DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Scanning Electron Micrographs of Late Cenozoic Nonmarine Diatoms from Interior Basin Deposits in Northern California

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards (and stratigraphic nomenclature).

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INTRODUCTION

This report illustrates 26 nonmarine diatom taxa from 9 late Tertiary localities in northern California. Some of these taxa have been previously named, whereas others are illustrated for the first time. Even though some of those taxa have long been known, many are so small that their fine structures cannot be readily understood using only the light microscrope. More meaningful and detailed observations of these relatively small diatom taxa are now possible using the SEM. For the first time, both external and internal surfaces of these diatoms can be clearly differentiated, and the structure of the valve wall can be more accurately ascertained. In addition, the tiny processes of the diatom valve can be observed and classified under high SEM magnification. These small processes have become increasingly important in diatom taxonomy in recent years.

A great deal of taxonomic confusion has resulted from the attempts of various workers to classify the smaller nonmarine diatoms, particularly the centric taxa, solely by means of light microscopy. A few of the centric taxa illustrated in this report have been assigned to named species and varieties, but these identifications, at best, should still be considered tentative; other taxa are indicated as showing affinities for named species and varieties; still others of even more uncertain affinity are labelled simply as "sp. A,B,C, etc." The pennate diatoms illustrated in Plates 11-13 can, in most instances, be more readily identified with a previously published name. However, such identifications are in many cases simplistic, and a great deal of new work on nonmarine pennate diatom taxonomy needs to be done with the aid of the scanning electron microscrope.

The purpose of this report is to provide primary documentation of the occurrence of particular nonmarine diatoms at defined localities and to provide a record of the SEM photographs of these diatoms in a permanent depository that will serve as a basis for biostratigraphic and paleolimnologic studies of Neogene continental diatoms in the western U.S. The preparation of this report has entailed the splitting of the diatoms observed in these assemblages into morphological entities of possible taxonomic value. No attempt is here made to present a formal taxonomic revision or placement of these nonmarine diatoms. Although these diatoms have been illustrated by external and internal views, when available, and by high magnification photographs of fine structures, when applicable, formal taxonomic treatment must be based on detailed morphologic observations and detailed descriptions and appropriate comparisons. No descriptions are included beyond brief comments in the plate captions designed to make the figures more intelligible. All forms for which adequate photographic documentation exists are illustrated, but by no means have all of the photographs taken for this study been included. Considerable further study under the SEM, particularly of the centric diatoms, will be needed for a meaningful taxonomic treatment.

STRATIGRAPHIC CONSIDERATIONS

This study has been undertaken in connection with a study of nonmarine diatoms in a core taken at Tulelake, California, and under examination by J. P. Bradbury, Branch of Paleontology and Stratigraphy, USGS, Denver. Most of the specimens illustrated were derived from seven samples collected by Bradbury in 1984. Two other assemblages, USGS Diatom Localities 4076 and 4077, collected by Perry Wood, Water Resources Division, USGS, are also represented in this report. The Bradbury samples are part of a larger collection of 80 diatomaceous outcrop samples from northern California and southern Oregon taken in the region around Tulelake, California, in June 1984. Outcrops of diatomaceous sediments are widely distributed but also discontinuous in that region, and accurate correlation between widely separated deposits requires detailed study of their diatom assemblages in conjunction with tephrochronology. For example, the distribution of some distinctive diatoms like Cyclotella aff. C. elgeri (Plate 10, Figures 3-6) allows precise correlation of outcrops that is supported by volcanic ash correlations (Andrei Sarna-Wojcicki, written communication). The volcanic ash correlations in this case indicate that the diatomites in question are 2.2 to 2.6 million years old. Although this time is spanned by the Tulelake core record, neither the distinctive diatoms nor the volcanic ash were encountered in that section, perhaps implying a local hiatus in the Tulelake core during that period.

Hopefully, a successful nonmarine diatom biostratigraphy may be developed for the region. This will certainly be dependent on more scanning electron microscopy than is represented by this report and substantially more field work. The occurrences of diatomite in southern Oregon (and adjacent to the California diatomaceous sediments herein examined) have been reported by Moore (1937, p. 20-51), but I do not know of any analogous treatment of nonmarine diatomites from northern California.

PALEOECOLOGIC CONSIDERATIONS

Many of the diatom assemblages studied for this report are dominated by only one or two centric nonmarine diatom taxa. None of the samples examined show any great diversity in diatom taxa, and specimens of pennate diatoms are infrequent to extremely rare. Aulacosira solida and Cyclotella elgeri, figured in this report, characterize the sediments of the Tulelake core, especially below the 100 m depth. The presence of these species in nearby outcrops of diatomite suggests that the Tulelake core may be either contemporaneous with the outcrops or that a substantial part of the diatoms in the core have been derived from erosion and redeposition of previously deposited lacustrine sediments.

The dominance of planktonic centric diatom taxa in the examined sample localities suggests deposition in comparatively large lacustrine systems with specific climatic and hydrologic characteristics. Distinctive diatom assemblages found in separated outcrops and in the Tulelake core may allow local correlations and assist in evaluation of the size, depth and hydrochemistry of ancient lacustrine environments encountered in and underlying the Tulelake core.

DIATOM LOCALITIES OF ILLUSTRATED SPECIMENS

The initial four-digit number is the USGS Diatom Locality Number.

4076. Siskiyou County, California about 12 miles southeast of Dorris. SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 9, T.46N., R.2E. Steep hillside east of Willow Creek, northwest of Hammond Ranch. Sample from bulldozer excavation of filter materials prospect. Altitude about 4280 feet. About 20 feet below contact with overlying cindery tuff-breccia. The diatomite and the breccia may be equivalent to the sedimentary section between Tertiary and Quaternary lavas in the Swan Lake - Yonna Valley area of Oregon. Collected by Perry R. Wood, USGS, 8-23-54.

4077. Siskiyou County, California, same geographic site as No. 4076. Diatomite from about 20 feet stratigraphically below No. 4076. Collected by Perry R. Wood, USGS, 8-23-54

7339. Susanville 15' quadrangle, Lassen County, California. Antelope Summit locality, about 9 kilometers northeast of Susanville and one-fourth mile east of the summit on State Highway 139. 200 meters south and 50 meters east of the northwest corner of sec. 18, T.30N., R.13E. Sample from base of stratigraphic section. Collected by J. P. Bradbury, USGS, 6-11-84, Field Number 11-VI-84-1a.

7340. Susanville 15' quadrangle, Lassen County, California, same geographic site as No. 7339. Sample from 60 centimeters above base of stratigraphic section. Collected by J. P. Bradbury, USGS, 6-11-84, Field Number 11-VI-84-1b.

7345. Bieber 15' quadrangle, Modoc County, California. Day Road - Lookout locality, on Day Road 3 kilometers west-northwest of Lookout. 750 meters south and 400 meters west of the northeast corner of sec. 17, T.39N., R.7E. Collected by J. P. Bradbury, USGS, 6-11-84, Field Number 11-VI-84-4.

7346. Canby 15' quadrangle, Modoc County, California. Pit river locality, 5.8 kilometers southwest of Canby. 500 meters south and 350 meters east of the northwest corner of sec. 10, T.41N., R.9E. Highly faulted diatomite. Collected by J. P. Bradbury, USGS, 6-11-84, Field Number 11-VI-84-5.

7350. Mt. Dome 15' quadrangle, Siskiyou County, California. Sheepy Mountain Trail locality, 1.2 kilometers north-northeast of Sheepy Peak. 300 meters south and 250 meters west of the northeast corner of sec. 36, T.48N., R.3E. Buff diatomite and volcanic ash about 1.5 meters thick. Collected by J. P. Bradbury, USGS, 6-13-84, Field Number 13-VI-84-1.

7357. Mt. Dome 15' quadrangle, Siskiyou County, California. Klamath National Wildlife Refuge locality, 6.6 kilometers east-southeast of center of Lower Klamath Lake. 400 meters west of the southeast corner of sec. 9, T.47N., R.3E. Exposure of diatomite about 3 meters in thickness, sample from near gray ash and with possible ash burrow filling. Collected by J. P. Bradbury, USGS, 6-13-84, Field Number 13-VI-84-6a.

7370. Mt. Dome 15' quadrangle, Siskiyou County, California. Chalk Bank Landing on South Lower Klamath Lake - Main bluff locality, 6.2 kilometers

southeast of the center of Lower Klamath Lake. 200 meters north and 150 meters west of the southeast corner of sec. 17, T.47N., R.3E. Sample from 50 centimeters below uppermost ash bed. Collected by J. P. Bradbury, USGS, 6-13-84, Field Number 13-VI-84-10g.

ACKNOWLEDGEMENTS

Thanks are expressed to J. Platt Bradbury, USGS, Denver, for supplying many of the samples studied for this report and for his considerable help on the nomenclature of the diatom taxa herein illustrated. The manuscript was reviewed by J. Platt Bradbury and David Adam, USGS, Menlo Park, and their helpful suggestions are appreciated.

REFERENCE CITED

Moore, B. N., 1937, Nonmetallic mineral resources of eastern Oregon: U.S. Geol. Survey Bull. 875, 180 p.

PLATE 1

Aulacosira aff. A. ambigua (Grunow) Simonsen

Figure

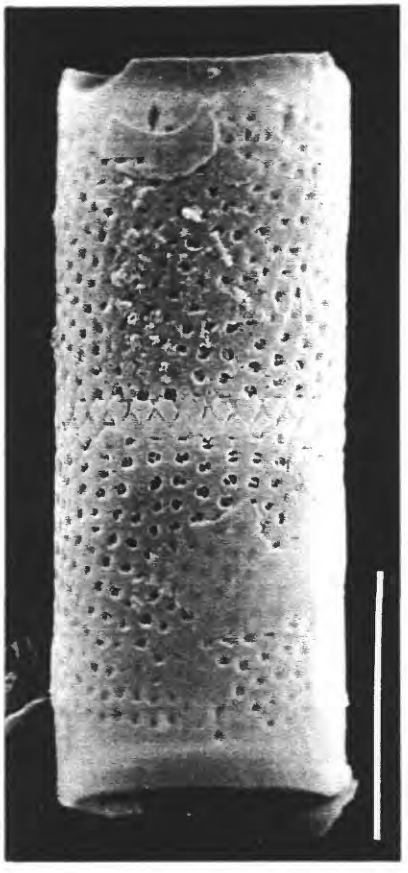
1. Girdle view of two attached valves, x3600, diameter 11 µm. USGS Diatom Locality 7346. Bar= 10 µm.
2. Oblique view of single valve showing both valve and girdle views, x4400, diameter 10 µm. USGS Diatom Locality 7346. Bar= 10 µm.

Aulacosira aff. A. solida (Eulenstein) Simonsen

3. Girdle view of two attached valves, x3000, diameter 19 µm. USGS Diatom Locality 7357. Bar= 10 µm.

Aulacosira aff. A. agassizii (Ostenfeld) Simonsen

4. Girdle view of chain fragment with two frustules and attached single valves on either end, x1200, diameter 13 µm. USGS Diatom Locality 7346. Bar= 10 µm.
5. Girdle view of two attached valves, x2600, diameter 15 µm. USGS Diatom Locality 7346. Bar= 10 µm.



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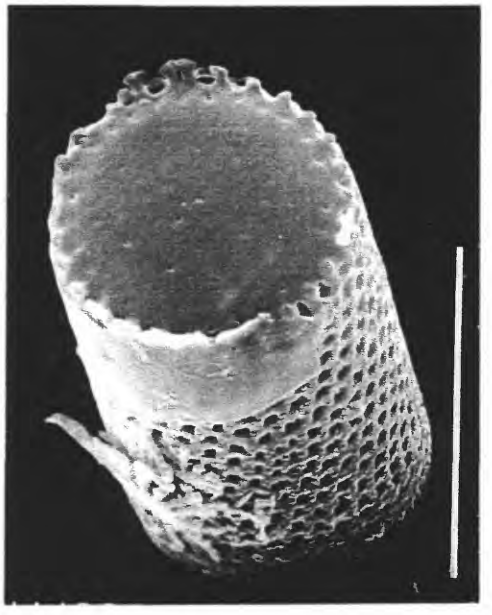

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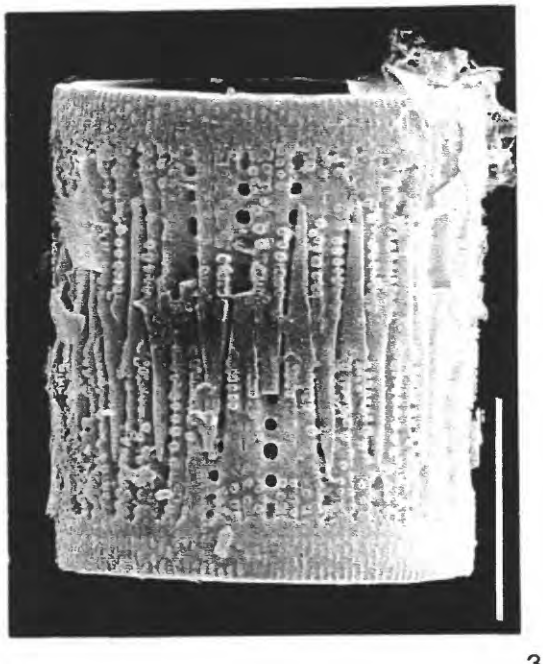

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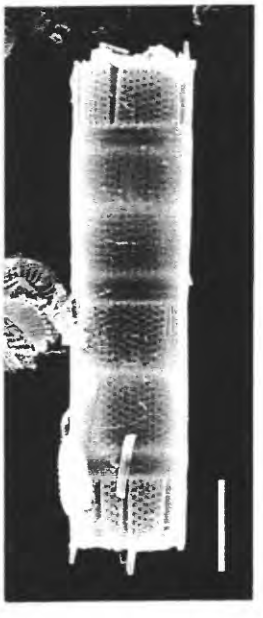

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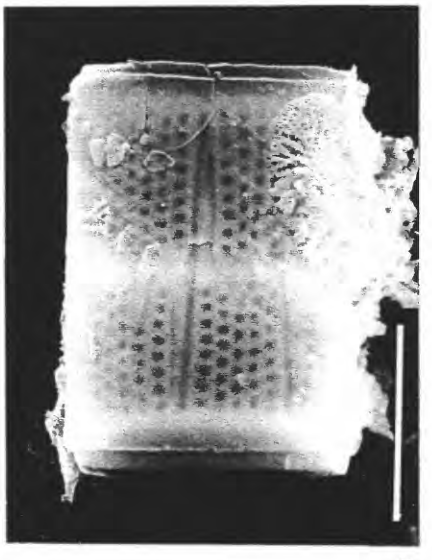

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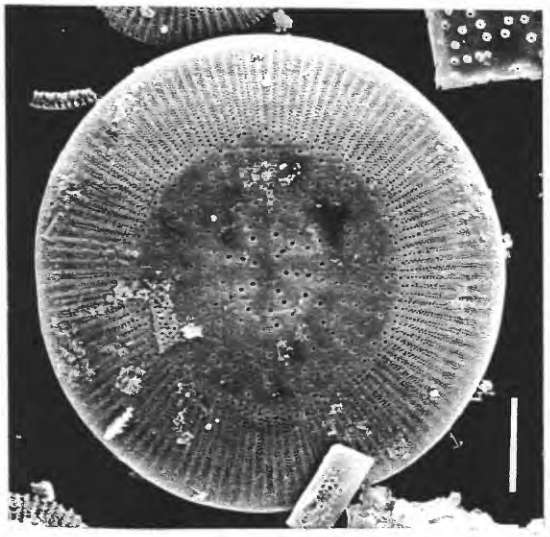
Plate 1

PLATE 2

Cyclotella elgeri Hustedt

Figure

1. Exterior of valve, x1200, diameter 53 µm. USGS Diatom Locality 4076. Bar= 10 µm.
2. Detail of exterior of valve, x3600, USGS Diatom Locality 4076. Bar= 10 µm.
3. Interior of valve, x1600, diameter 42 µm. USGS Diatom Locality 4077. Bar= 10 µm.
4. Interior of valve, x1300, diameter 42 µm. USGS Diatom Locality 4077. Bar= 10 µm.
5. Interior of marginal area of valve, x12,000. USGS Diatom Locality 4077. Bar= 10 µm.



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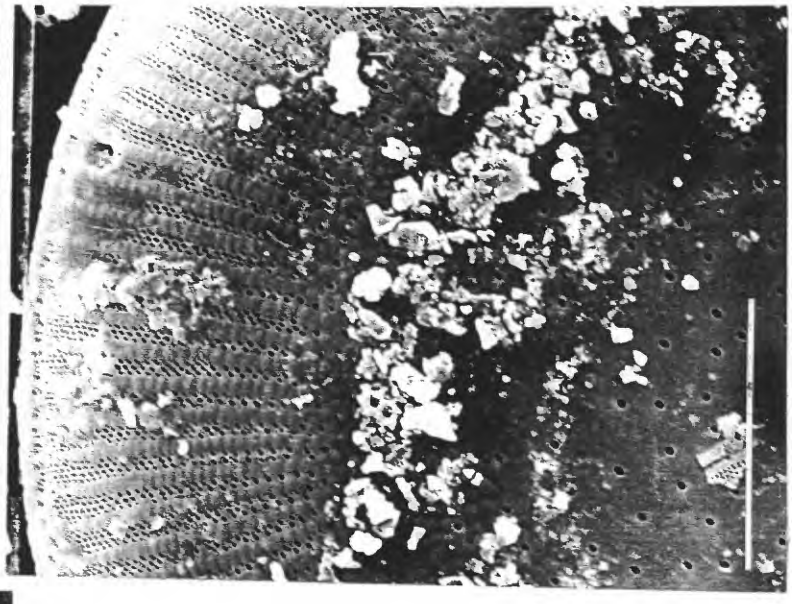

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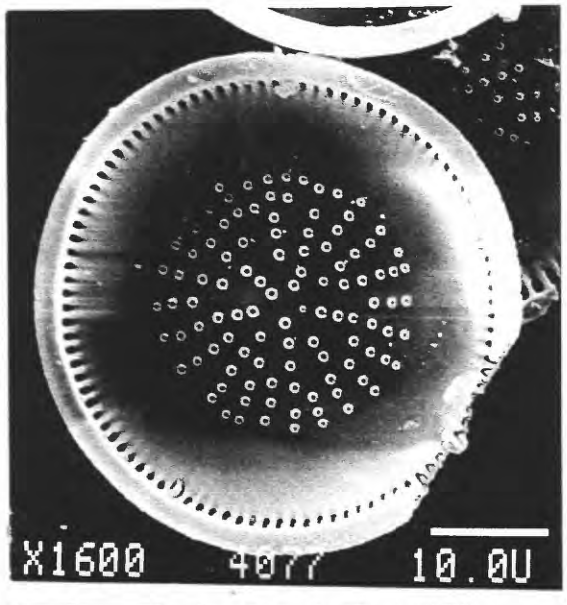

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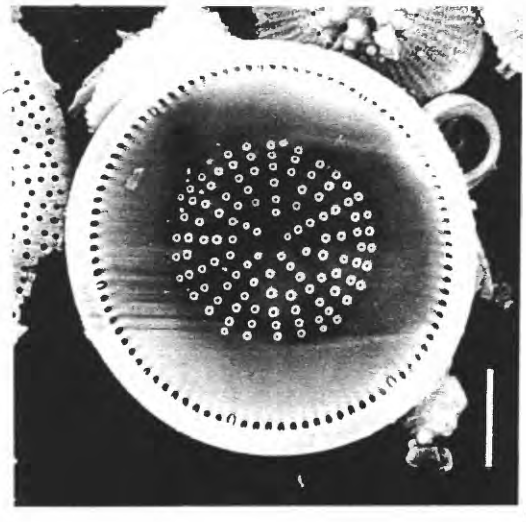

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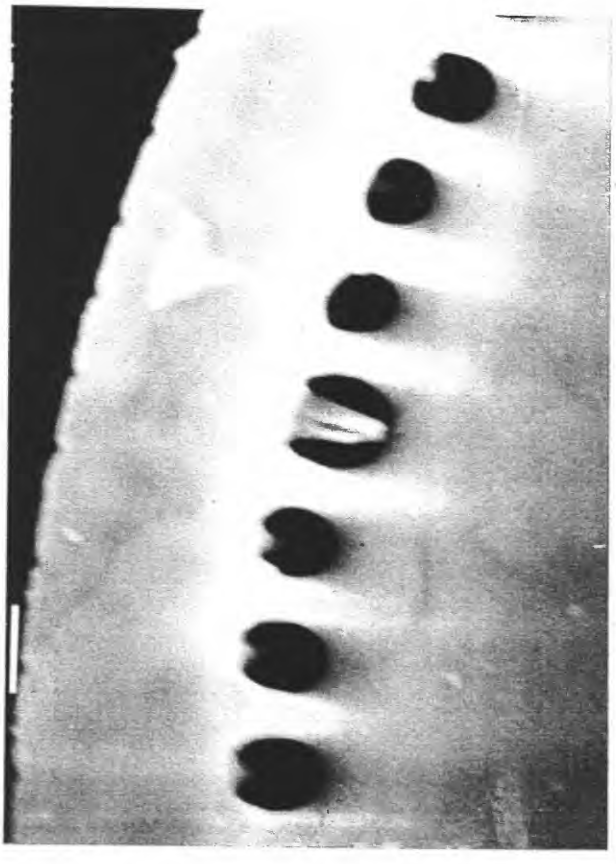

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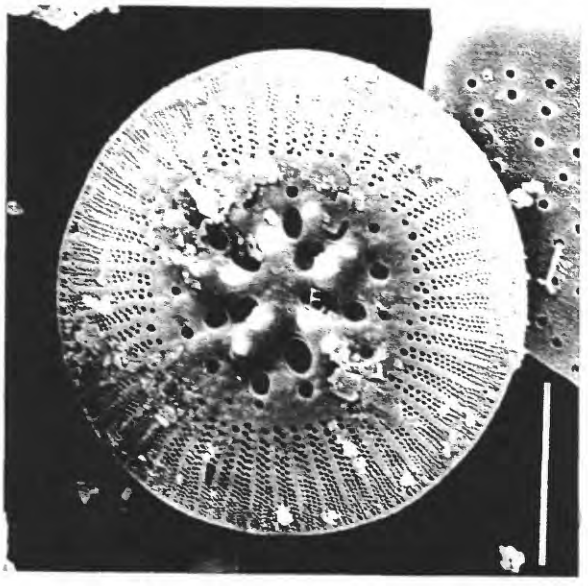
Plate 2

PLATE 3

Cyclotella elgeri Hustedt var. A

Figure

1. Exterior of valve, x2400, diameter 26 µm. USGS Diatom Locality 4076. Bar= 10 µm.
2. Exterior of valve, x2400, diameter 27 µm. USGS Diatom Locality 4077. Bar= 10 µm.
3. Interior of valve, x2000, diameter 35 µm. USGS Diatom Locality 4076. Bar= 10 µm.
4. Girdle view of valve, x2000, diameter 43 µm. USGS Diatom Locality 4077. Bar= 10 µm.
5. Exterior of valve x1200, diameter 51 µm. USGS Diatom Locality 4077. Bar= 10 µm.
6. Detail of exterior of valve, x4000. USGS Diatom Locality 4077. Bar= 10 µm.



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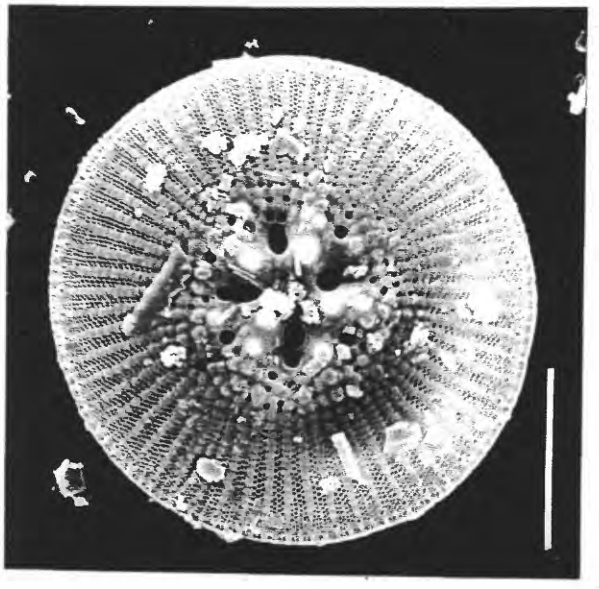

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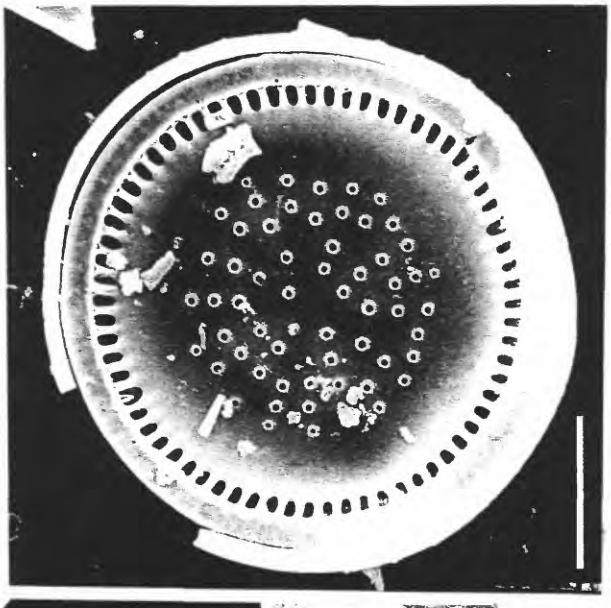

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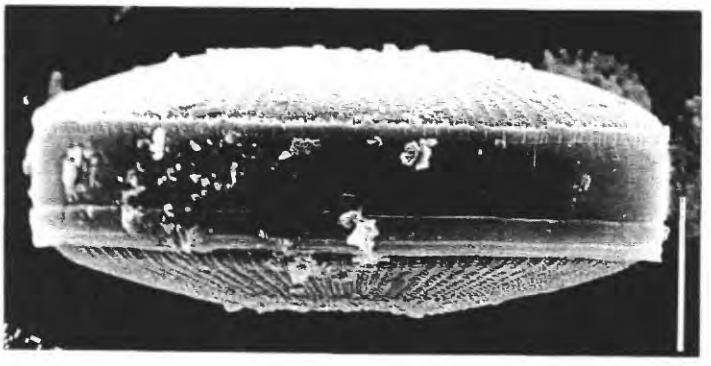

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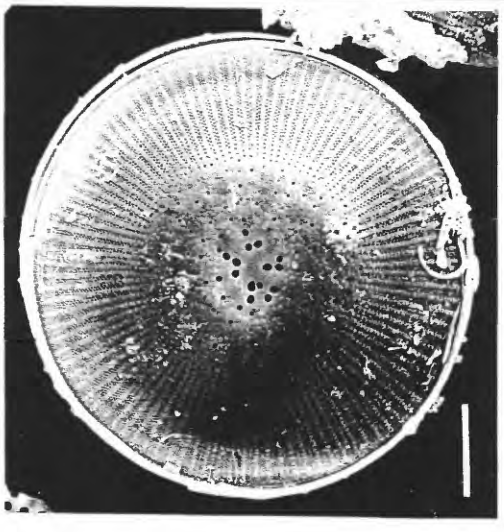

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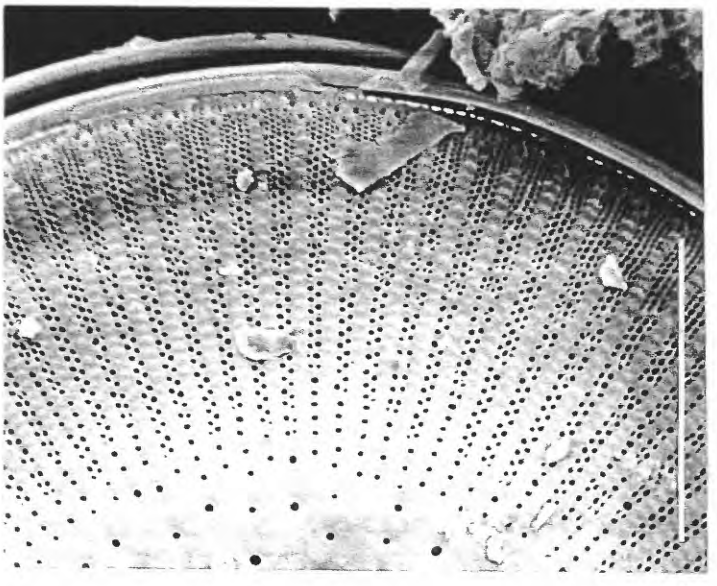

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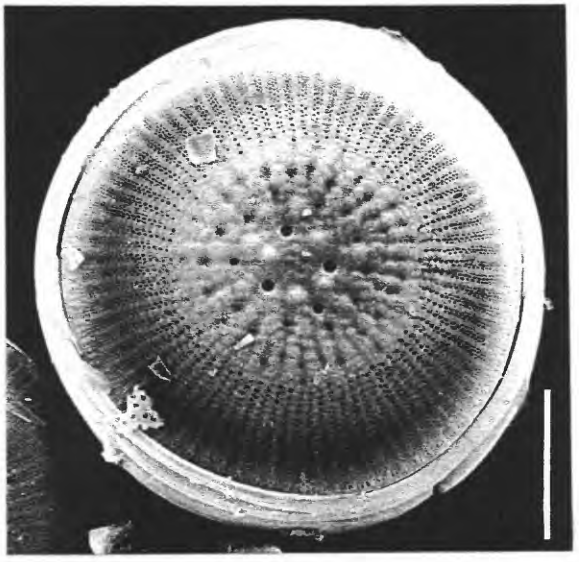
Plate 3

PLATE 4

Cyclotella elgeri Hustedt var. B

Figure

1. Exterior of valve, x2000, diameter (excluding girdle) 31 µm. USGS Diatom Locality 7357. Bar= 10 µm.
2. Exterior of valve, x1300, diameter 47 µm. USGS Diatom Locality 7357. Bar= 10 µm.
3. Detail of exterior of valve, x6600. USGS Diatom Locality 7357. Bar= 1 µm.
4. Interior of valve, x1600, diameter 42 µm. USGS Diatom Locality 7357. Bar= 10 µm.
5. Interior of marginal area of valve, x7800. USGS Diatom Locality 7357. Bar= 1 µm.



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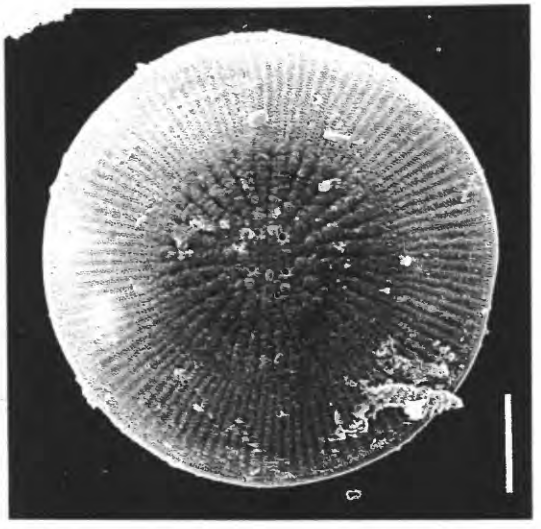

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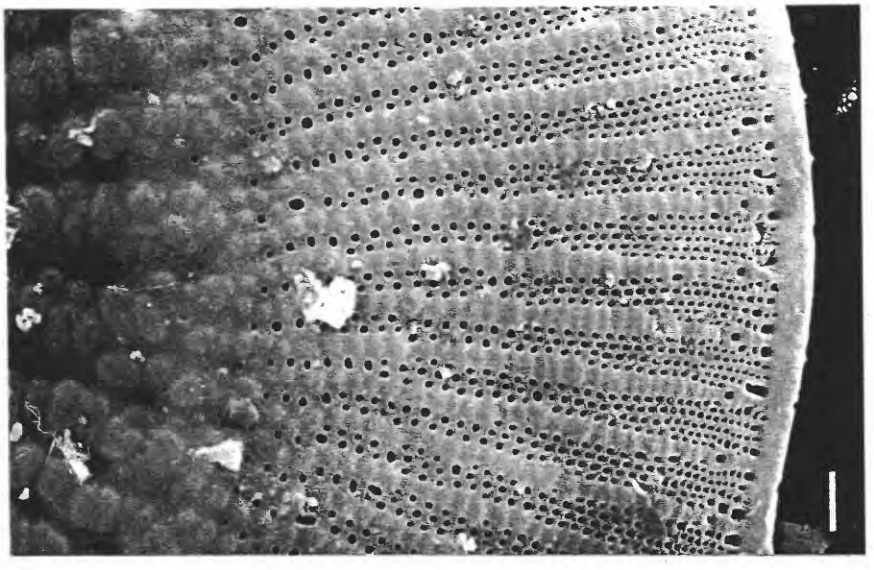

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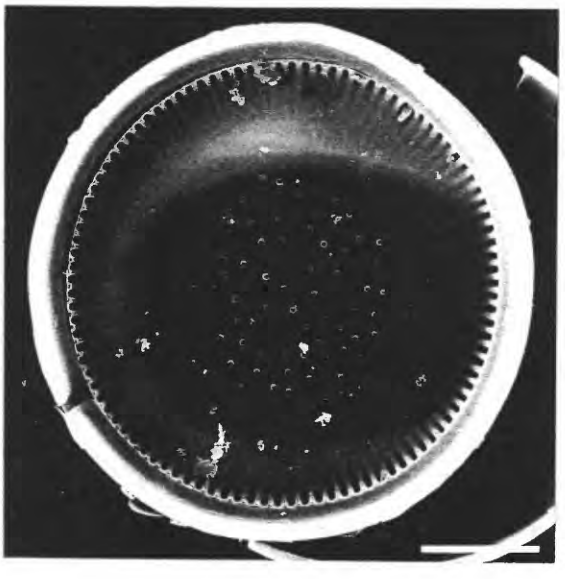

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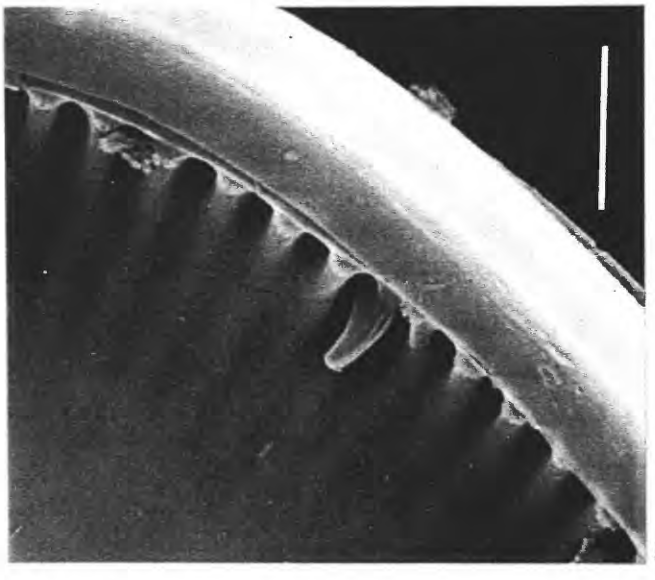

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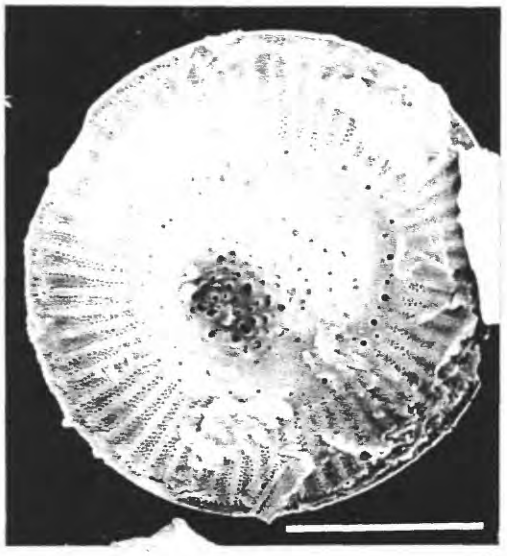
Plate 4

PLATE 5

Cyclotella aff. C. striata (Kützing) Grunow

Figure

1. Exterior of valve, x2600, diameter 25 µm. USGS Diatom Locality 7340. Bar= 10 µm.
2. Detail of exterior of valve, x6000, USGS Diatom Locality 7340. Bar= 1 µm.
3. Exterior of valve, x1600, diameter 43 µm. USGS Diatom Locality 7340. Bar= 10 µm.
4. Detail of exterior of valve, x4400. USGS Diatom Locality 7340. Bar= 10 µm.
5. Interior of valve, x1800, diameter 34 µm. USGS Diatom Locality 7340. Bar= 10 µm.
6. Detail of interior margin of valve, x6000. USGS Diatom Locality 7340. Bar= 1 µm.



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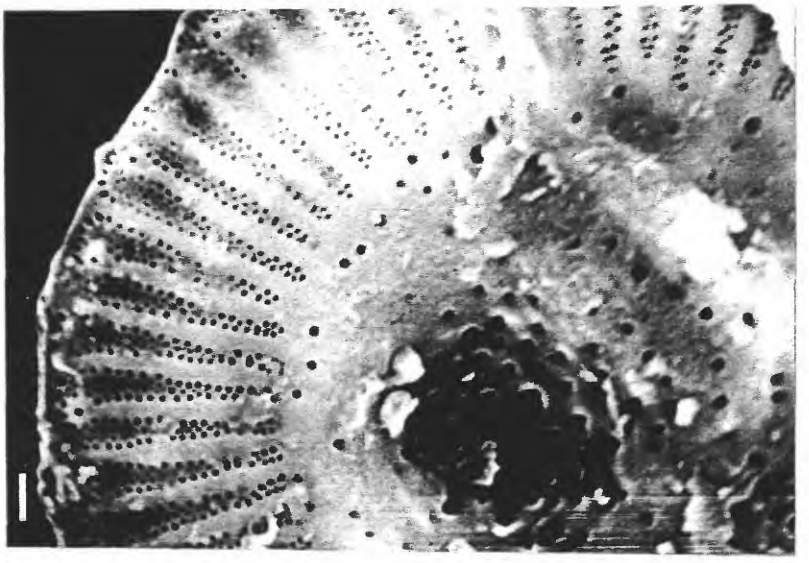

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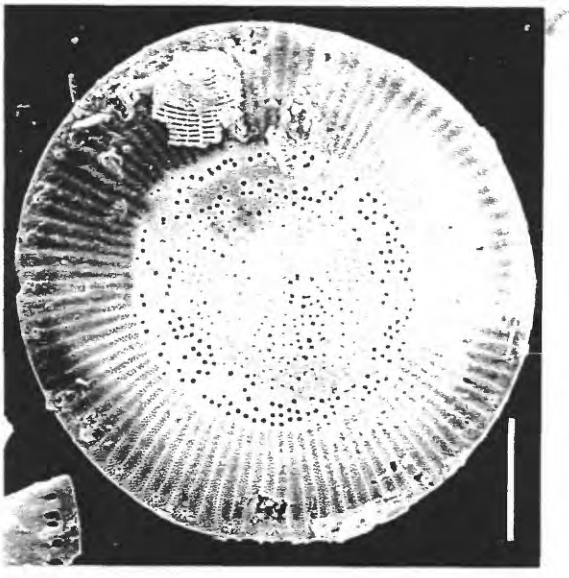

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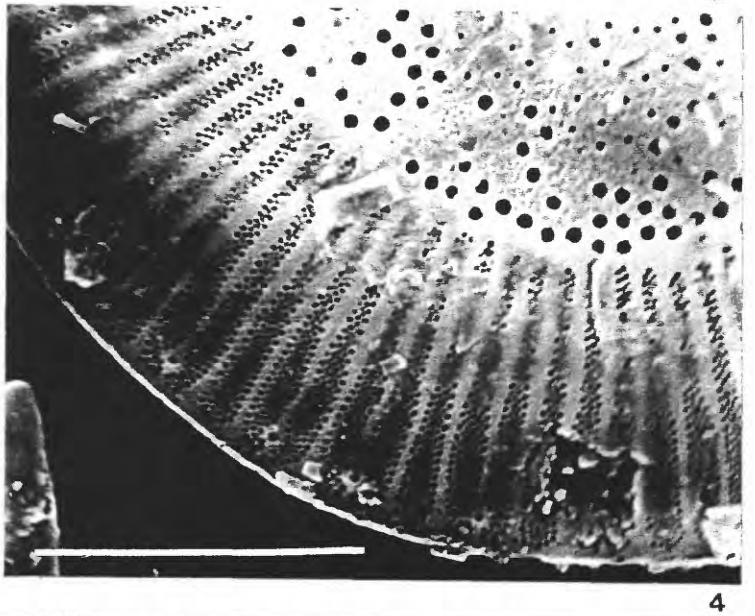

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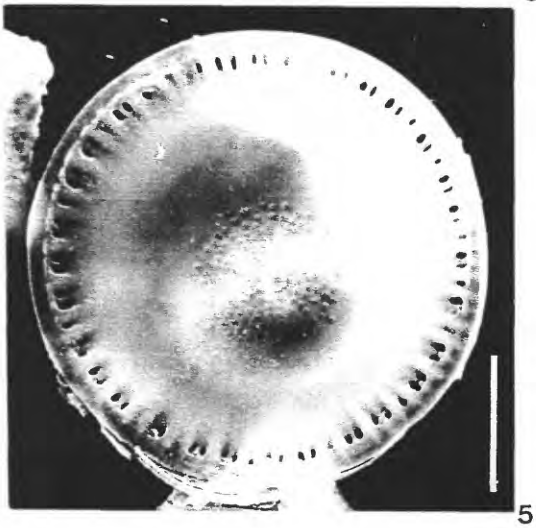

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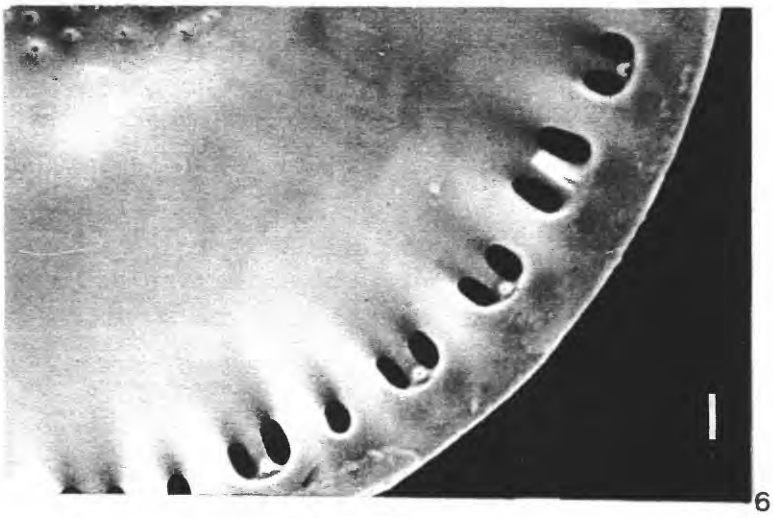

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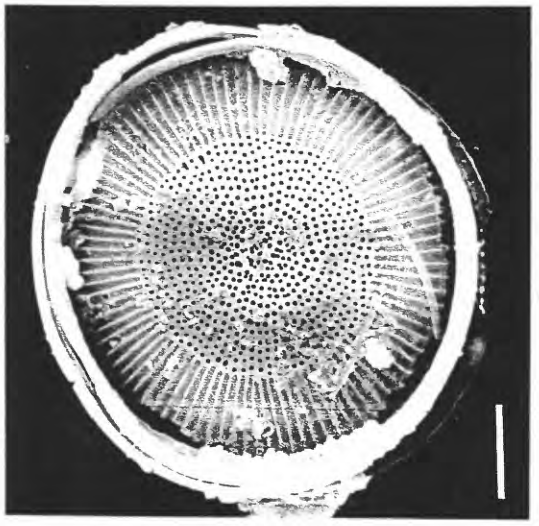
Plate 5

PLATE 6

Cyclotella sp. A

Figure

1. Exterior of valve with girdle, x1200, diameter 50 µm. USGS Diatom Locality 7339. Bar= 10 µm.
2. Exterior of valve x860, diameter 76 µm. USGS Diatom Locality 7339. Bar= 10 µm.
3. Detail of exterior of valve, x7400, USGS Diatom Locality 7339. Bar= 1 µm.
4. Eroded part of valve, showing internal structure, x1100, diameter about 64 µm. USGS Diatom Locality 7339. Bar= 10 µm.
5. Interior of valve, x940, diameter 66 µm. USGS Diatom Locality 7339. Bar= 10 µm.
6. Detail of interior of valve, x3600. USGS Diatom Locality 7339. Bar= 10 µm.



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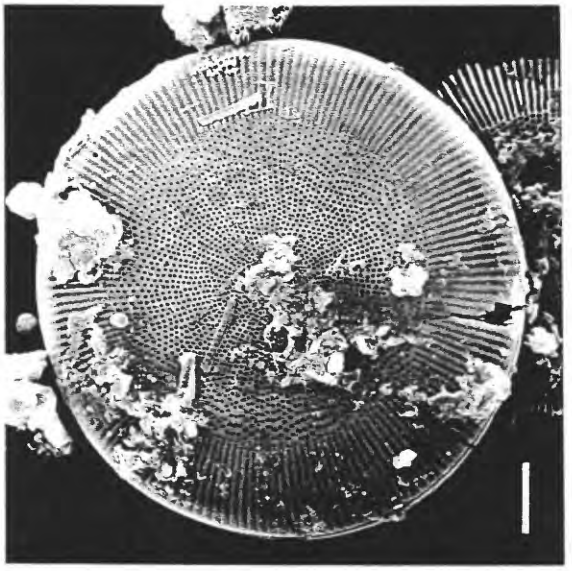

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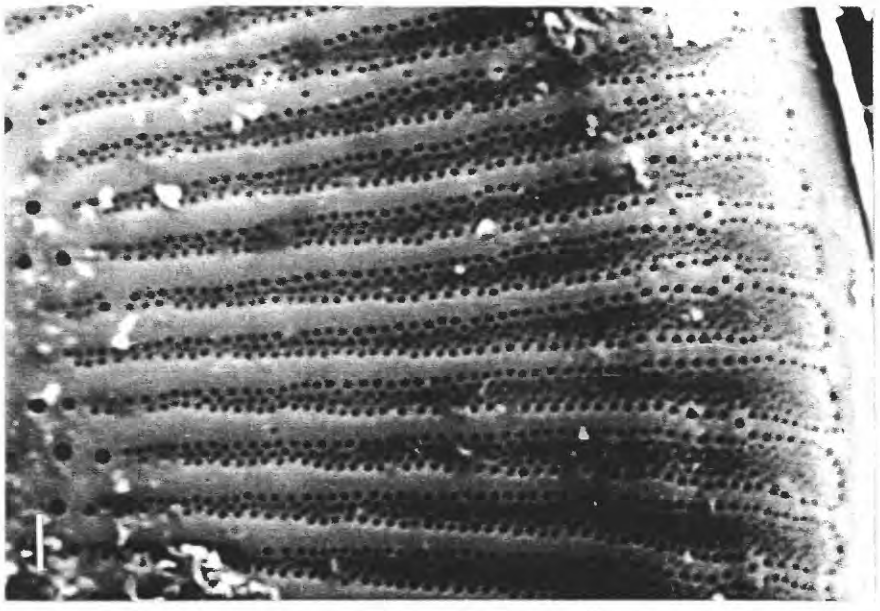

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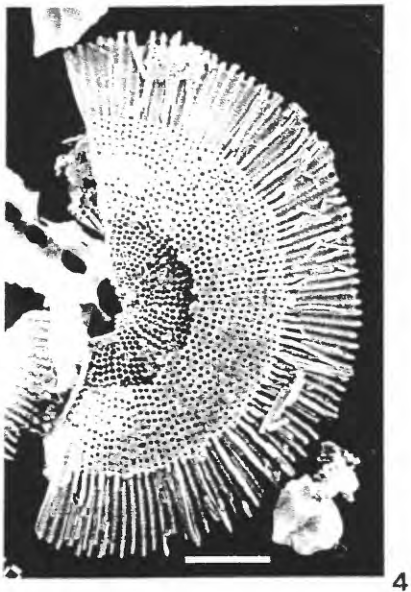

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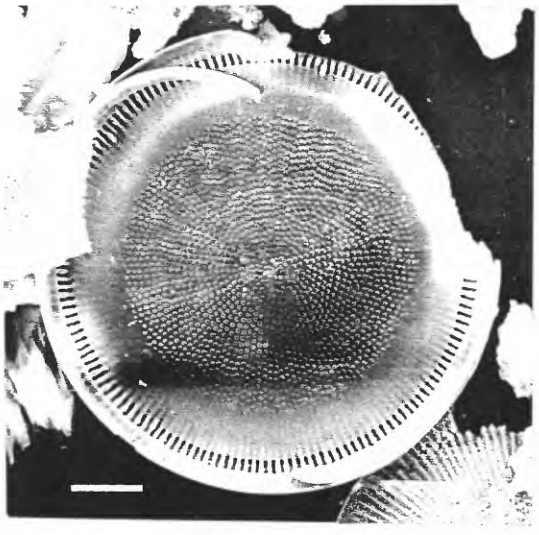

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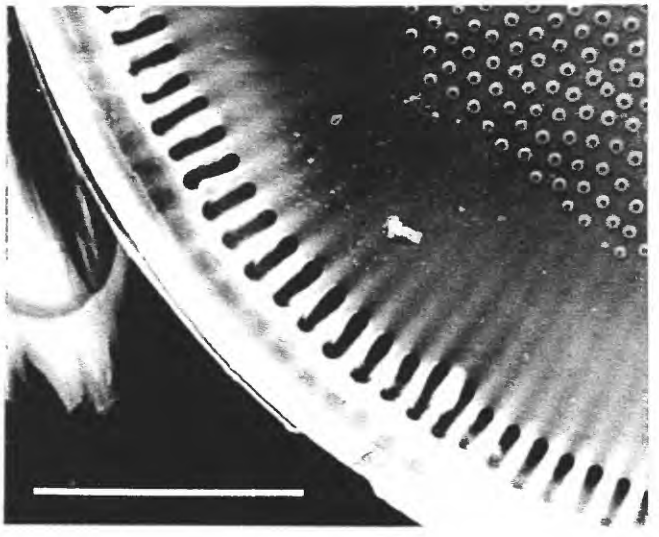


6

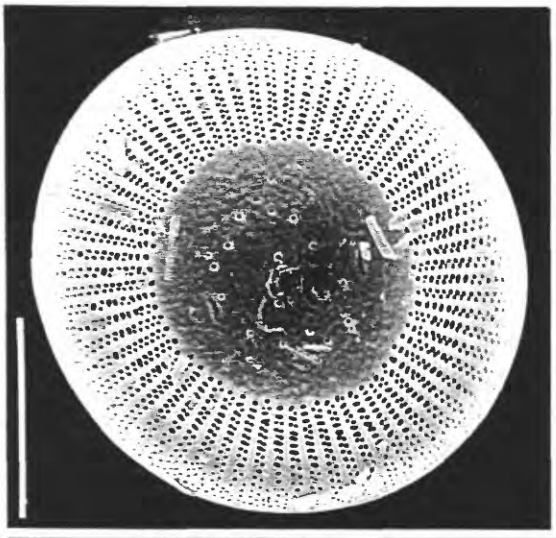
Plate 6

PLATE 7

Cyclotella sp. B

Figure

1. Exterior of valve, x2600, diameter 25 µm. USGS Diatom Locality 7346. Bar= 10 µm.
2. Exterior of frustule, x3000, diameter 23 µm. USGS Diatom Locality 7346. Bar= 10 µm.
3. Detail of exterior of valve, x7800. USGS Diatom Locality 7346. Bar= 1 µm.
4. Interior of valve, x3000, diameter 23 µm. USGS Diatom Locality 7346. Bar= 10 µm.
5. Interior of valve, x3200, diameter 23 µm. USGS Diatom Locality 7346. Bar= 10 µm.
6. Interior of marginal area of valve, x12,000. USGS Diatom Locality 7346. Bar= 1 µm.



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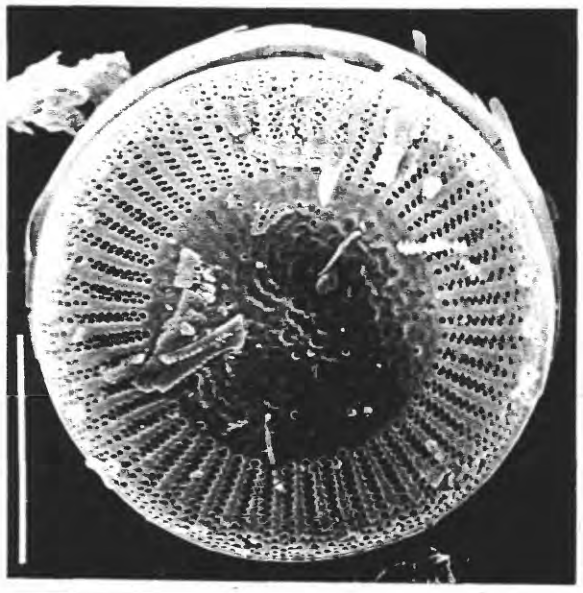

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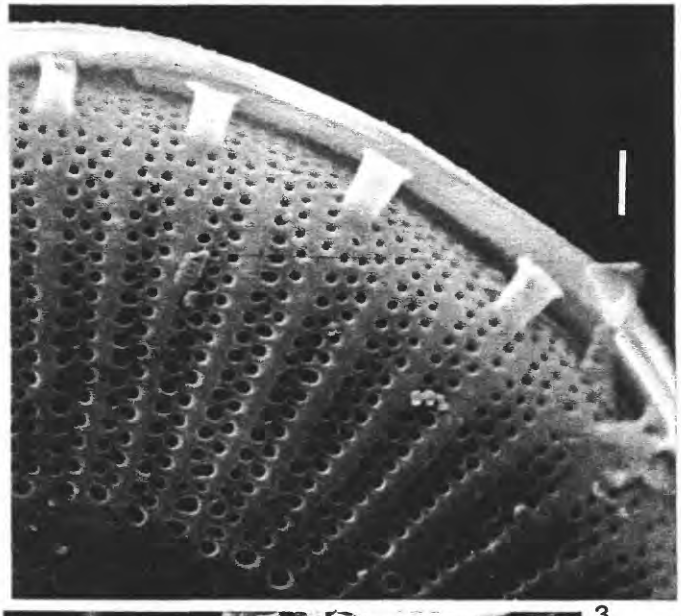

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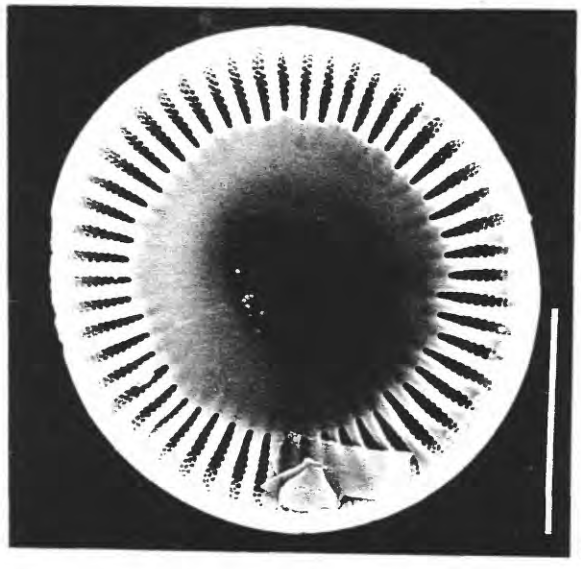

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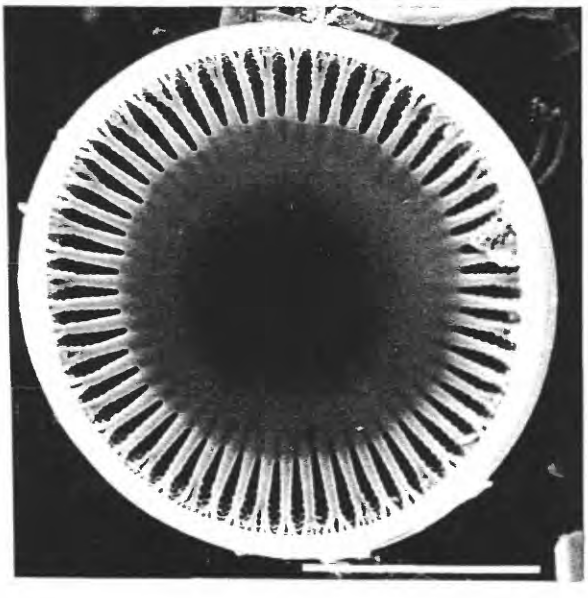

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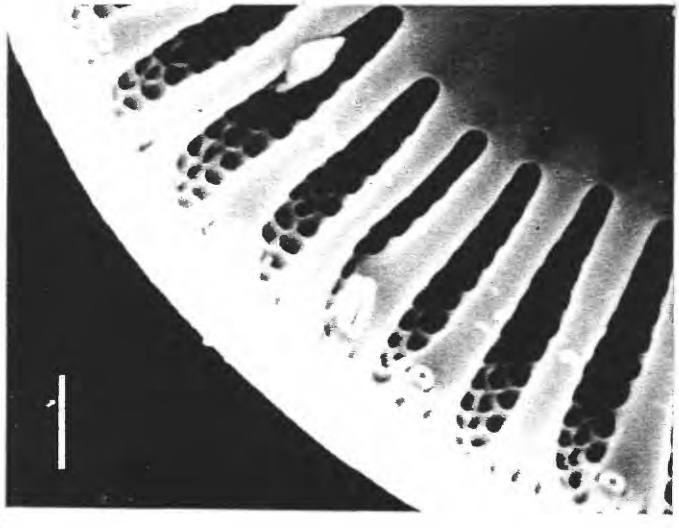

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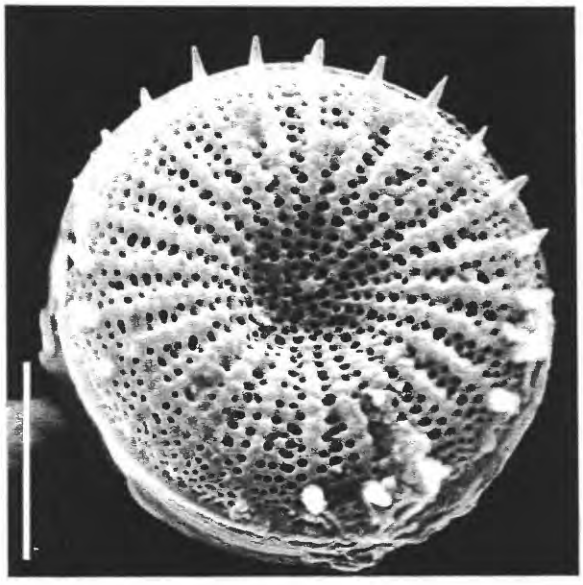
Plate 7

PLATE 8

Stephanodiscus aff. S. carconensis (Eulenstein) Grunow

Figure

1. Exterior of valve with depressed center, x2600, diameter 25 µm. USGS Diatom Locality 7345. Bar= 10 µm.
2. Exterior of valve with raised center, x1800, diameter 34 µm. USGS Diatom Locality 7345. Bar= 10 µm.
3. Detail of exterior margin of valve, x7800. USGS Diatom Locality 7345. Bar= 1 µm.
4. Interior of valve with depressed center, x1800, diameter 35 µm. USGS Diatom Locality 73 Bar= 10 µm.
5. Detail of interior margin of valve, x10,000. USGS Diatom Locality 7345. Bar= 1 µm.
6. Detail of interior center of valve, showing two specialized pores, x10,000. USGS Diatom Locality 7345. Bar= 1 µm.



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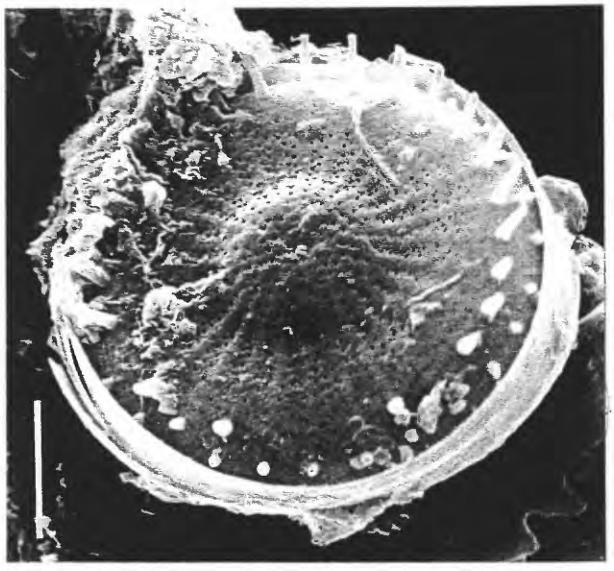

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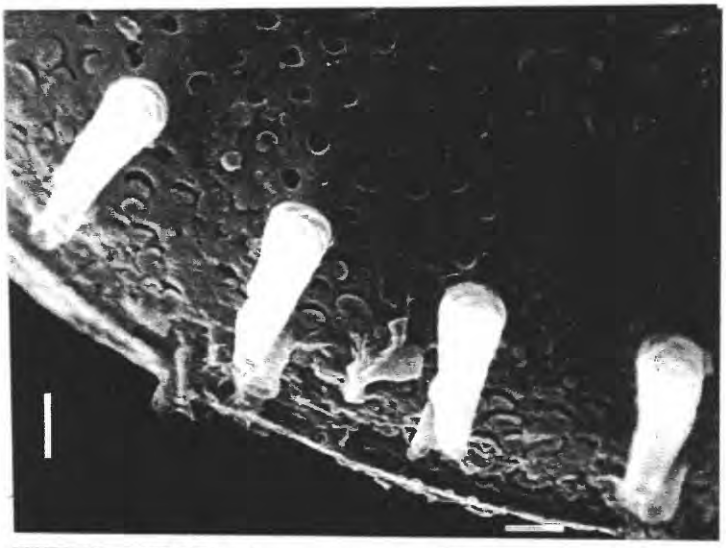

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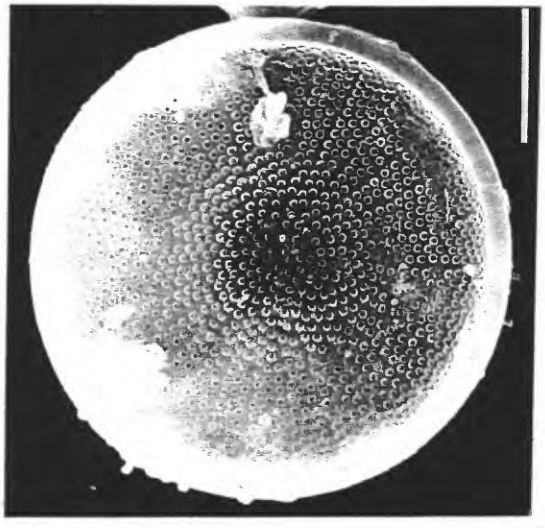

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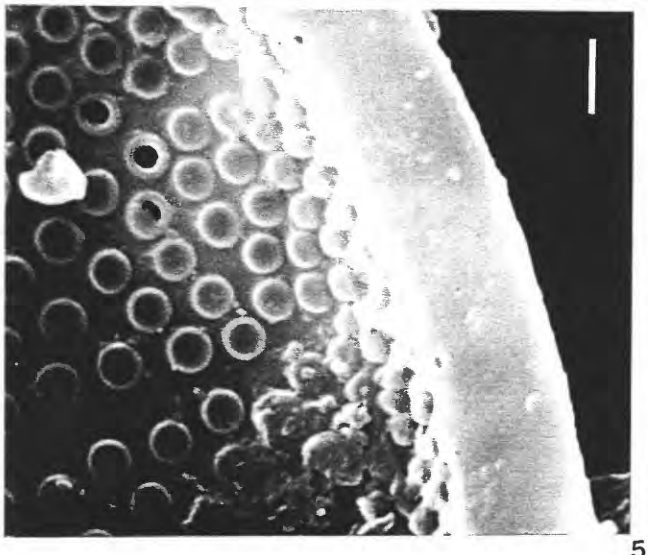

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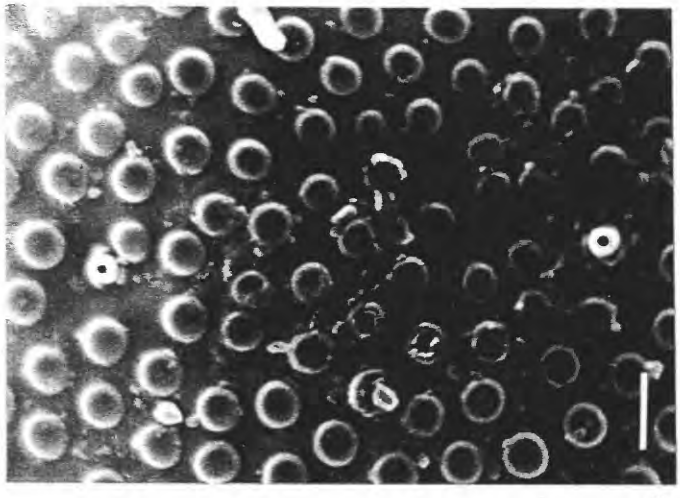

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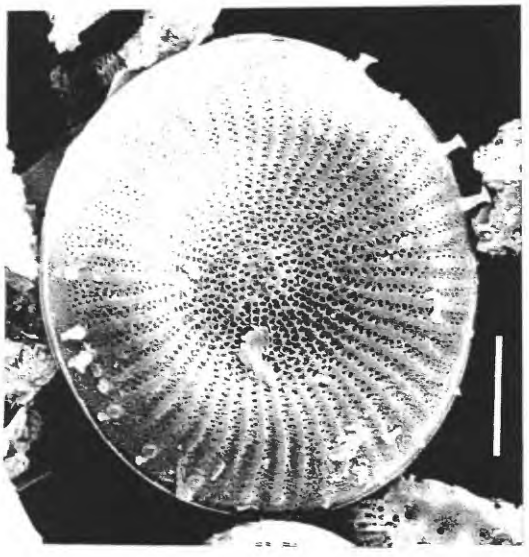
Plate 8

PLATE 9

Stephanodiscus rotula var. *intermedia* Fricke

Figure

1. Exterior of valve, x1600, diameter 40 μm. USGS Diatom Locality 4077. Bar= 10 μm.
2. Exterior of valve, x2400, diameter 28 μm. USGS Diatom Locality 4077. Bar= 10 μm.
3. Detail of exterior margin of valve, x4800. USGS Diatom Locality 4077. Bar= 10 μm.
4. Detail of center of valve in figure 1, showing two specialized pores, x11,000. USGS Diatom Locality 4077. Bar= 1 μm.
5. Detail of center of valve in figure 2, showing two specialized pores, x13,000. USGS Diatom Locality 4077. Bar= 1 μm.



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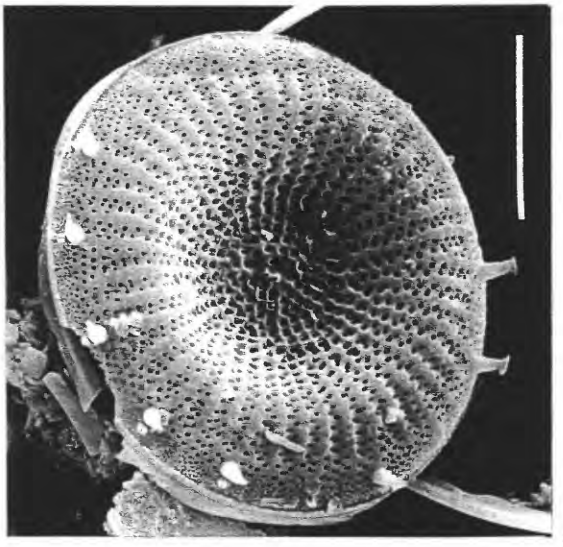

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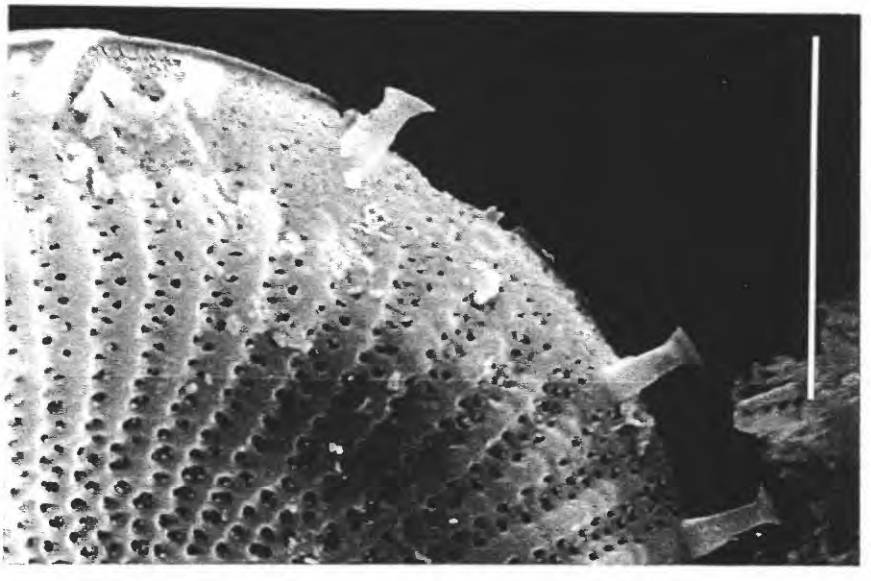

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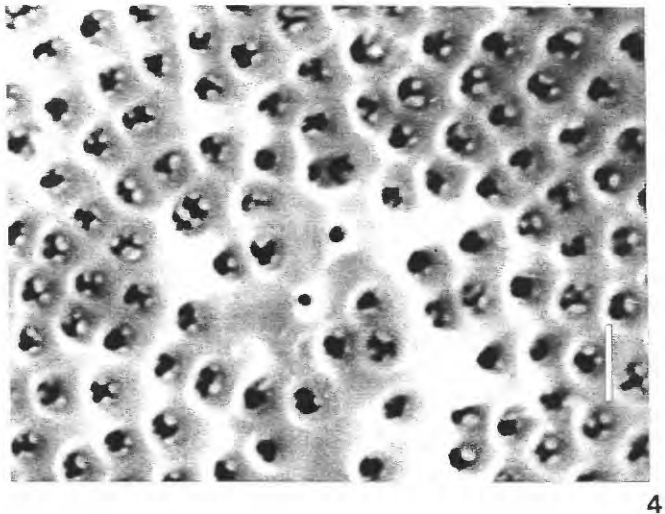

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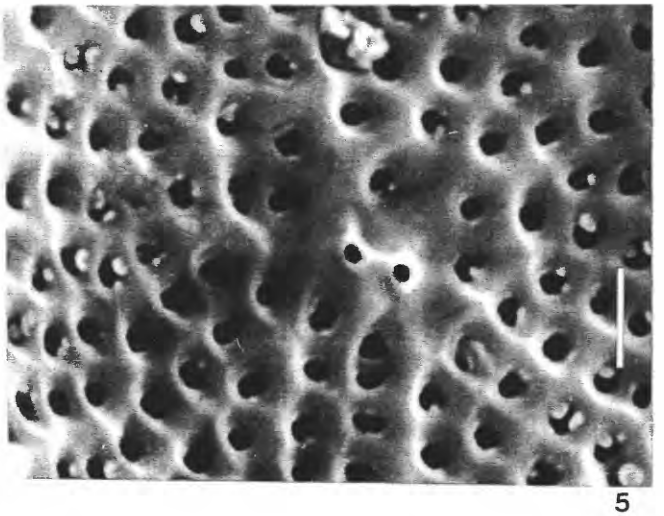

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Plate 9

PLATE 10

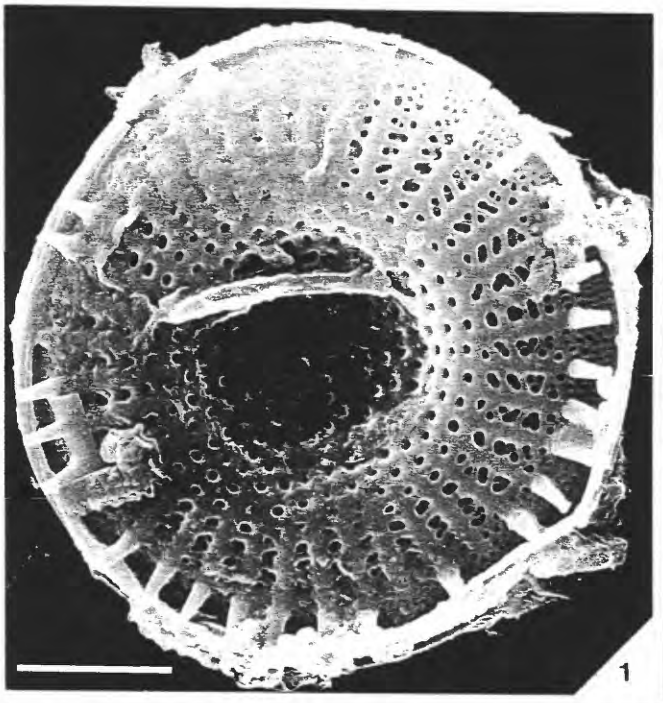
Stephanodiscus sp. A

Figure

1. Exterior of valve with depressed center, x4,000, diameter 21 µm. USGS Diatom Locality 7370. Bar= 5 µm.
2. Exterior of valve with raised center, x4,000, diameter 22 µm. USGS Diatom Locality 7370. Bar= 5 µm.

Cyclotella aff. C. elgeri Hustedt

3. Interior of valve, oblique view, x5500, diameter 15 µm. USGS Diatom Locality 7370. Bar= 5 µm.
4. Detail of interior of valve, showing labiate process and bracketed process, x50,000. USGS Diatom Locality 7370. Bar= 1 µm.
5. Detail of interior of valve, showing labiate process and bracketed processes, x50,000. USGS Diatom Locality 7370. Bar= 1 µm.
6. Detail interior of valve, showing bracketed process, x50,000. USGS Diatom Locality 7370. Bar= 1 µm.



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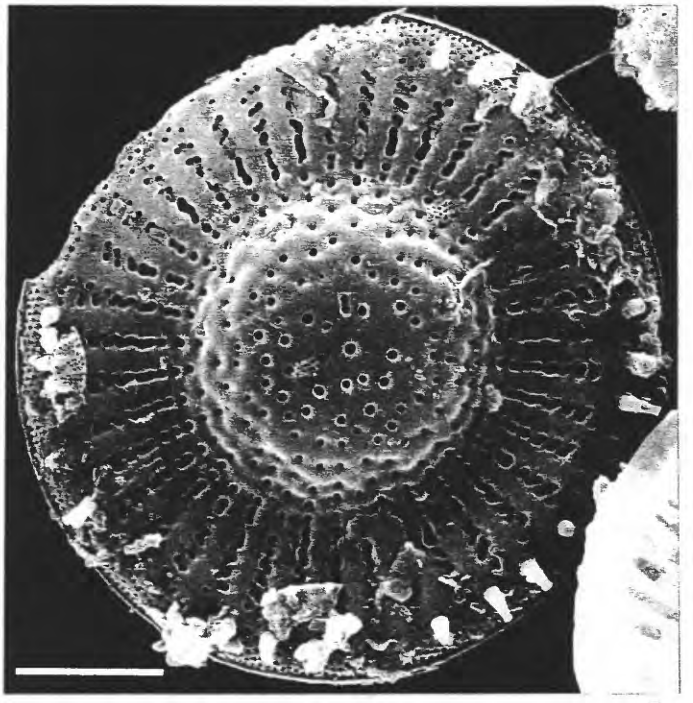

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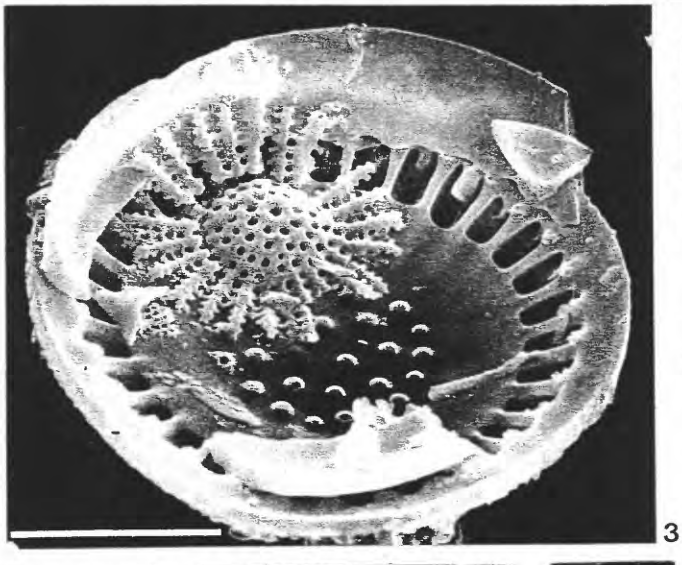

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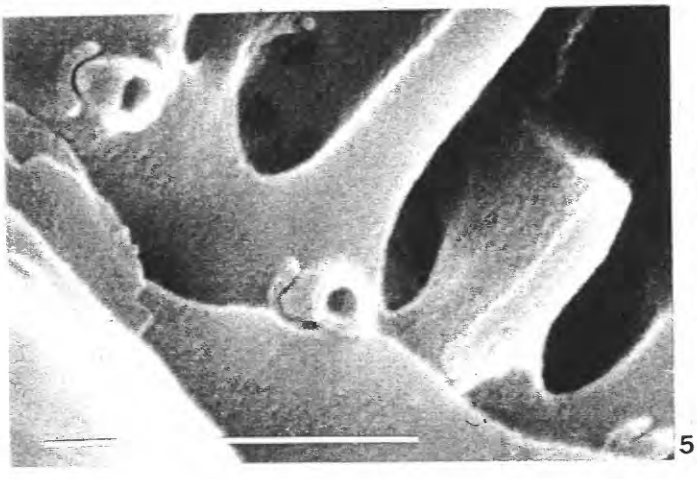

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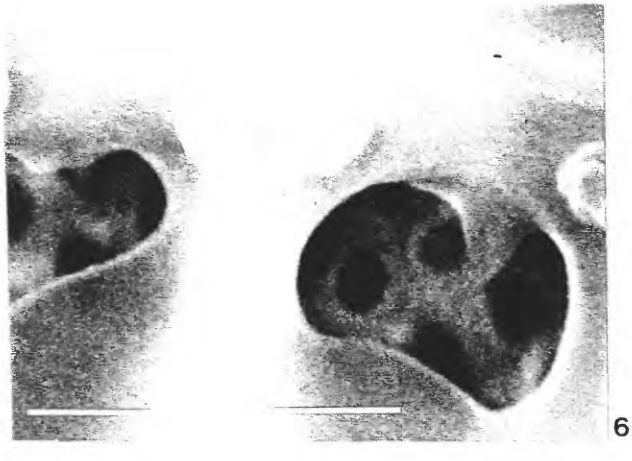

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Plate 10

PLATE 11

Achnanthes lanceolata Brébisson var. A

Figure

1. Inside of rapheless valve, x4000, length 21 µm. USGS Diatom Locality 4077. Bar= 10 µm.

Cocconeis placentula var. euglypta (Ehrenberg) Cleve

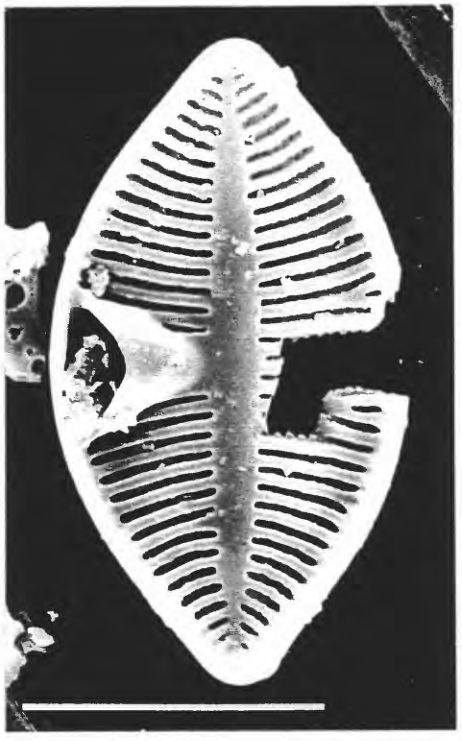
2. Outside of rapheless valve, x2400, length 27 µm. USGS Diatom Locality 7345. Bar= 10 µm.

Cocconeis placentula var. lineata (Ehrenberg) Cleve.

3. Inside of rapheless valve, x3600, length 25 µm. USGS Diatom Locality 7350 Bar= 10 µm.

Cocconeis placentula (Ehrenberg) Cleve var. A.

4. Inside of rapheless valve, x2600, length 34 µm. USGS Diatom Locality 7340. Bar= 10 µm.



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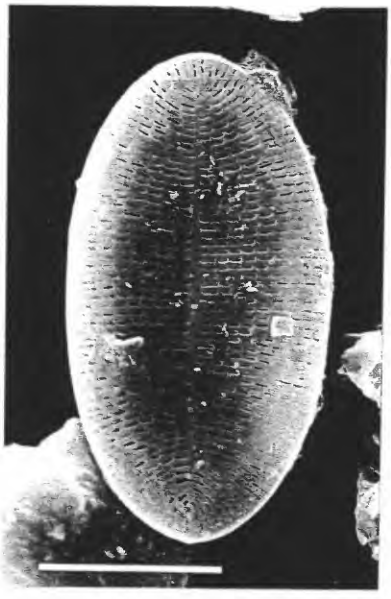

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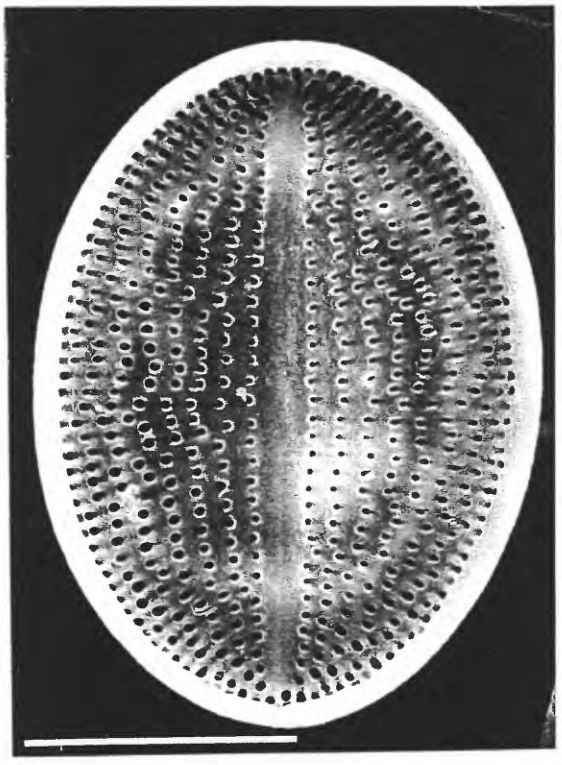

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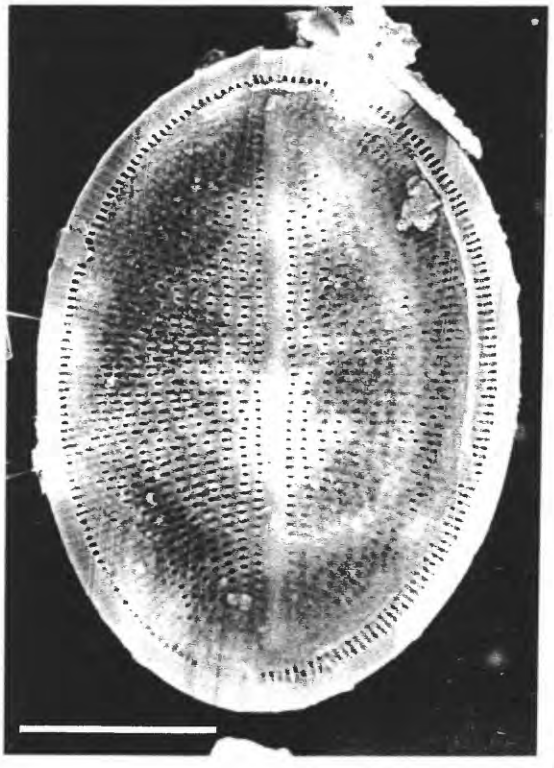

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Plate 11

PLATE 12

Cymbella cistula var. maculata (Kützing) Van Heurck

Figure

1. Outside of valve, x780, length 110 µm. USGS Diatom Locality 7346. Bar= 10 µm.

Cymbella minuta Hilse

2. Inside of valve, x2400, length 30 µm. USGS Diatom Locality 7345. Bar= 10 µm.

Diploneis ovalis (Hilse) Cleve

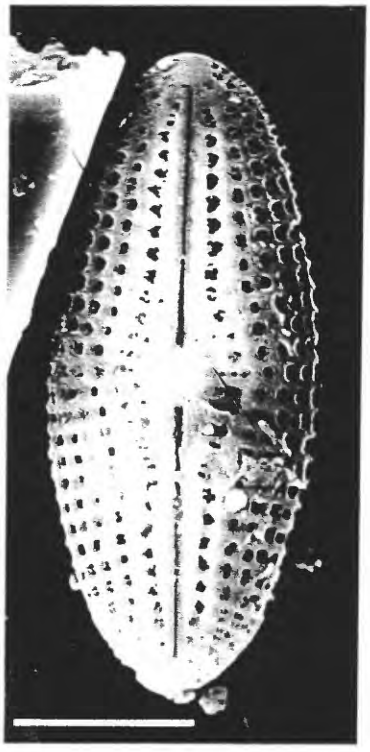
3. Outside of valve, x2400, length 36 µm. USGS Diatom Locality 7340. Bar= 10 µm.
4. Inside of valve, x2600, length 30 µm. USGS Diatom Locality 7340. Bar= 10 µm.

Epithemia turgida (Ehrenberg) Kützing

5. Outside of valve, x1500, length 65 µm. USGS Diatom Locality 7350. Bar= 10 µm.
6. Inside of valve, x1000, length about 64 µm. USGS Diatom Locality 7350. Bar= 10 µm.

1

2



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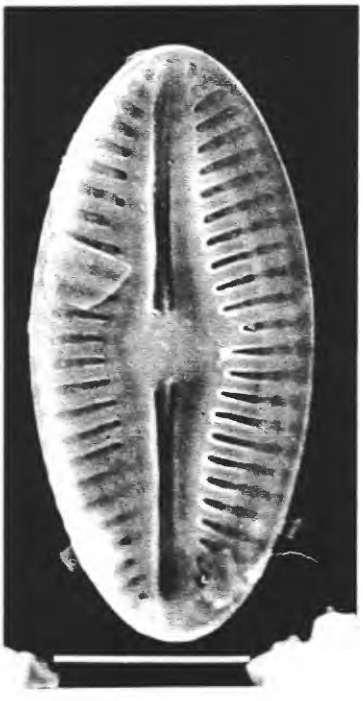

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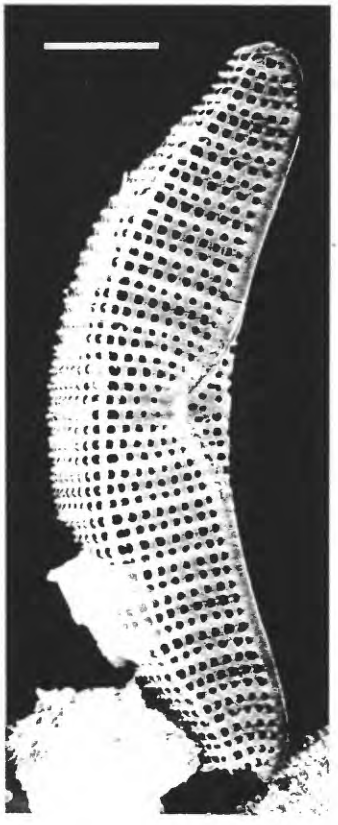

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6

Plate 12

PLATE 13

Epithemia sorex Kützing

Figure

1. Outside oblique view of frustule, x1800, length 42 µm. USGS Diatom Locality 7345. Bar= 10 µm.

Fragilaria construens var. venter (Ehrenberg) Grunow

2. Outside of frustule, x4400, length 16 µm. USGS Diatom Locality 7340. Bar= 10 µm.

Navicula aff. N. radiosa Kützing

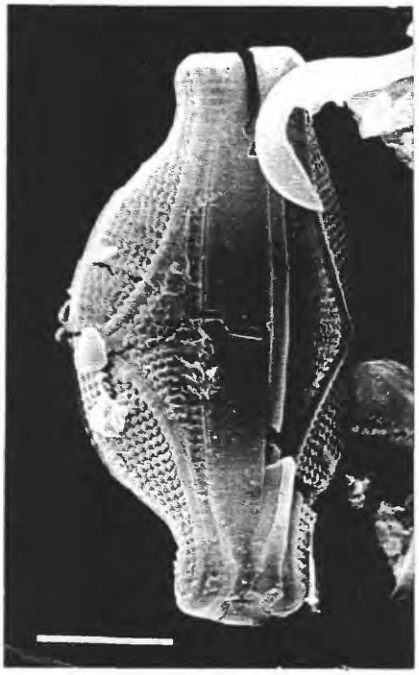
3. Inside of valve, x600, length 115 µm. USGS Diatom Locality 7339. Bar= 10 µm.

Nitzschia aff. N. frustulum (Kützing) Grunow

4. Inside of valve, x2600, length 24 µm. USGS Diatom Locality 4077. Bar=10 µm.
5. Outside of frustule, x2400, length 28 µm. USGS Diatom Locality 7340. Bar= 10 µm.

Tetracyclus lacustris Ralfs

6. Inside of valve, x2200, length 30 µm. USGS Diatom Locality 7345. Bar= 10 µm.



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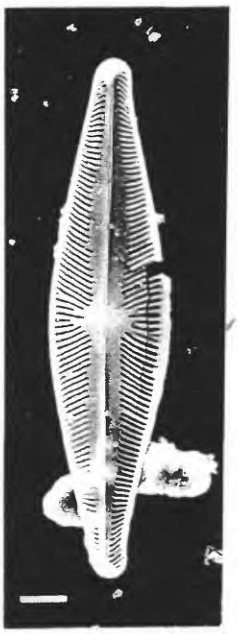

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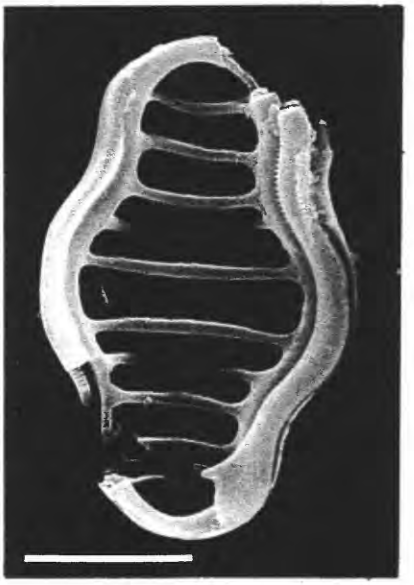

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Plate 13