrence of taxon; ↓ = last occurrence.) Shaded intervals represent the amount of sediment recovered in each core (numbered to the left).

in 10 μm). The margin contains numerous short spines (2 μm in length) which are spaced about five in 10 μm . The diameter of the figured specimen is 38 μm .

Thalassiosira sp. 3
(Plate 9, Figure 12)

Thalassiosira sp. 3 superficially resembles *T.* sp. 1; however, its areolae show a greater range in size (seven in 10 μm near the center to 14 in 10 μm at the margin). One mucus pore is located at the center and at least three others surround it separated by four to five areolae. The areolation is of the eccentric type, and the margin is undifferentiated. The figured specimen is 34 μm in diameter.

ACKNOWLEDGMENTS

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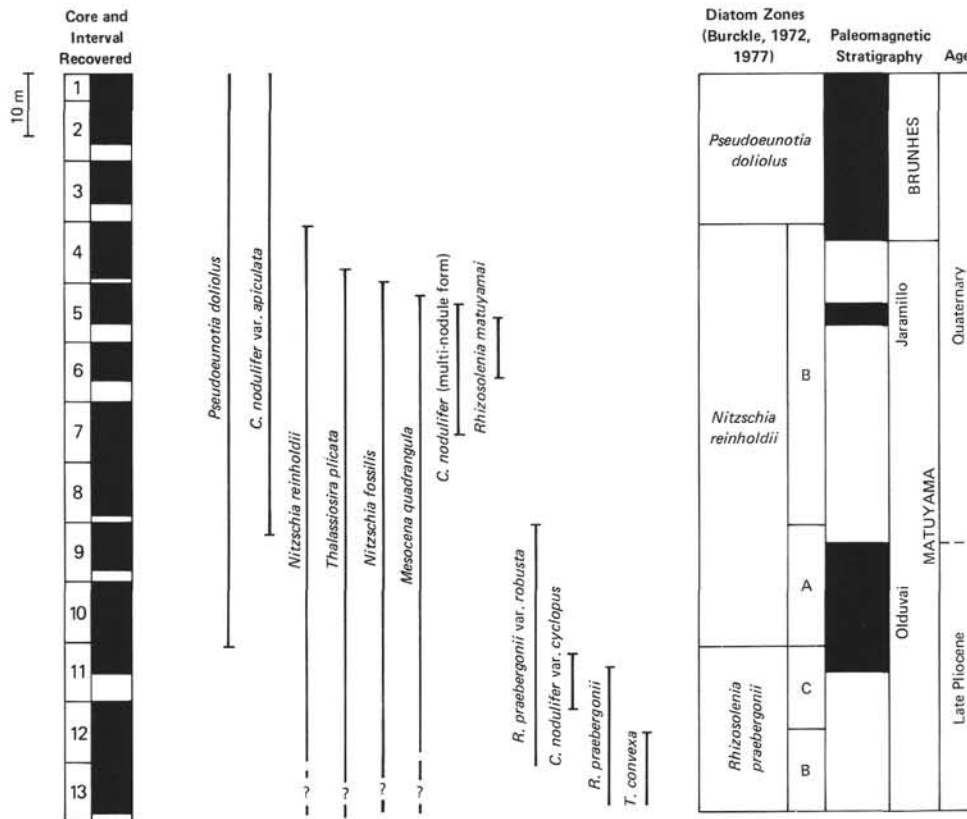


Figure 5. Stratigraphic ranges of selected siliceous microfossils at Site 420 of Leg 54. Paleomagnetic stratigraphy inferred from diatom biostratigraphy.

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PLATE 1

Diatoms from Leg 54.

Figures 1-7; scale bar equals 10 μ m.

Figures 8-10; scale bar equals 20 μ m.

- Figure 1 *Actinocyclus curvatus* Janisch. Sample 420-4-1, 66-68 cm.
- Figure 2 *Actinocyclus* sp. aff. *A. neogradensis* Pantocsek. Sample 420-1-1, 55-57 cm.
- Figures 3, 6 *Actinocyclus ellipticus* Grunow. Sample 420-7-1, 54-56 cm.
- Figure 4 *Actinocyclus* sp. cf. *A. curvatus* Janisch. Sample 419-4-2, 63-65 cm.
- Figure 5 *Actinocyclus ehrenbergii* Ralfs. Sample 425-4-3, 99-101 cm.
- Figure 7 *Actinocyclus ellipticus* f. *lanceolata* Kolbe. Sample 425-6-2, 99-101 cm.
- Figure 8 *Hemidiscus cuneiformis* Wallich (elongate). Sample 425-4-3, 99-101 cm.
- Figure 9 *Hemidiscus cuneiformis* Wallich. Sample 425-5-2, 99-101 cm.
- Figure 10 *Hemidiscus cuneiformis* Wallich (heavily silicified form). Sample 420-11-4, 19-21 cm.

PLATE 1

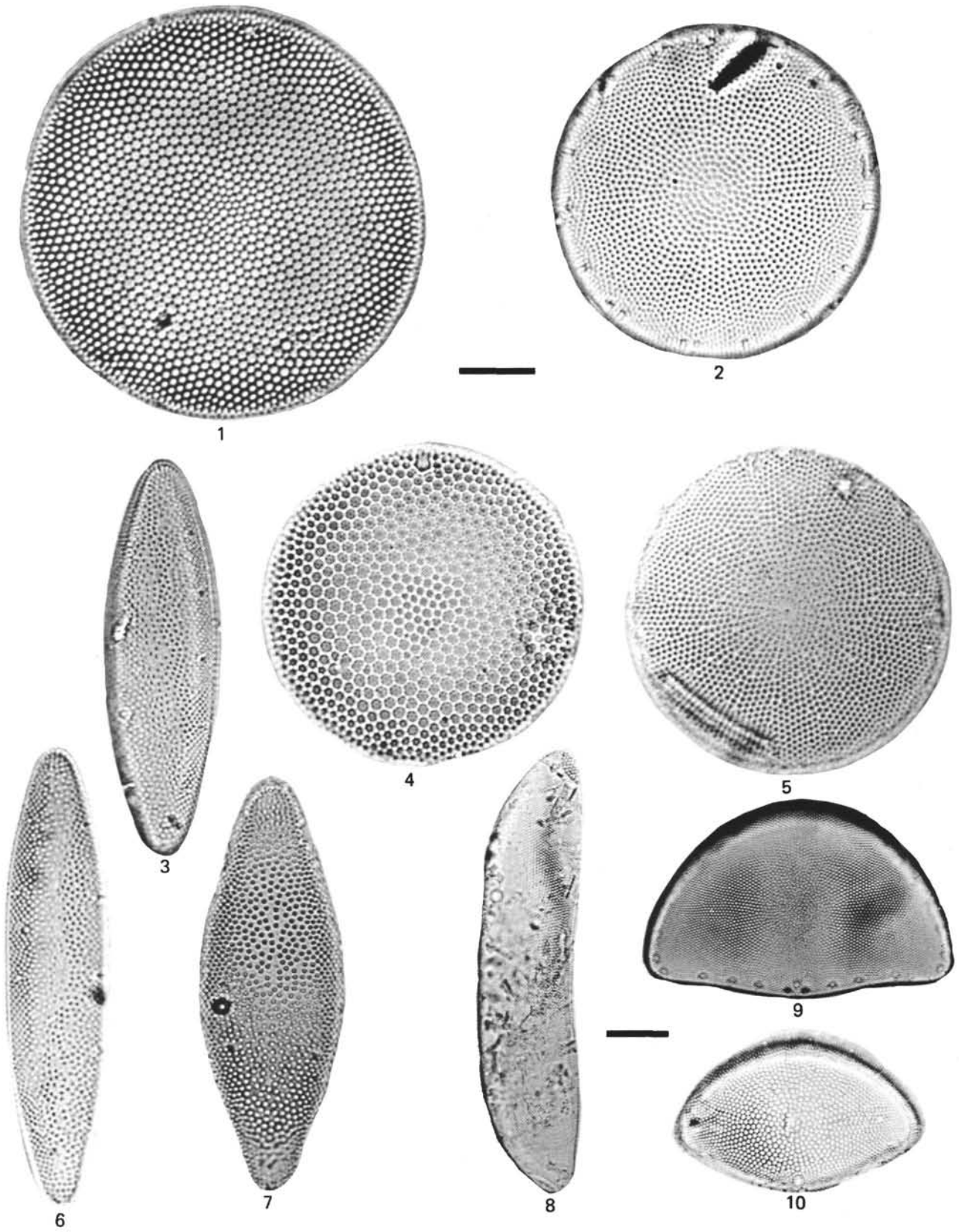


PLATE 2

Diatoms from Leg 54

Figures 1-7, 9; scale bar equals 10 μ m.
Figures 8, 10, 11; scale bar equals 20 μ m.

- Figure 1 *Asterolampra marylandica* Ehrenberg. Sample 420-1-1, 55-57 cm.
- Figure 2 *Asteromphalus arachne* (Brebisson) Ralfs. Sample 419-5-2, 69-71 cm.
- Figure 3 *Asteromphalus hookeri* Ehrenberg. Sample 425-5-2, 99-101 cm.
- Figures 4, 6 *Asteromphalus* sp. cf. *A. flabellatus* (Brebisson) Greville.
4. Sample 425-5-2, 99-101 cm.
6. Sample 427-3-1, 40-42 cm.
- Figures 5, 7, 8 *Asteromphalus imbricatus* Wallich.
5. Sample 425-5-2, 99-101 cm.
7. Sample 420-9-4, 69-71 cm.
8. Sample 425-3-3, 99-101 cm.
- Figure 9 *Asteromphalus hiltonianus* Greville. Sample 420-1-1, 55-57 cm.
- Figure 10 *Bacteriastrum hyalinum* Lauder. Sample 425-5-2, 99-101 cm.
- Figure 11 *Asteromphalus elegans* Greville. Sample 420-5-2, 66-68 cm.

PLATE 2

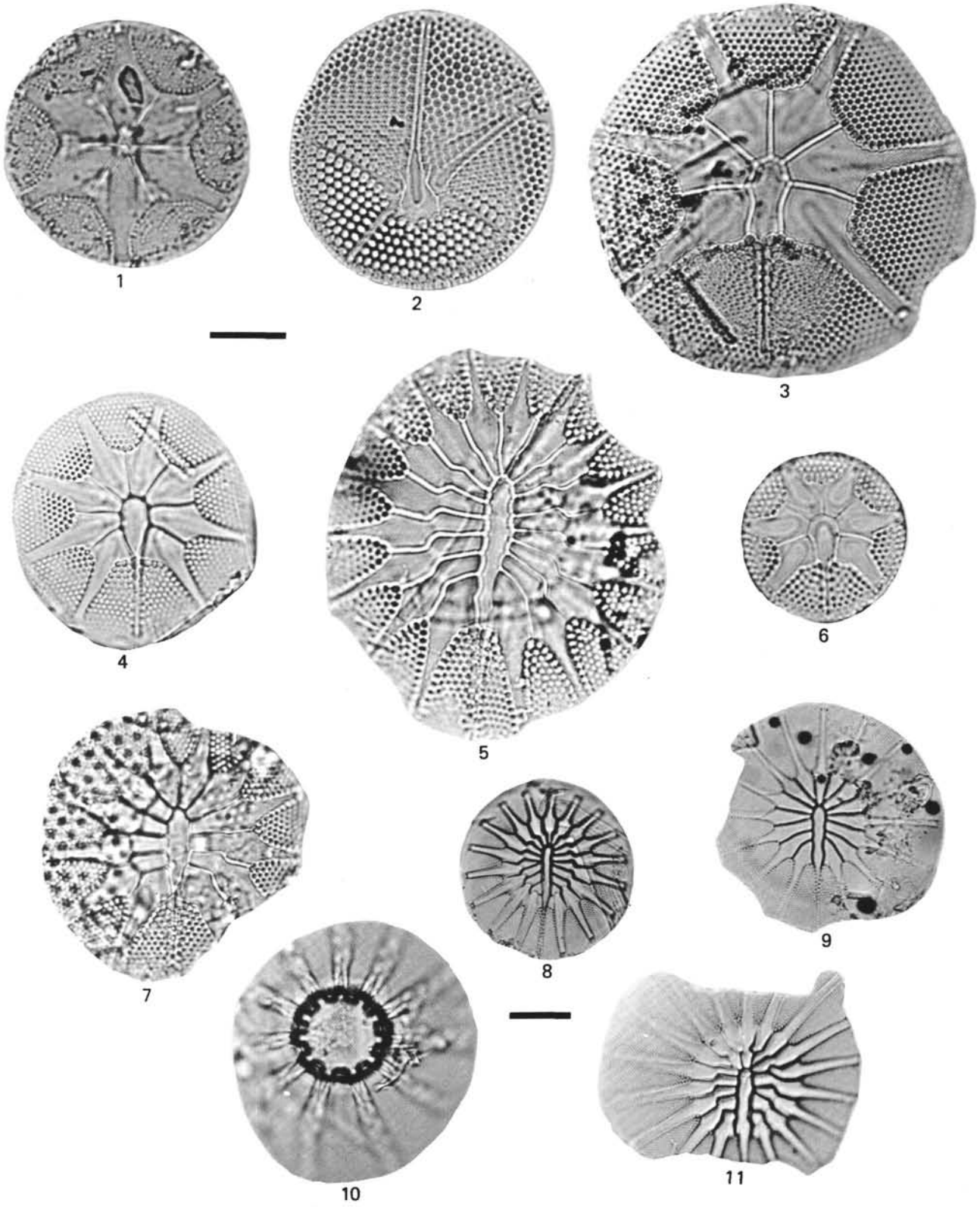


PLATE 3

Diatoms from Leg 54

Figures 1-10, 12, 13; scale bar equals 10 μ m.

Figure 11; scale bar equals 20 μ m.

- Figures 1, 2, 3 *Coscinodiscus tabularis* var. *egregius* (Rattray) Hustedt.
1. Sample 420-4-1, 66-68 cm.
2. Sample 420-7-1, 54-56 cm.
3. Sample 420-12-5, 68-70 cm.
- Figures 4, 6 *Coscinodiscus crenulatus* Grunow.
4. Sample 420-4-4, 66-68 cm.
6. Sample 420-10, CC.
- Figure 5 *Coscinodiscus africanus* Janisch. Sample 420-7-1, 54-56 cm.
- Figures 7, 11
12 *Coscinodiscus curvatulus* Grunow.
7. Sample 420-12-4, 50-52 cm.
11, 12. Sample 420-7-1, 54-56 cm.
- Figures 8, 10 *Roperia tessellata* (Roper) Grunow.
8. Sample 420-5-4, 66-68 cm.
10. Sample 420-1-1, 55-57 cm.
- Figure 9 *Coscinodiscus* sp. cf. *C. perforatus* Ehrenberg.
Sample 420-12-4, 50-52 cm.
- Figure 13 *Roperia tessellata* var. *ovata* Mann. Sample 420-1-1, 55-57 cm.

PLATE 3

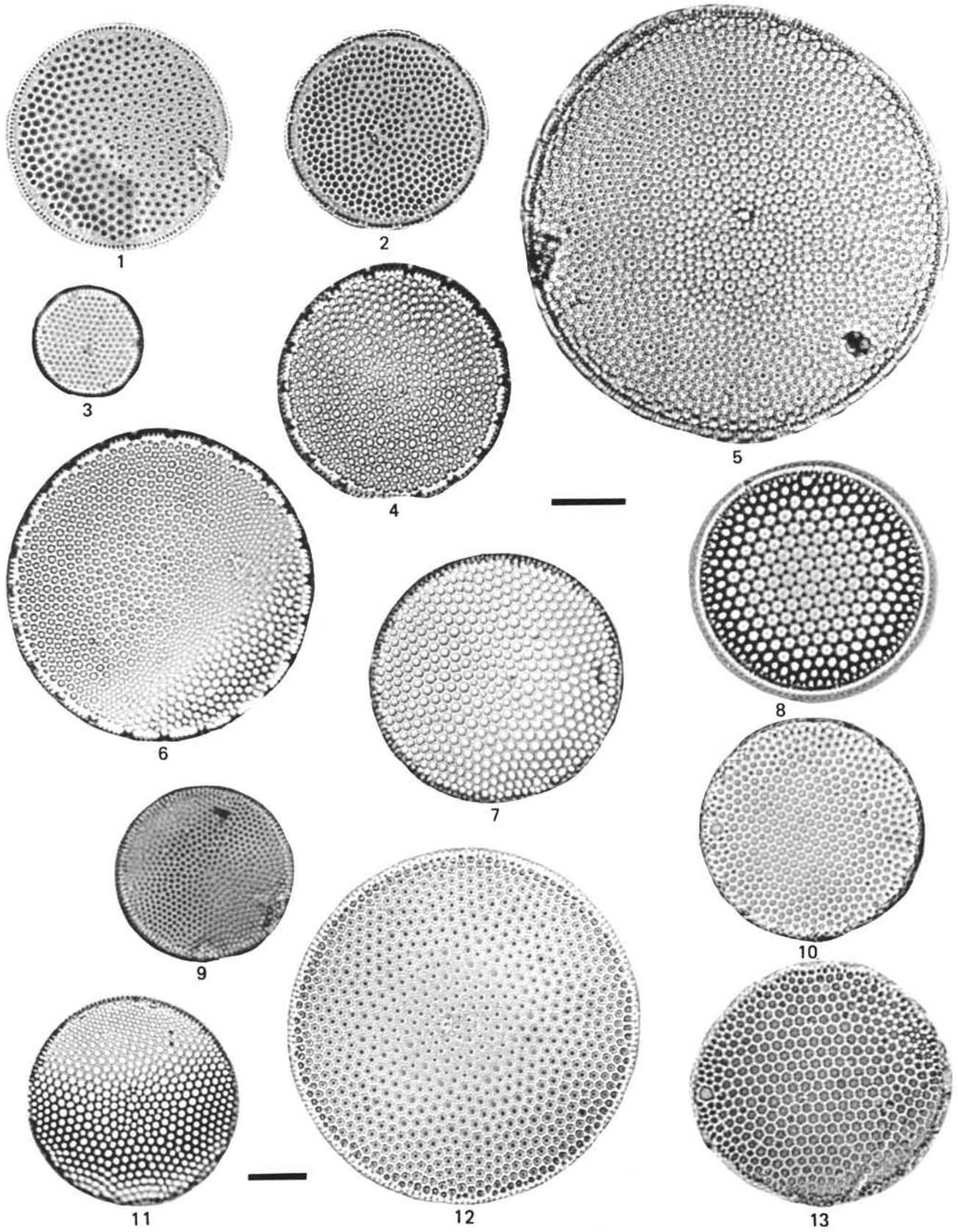


PLATE 4

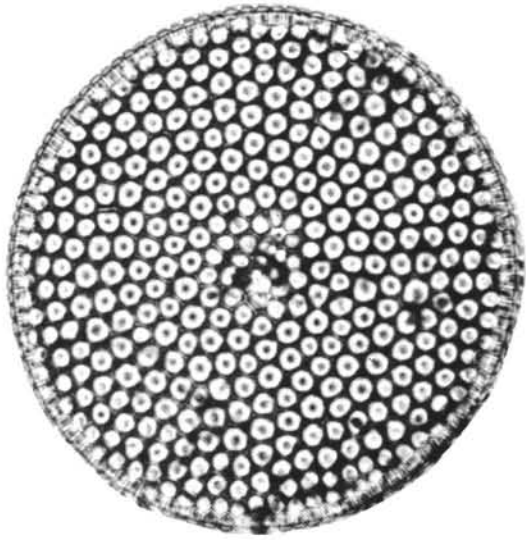
Diatoms from Leg 54

Figures 1, 4; scale bar equals 10 μ m.

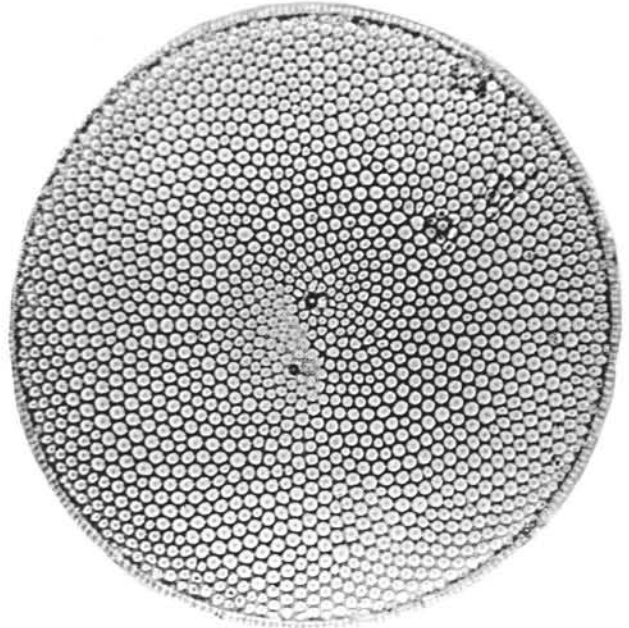
Figures 2, 3, 5-8; scale bar equals 20 μ m.

- Figure 1 *Coscinodiscus nodulifer* Schmidt. Sample 420-7-4, 66-68 cm.
- Figures 2, 5 *Coscinodiscus nodulifer* Schmidt (multi-nodule form). Sample 420-5-4, 66-68 cm.
- Figure 3 *Coscinodiscus nodulifer* var. *cyclopus* Jousé. Sample 420-11-3, 69-71 cm.
- Figure 4 *Coscinodiscus nodulifer* Schmidt (without central nodule). Sample 425-3-3, 99-101 cm.
- Figures 6, 7, 8 *Coscinodiscus nodulifer* var. *apiculata* Rattray.
6. Sample 420-2-4, 53-55 cm.
7. Sample 420-1-1, 55-57 cm.
8. Sample 420-7-4, 66-68 cm.

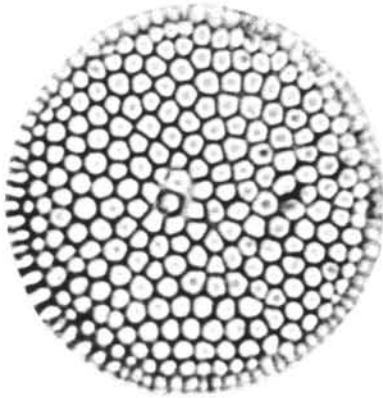
PLATE 4



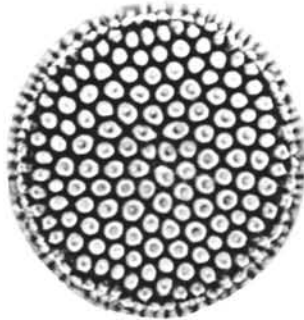
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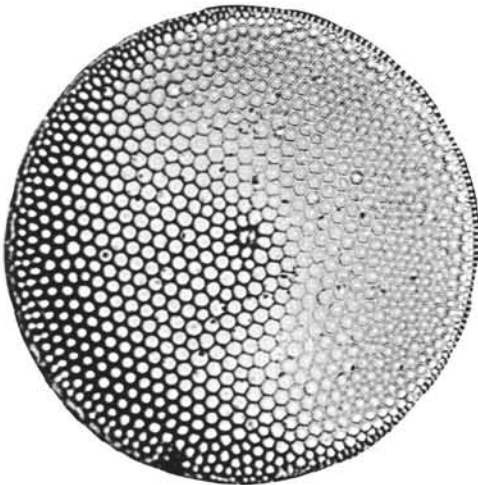
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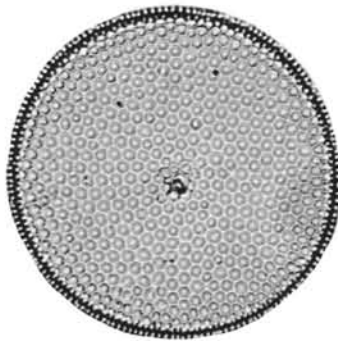
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5



6



7



8

PLATE 5
Diatoms from Leg 54
Scale bar equals 10 μ m.

- Figure 1 *Coscinodiscus* sp. cf. *C. oculusiridis* Ehrenberg
(focal change). Sample 420-4-1, 66-68 cm.
- Figures 2, 5, 7 *Coscinodiscus radiatus* Ehrenberg.
2. Sample 420-1-1, 55-57 cm.
5. Sample 420-9-2, 68-70 cm.
7. Sample 420-7-1, 54-56 cm.
- Figures 3, 4 *Thalassiosira pacifica* Gran and Angst.
3. Sample 425-5-2, 99-101 cm.
4. Sample 420-2-4, 53-55 cm (focal change).
- Figure 6 *Thalassiosira* sp. 6 of Schrader, 1974. Sample
420-7-1, 54-56 cm.
- Figures 8, 9, 10 *Coscinodiscus plicatus* Grunow (group).
8. Sample 420-4-1, 66-68 cm.
9. Sample 420-2-4, 53-55 cm.
10. Sample 425-3-3, 99-101 cm.

PLATE 5

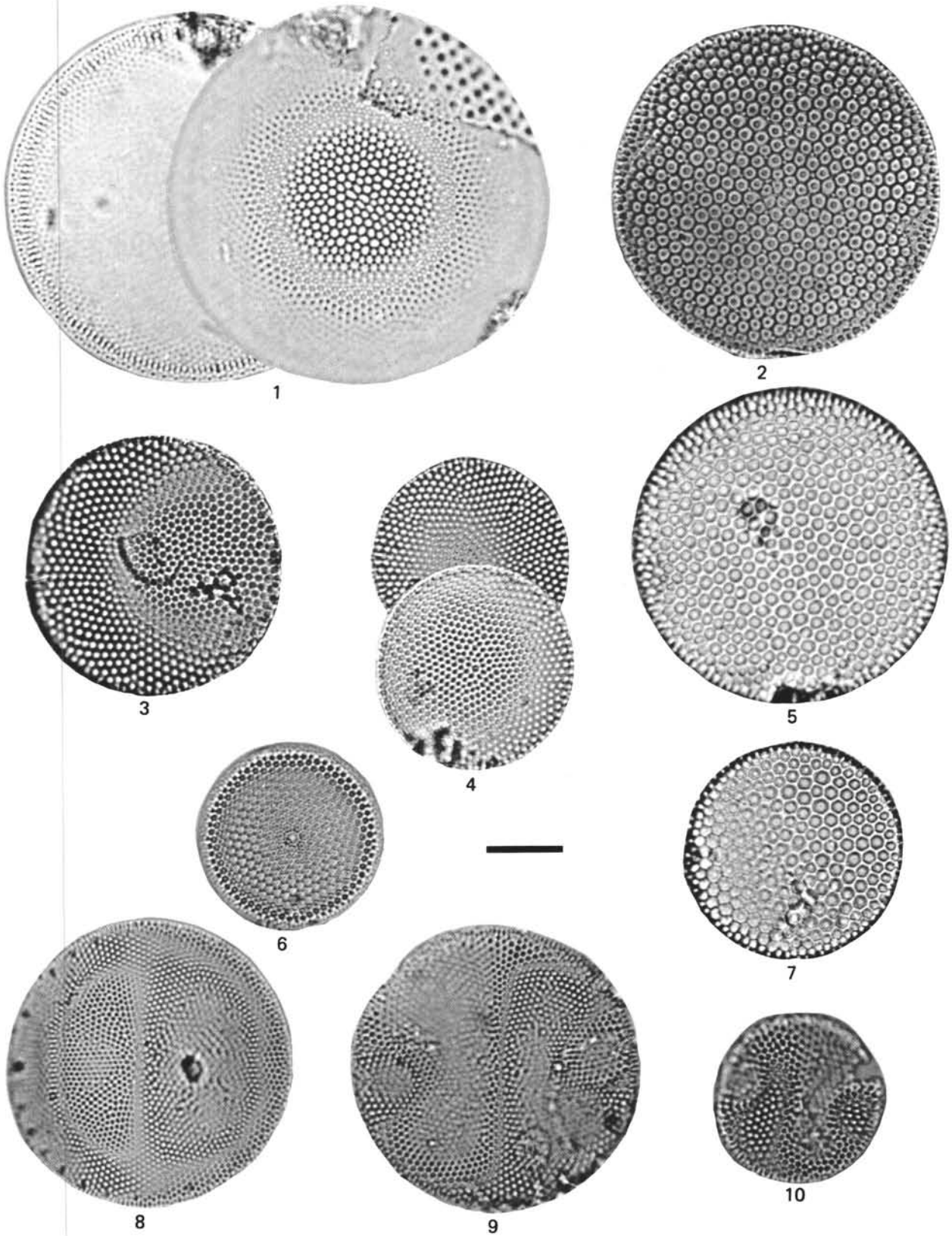


PLATE 6

Diatoms from Leg 54

Figures 1-15, 18-20; scale bar equals 10 μ m.

Figures 16, 17; scale bar equals 20 μ m.

- Figures 1, 2, 3 *Pseudoeunotia doliolus* (Wallich) Grunow.
1. Sample 420-7-4, 66-68 cm.
2. Sample 420-4-1, 66-68 cm.
3. Sample 420-7-1, 54-56 cm.
- Figure 4 *Nitzschia fossilis* (Frenguelli) Kanaya (fine form).
Sample 420-7-4, 66-68 cm.
- Figures 5, 6, 7 *Nitzschia fossilis* (Frenguelli) Kanaya (coarse form).
5. Sample 425-4-3, 99-101 cm.
6. Sample 420-5-3, 66-68 cm.
7. Sample 420-7-1, 54-56 cm.
- Figure 8 *Nitzschia fossilis* (Frenguelli) Kanaya s. ampl.
Sample 420-12-2, 69-71 cm.
- Figure 9 *Pseudoeunotia doliolus* (Wallich) Grunow. Transitional form from *Nitzschia fossilis* (Frenguelli) Kanaya. Sample 420-10-6, 68-70 cm.
- Figures 10, 11 *Nitzschia reinholdii* Kanaya and Koizumi.
10. Sample 419-5-2, 69-71 cm.
11. Sample 420-9-4, 69-71 cm.
- Figure 12 *Nitzschia* sp. cf. *N. reinholdii* Kanaya and Koizumi. Sample 420-7-4, 66-68 cm.
- Figures 13, 19 *Nitzschia interrupta* Heiden.
13. Sample 420-7-4, 66-68 cm.
19. Sample 420-10-6, 68-70 cm.
- Figure 14 *Nitzschia miocenica* Burckle. Sample 425-6-2, 99-101 cm (reworked specimen).
- Figures 15, 21 *Thalassionema nitzschioides* Grunow.
15. Sample 420-5-4, 66-68 cm.
21. Sample 419-5-2, 69-71 cm.
- Figure 16 *Nitzschia marina* Grunow. Sample 420-1-1, 55-57 cm.
- Figure 17 *Thalassiothrix longissima* Cleve and Grunow. Sample 425-3-3, 99-101 cm.
- Figure 18 *Cussia* sp. cf. *C. lancettula* Schrader. Sample 420-9-1, 64-66 cm.
- Figure 20 *Nitzschia* sp. Sample 425-5-2, 99-101 cm.

PLATE 6

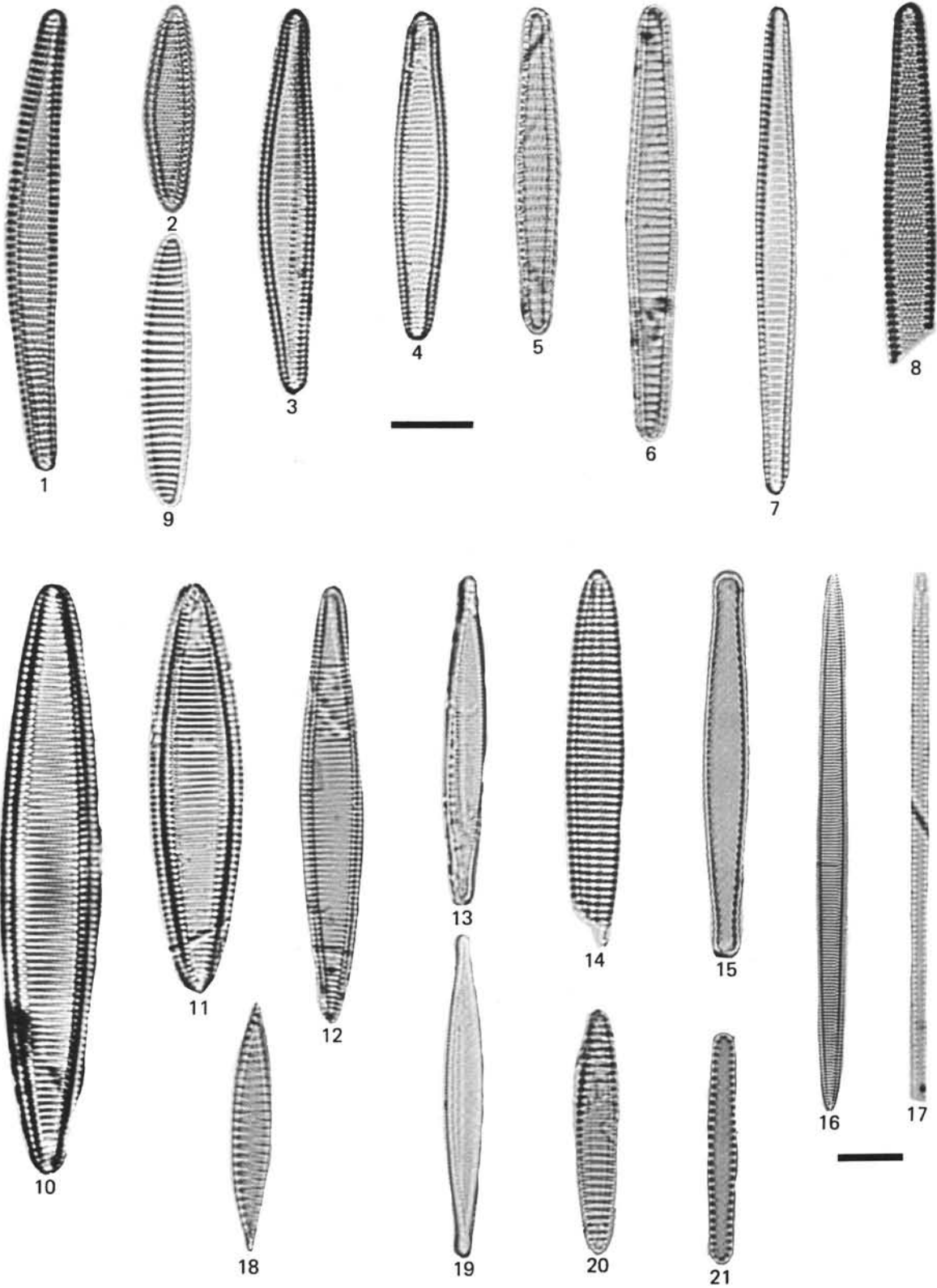


PLATE 7

Diatoms from Leg 54

Figures 1-12; scale bar equals 10 μm .

Figures 13, 14; scale bar equals 20 μm .

- Figure 1 *Rhizosolenia bergonii* Peragallo (coarse form).
Sample 419-4-2, 63-65 cm.
- Figure 2 *Rhizosolenia bergonii* Peragallo (fine form). Sam-
ple 425-5-2, 99-101 cm.
- Figures 3, 4 *Rhizosolenia praebergonii* Mukhina.
3. Sample 420-11-4, 19-21 cm.
4. Sample 420-13-4, 66-68 cm.
- Figures 5-8 *Rhizosolenia praebergonii* var. *robusta* Burckle
and Trainer.
5. Sample 420-12-2, 69-71 cm.
6, 7. Sample 420-12-4, 50-52 cm.
8. Sample 420-10-6, 68-70 cm.
- Figures 9-12 *Rhizosolenia matuyamai* Burckle.
9. Sample 425-4-3, 99-101 cm.
10. Sample 425-4-2, 99-101 cm.
11. Sample 425-4-3, 99-101 cm.
12. Sample 420-6-3, 66-68 cm.
- Figure 13 *Rhizosolenia syliformis* Brightwell. Sample 425-
4-3, 99-101 cm.
- Figure 14 *Chaetoceros* spine. Sample 419-5-2, 99-101 cm.

PLATE 7

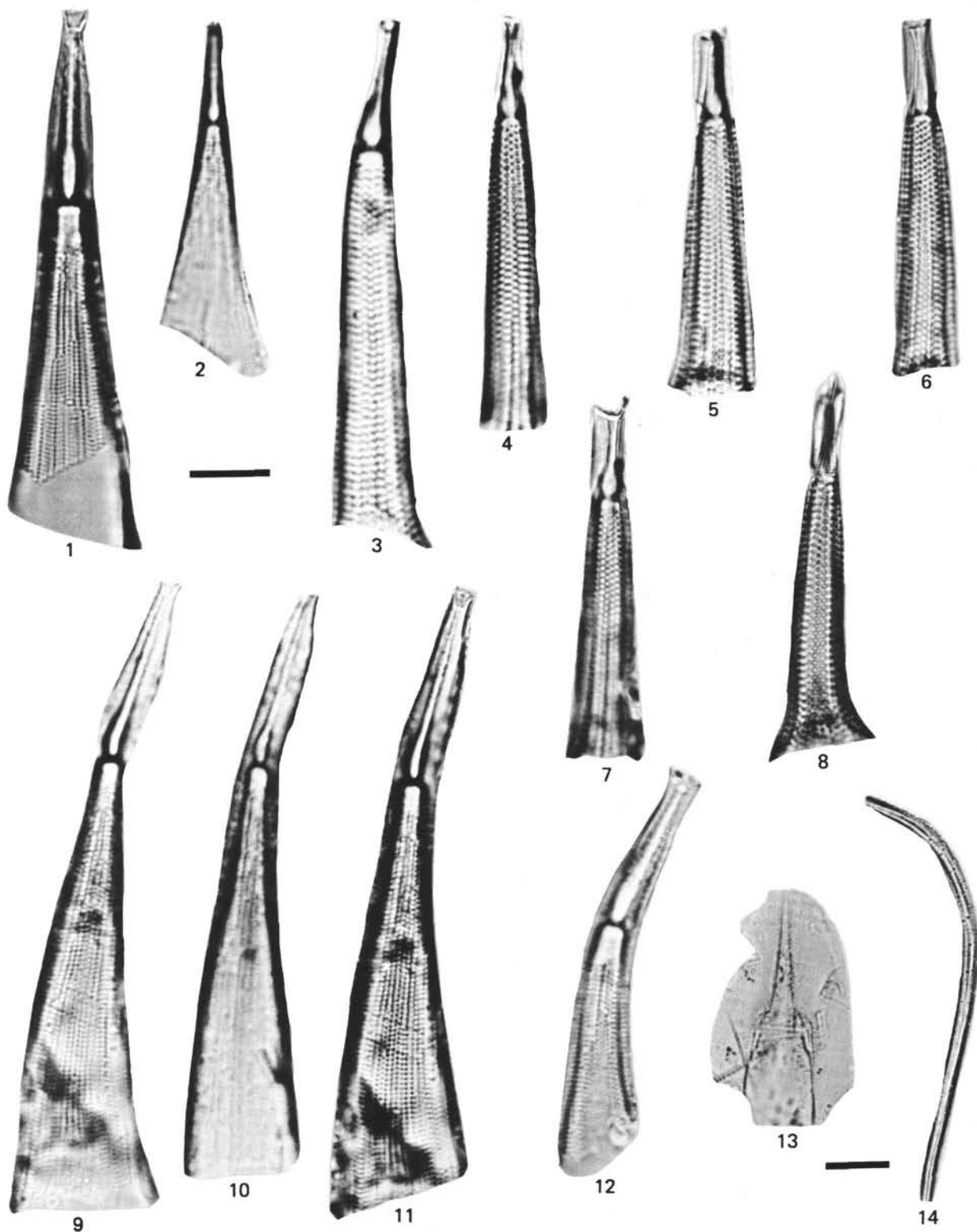


PLATE 8

Diatoms from Leg 54

Figures 1-1, 11; scale bar equals 10 μm .

Figure 10; scale bar equals 20 μm .

- Figure 1 *Thalassiosira convexa* Mukhina (focal change).
Sample 420-12-4, 50-52 cm.
- Figure 2 *Thalassiosira* sp. 1. Sample 420-7-1, 54-56 cm.
- Figure 3 *Thalassiosira convexa* var. *aspinosa* Schrader.
Sample 425-6-2, 99-101 cm (reworked specimen).
- Figure 4 *Thalassiosira miocenica* Schrader (focal change).
Sample 425-6-2, 99-101 cm (reworked specimen).
- Figure 5 *Thalassiosira* sp. 2 (focal change). Sample 420-
2-4, 53-55 cm.
- Figures 6, 9,
10 *Thalassiosira plicata* Schrader.
6. Sample 419-5-2, 69-71 cm.
9. Sample 420-11-2, 75-77 cm (focal change).
10. Sample 419-5-2, 69-71 cm.
- Figures 7, 8,
11 *Thalassiosira symbolophora* Schrader.
7. Sample 419-4-2, 63-65 cm.
8. Sample 427-3-1, 40-42 cm.
11. Sample 420-4-1, 66-68 cm.

PLATE 8

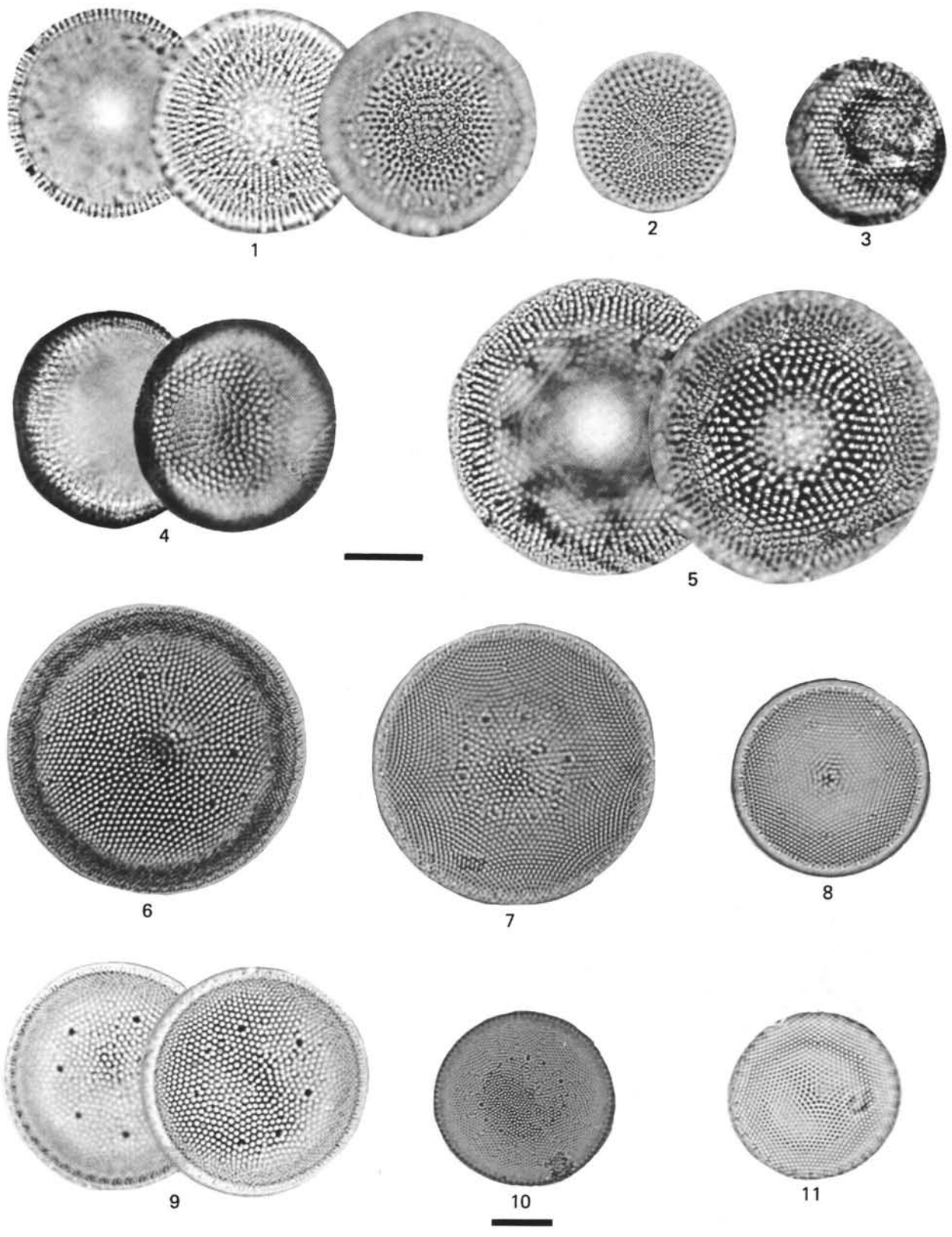


PLATE 9

Diatoms from Leg 54

Figures 1-9, 11, 12; scale bar equals 10 μ m.

Figure 10; scale bar equals 20 μ m.

- Figure 1 *Thalassiosira excentrica* (Ehrenberg) Cleve. Sample 420-2-4, 53-55 cm.
- Figures 2, 4, 7 *Thalassiosira oestrupii* (Ostenfeld) Proshkina-Lavrenko.
2. Sample 420-7-1, 54-56 cm.
4. Sample 420-8-4, 68-70 cm.
7. Sample 420-1-1, 55-57 cm.
- Figure 3 *Thalassiosira* sp. cf. *T. excentrica* (Ehrenberg) Cleve. Sample 420-9-1, 64-66 cm.
- Figure 5 *Thalassiosira oestrupii* (Ostenfeld) Proshkina-Lavrenko (focal change). Sample 420-5-4, 66-68 cm.
- Figure 6 *Thalassiosira leptopus* (Grunow) Hasle and Fryxell. Sample 419-4-2, 63-65 cm.
- Figures 8, 11 *Thalassiosira ferelineata* Hasle and Fryxell.
8. Sample 420-7-4, 66-68 cm.
11. Sample 420-7-1, 54-56 cm.
- Figure 9 *Thalassiosira* sp. aff. *T. symbolophora* Schrader (focal change). Sample 419-4-2, 63-65 cm.
- Figure 10 *Thalassiosira leptopus* var. *elliptica* (Kolbe) Barron n. comb. Sample 420-7-1, 54-56 cm.
- Figure 12 *Thalassiosira* sp. 3 (focal change). Sample 420-1-3, 66-68 cm.

PLATE 9

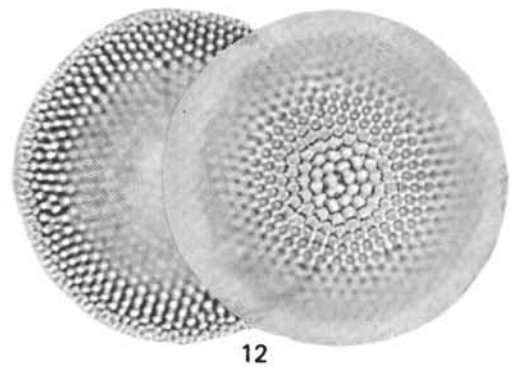
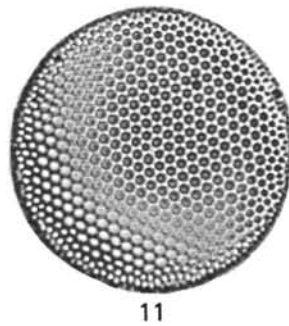
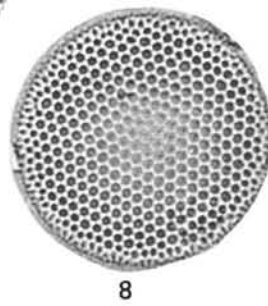
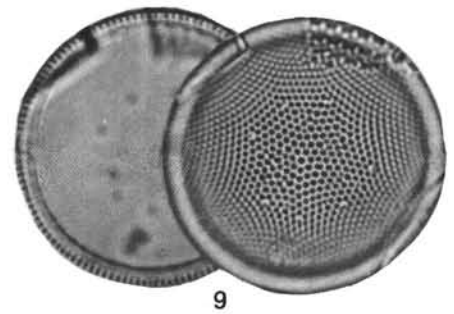
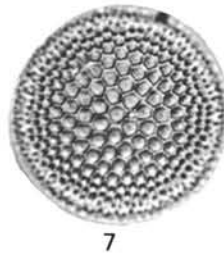
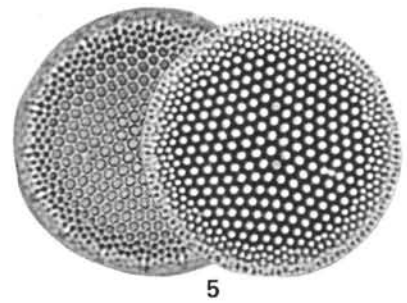
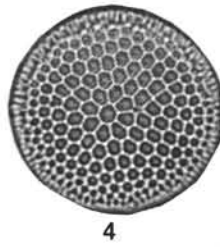
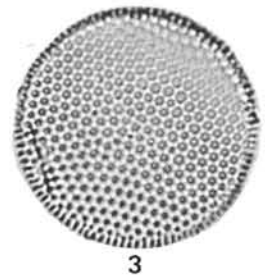
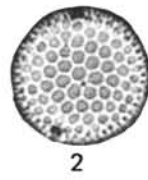


PLATE 10

Diatoms from Leg 54

Figures 1-3, 5-12; scale bar equals 10 μm .

Figure 4; scale bar equals 20 μm .

- Figures 1, 2 *Actinoptychus bipunctatus* Lohman.
1. Sample 425-5-2, 99-101 cm.
2. Sample 420-1-1, 55-57 cm.
- Figures 3, 6 *Ethmodiscus rex* (Rattray) Hendey.
3. Valve center. Sample 427-4-1, 50-52 cm.
6. Fragment. Sample 420-9-4, 69-71 cm.
- Figure 4 *Actinoptychus undulatus* (Bailey) Ralfs. Sample
425-5-2, 99-101 cm.
- Figures 5, 10 *Triceratium cinnamomeum* (Greville) Grunow.
5. Sample 425-4-3, 99-101 cm.
10. Sample 420-11-4, 19-21 cm.
- Figures 7, 8 *Triceratium cinnamomeum* var. *minor* Grunow.
7. Sample 419-5-2, 69-71 cm.
8. Sample 420-4-1, 66-68 cm.
- Figure 9 *Navicula hennedyi* Wm. Smith. Sample 425-5-2,
99-101 cm.
- Figures 11, 12 *Biddulphia alternans* van Heurck. Sample 425-5-
2, 99-101 cm.

PLATE 10

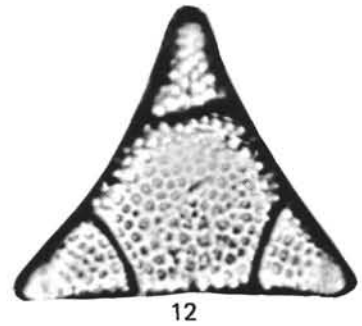
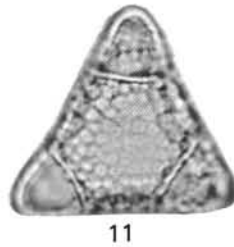
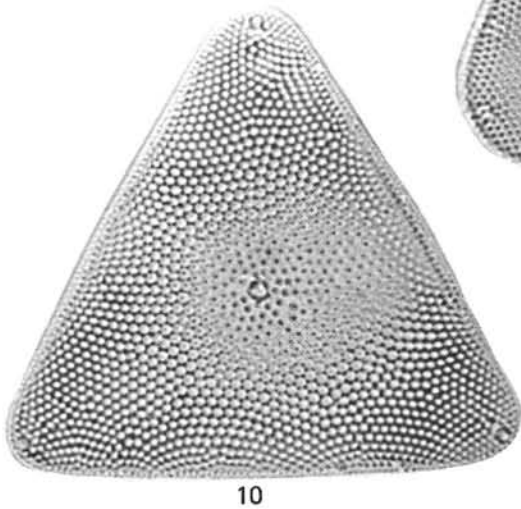
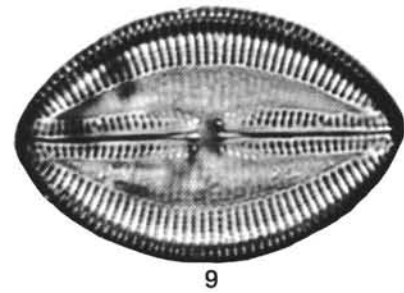
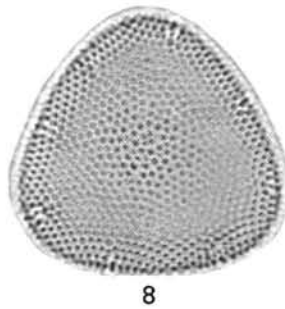
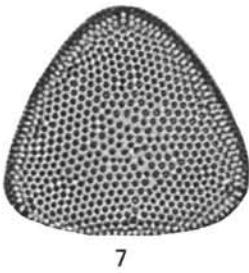
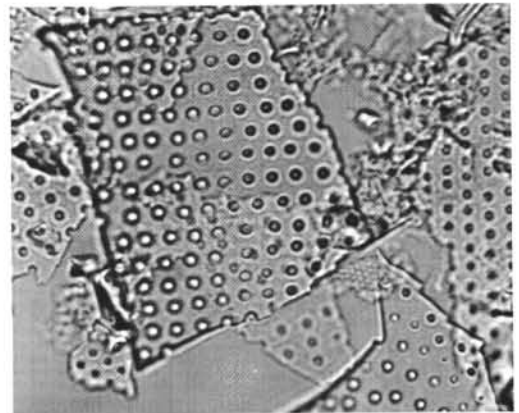
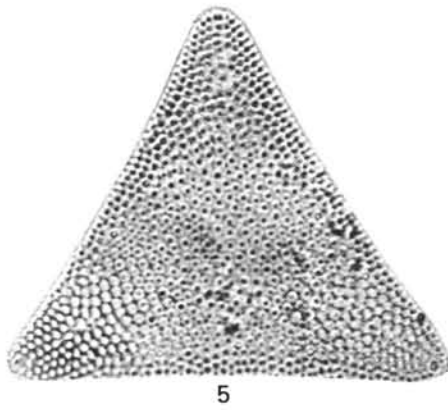
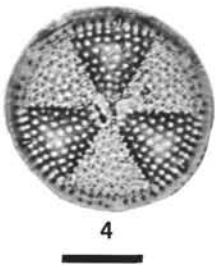
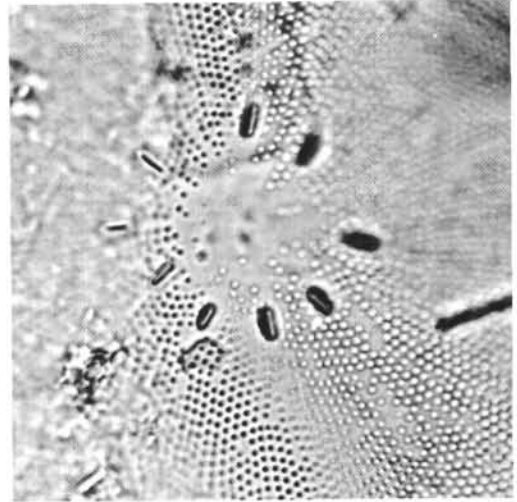
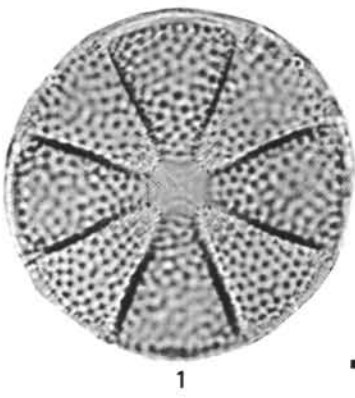
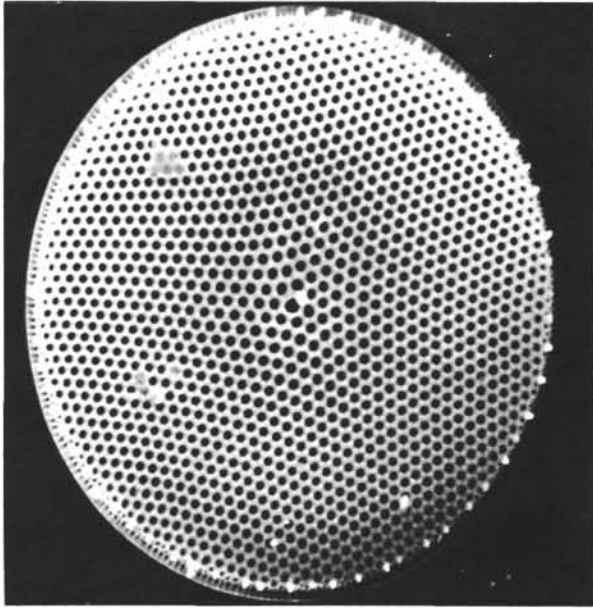


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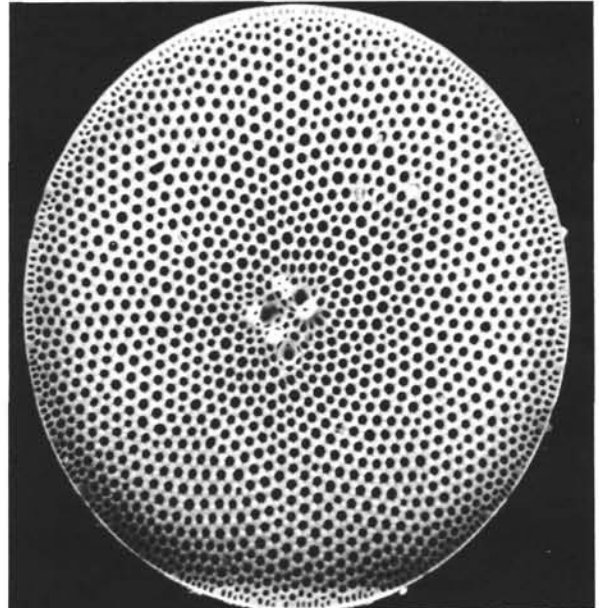
Diatoms from Leg 54. Scanning electron microscope photographs. All specimens from Sample 420-7-1, 54-56 cm. Scale bar represents 10 μm for all figures, except Figure 4, where it represents 3 μm .

- Figure 1 *Thalassiosira excentrica* (Ehrenberg) Cleve.
- Figures 2-4 *Coscinodiscus nodulifer* Schmidt (multi-nodule form).
2. Valve view.
3. Inclined girdle view.
4. Close-up of the central nodules of Figure 2.
- Figures 5, 6 *Coscinodiscus nodulifer* var. *apiculata* Rattray.
5. Whole valve view.
6. Threefold enlargement of central nodule of Figure 5.

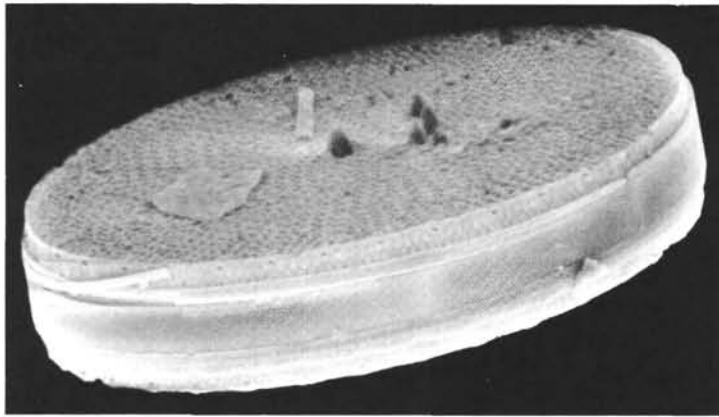
PLATE 11



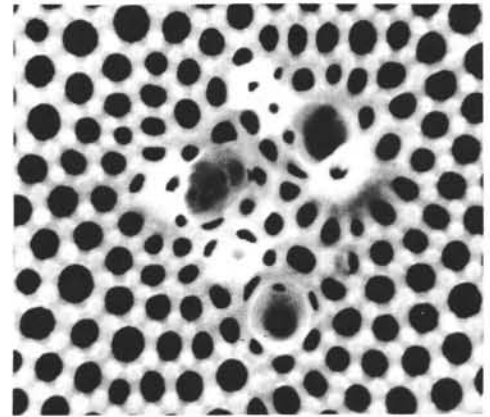
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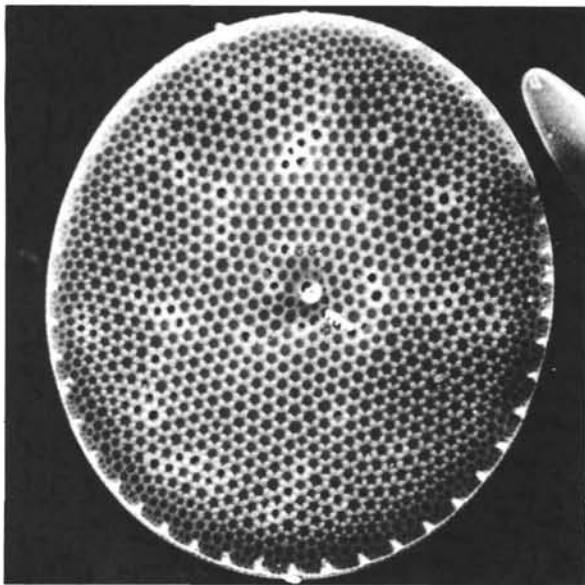
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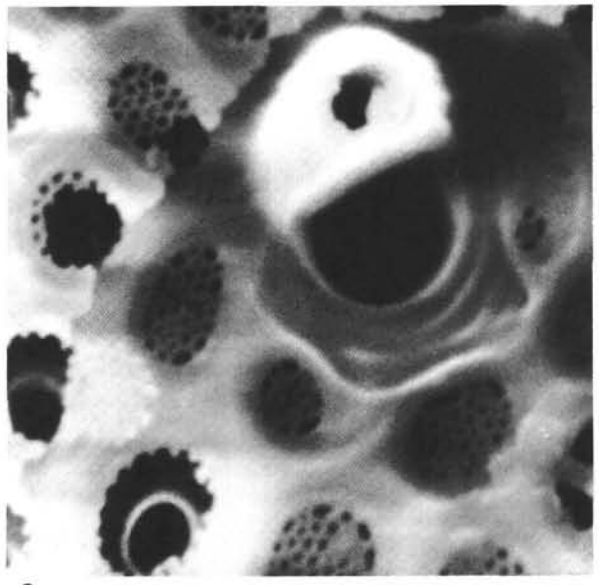
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4



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6