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# Miocene Diatoms from the Hawthorn Formation, Thomas County, Georgia

by

George W. Andrews and William H. Abbott

**Paleontological Research Institution**
**1259 Trumansburg Road**
**Ithaca, New York, 14850 U.S.A.**

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## ABSTRACT

Diatomaceous sediments of the Hawthorn Formation occur in commercially mined fuller's earth and related deposits near Ochlocknee, Thomas County, southwestern Georgia. These sedimentary rocks were deposited in the Gulf Trough, a relatively narrow linear area of subsidence connecting the Applachicola Embayment and the Southeast Georgia Embayment during a part of Tertiary time. Eighty-four taxa of marine diatoms have been identified, including one new species, *Actinoptychus aequalis*. These diatoms indicate deposition in a shallow marine environment. An intercalated nonmarine diatom assemblage has been found near the top of the section and contains a mixture of brackish- and freshwater diatoms. The marine diatom assemblage of this deposit of the Hawthorn Formation is correlative with approximately the lower part of Miocene Lithologic Unit 14 of the Calvert Formation in the Chesapeake Bay Region of Maryland; thus, it is early middle Miocene in age.

## INTRODUCTION

Extensive deposits of fuller's earth in the Hawthorn Formation in southwestern Georgia and northern Florida have been commercially exploited since 1895 (Patterson, 1974, p. 1). The term "fuller's earth" originally referred to any fine-grained earthy material used in fulling and cleaning wool, usage that dates back to ancient time. The term is now generally applied to highly absorbent clays that have a wide variety of industrial and domestic uses. A commercial deposit of fuller's earth, consisting principally of the minerals palygorskite, sepiolite, and montmorillonite, is currently being mined by the Oil-Dri Corporation of America near Ochlocknee, Georgia. The fuller's earth and the overburden of this mine contain fossil marine and nonmarine diatom assemblages that provide data on the age and paleoecology of the Hawthorn Formation in southwestern Georgia.

The name "Hawthorne beds" was originally applied to deposits of phosphatic sandstone, sand, ferruginous gravel, and greenish clay of Alachua County, Florida, by Dall *in* Dall and Harris (1892, p. 107). It has since been applied to a variety of Tertiary deposits scattered through Alabama, Georgia, Florida and South Carolina. Puri and Vernon (1964, p. 145) commented cogently on the formation as follows: "The Hawthorn Formation perhaps is the most misunderstood formational unit in the southeastern United States. It has been the dumping ground for alluvial, terrestrial, marine, deltaic and prodeltaic beds of diverse lithologic units in Florida and Georgia, that are stratigraphic equivalents of the Alum Bluff Stage." Patterson (1974, pp. 10–11) outlined paleontological work that has been done on the Hawthorn Formation and concluded "that it is neither the youngest nor the oldest of the Miocene formations in the Coastal Plain and that the middle Miocene is a realistic age assignment for this formation."

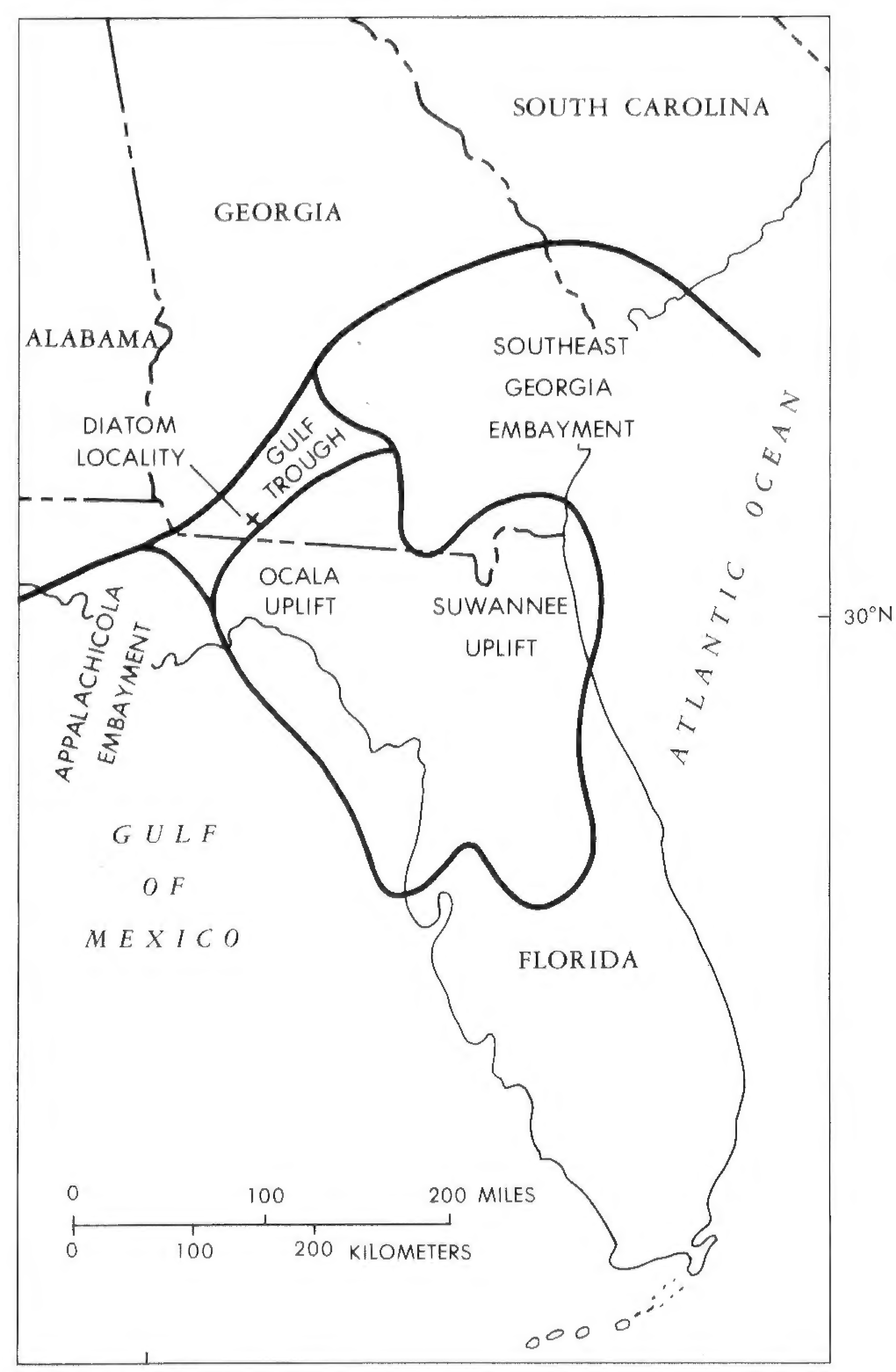
Abbott and Huddlestun (1980) revised the Hawthorn Formation to group status and raised the former members of the Hawthorn to formational rank. The uppermost formation in their Hawthorn Group is the Coosawhatchie Clay, described initially by Johnson and Geyer (1965) as the Coosawhatchie Clay Member of the Hawthorn Formation. The fuller's earth deposits of Thomas County, Georgia are considered to be correlative with the Coosawhatchie Clay by Paul Huddlestun, Georgia Geological Survey (written commun., 1981), but he does not believe that the field evidence justifies an unqualified assignment of these deposits to the Coosawhatchie Clay. We shall, therefore, formally consider these diatomaceous deposits of Thomas County, Georgia as a part of the Hawthorn Formation. The establishment of the "Coosawhatchie Clay" as a formation of the "Hawthorn Group" has not yet been formally published, nor has the Coosawhatchie been mapped in Thomas County. We shall, therefore, refer to the deposits under consideration in this report as "Coosawhatchie equivalent beds" in a strictly informal sense.

The location of the deposit of the Coosawhatchie equivalent beds studied for this report is shown in the index map (Text-fig. 1). Ochlocknee, Georgia is in northwestern Thomas County, a southwestern Georgia county bordering on Florida. An elongate structural trough filled with Miocene sedimentary rocks trends northeastward through this part of Thomas County and adjacent counties of Georgia and Florida. This trough was originally recognized by Johnson (1892) and was included in what he termed the "Chattahoochee embayment." This same structural feature has also been included in the "Apalachicola embayment" and the "southwest Georgia basin" by others (Patterson, 1974, p. 6). Part of this embayment was named the "Gulf Trough of Georgia" by Herrick and Vorhis (1963, p. 55, figs. 2, 3) and modified to "Gulf Trough" by Hendry and Sproul (1966, p. 97). In this report, we follow Patterson (1974, p. 6) in using the term "Gulf Trough" to denote the elongate Miocene depocenter northeast of the Apalachicola Embayment in southwestern Georgia. Locations of the principal structural features of the region are shown in Text-figure 1. The position of the Gulf Trough as a linear structural basin connecting the Southeast Georgia Embayment that opens to the Atlantic Ocean and the Appalachicola Embayment that opens to the Gulf of Mexico is delineated in Text-figure 2, an isopach map of upper Oligocene and Miocene sedimentary rocks in the region.

Patterson (1974, p. 7) has suggested that the Gulf Trough was probably a strait separating peninsular Florida from the mainland during Oligocene and much of Miocene time. Probably no open-water connection existed through the Gulf Trough between the Gulf of Mexico and the Southeast Georgia Embayment of Toulmin (1955) during deposition of the Coosawhatchie equivalent beds. Weaver and Beck (1977, pp. 15–16) have suggested that the Gulf Trough was open to the Atlantic waters of the Southeast Georgia Embayment and that it was either closed or greatly restricted toward the southwest during the time of deposition of the Coosawhatchie equivalent beds of Thomas County, Georgia. Paul Huddlestun (written commun., 1981) has indicated that the Gulf Trough and the Southeast Georgia Embayment were almost certainly connected during early and middle Miocene time when inner shelf and upper estuarine deposits were laid down. He believes that the Gulf Trough and the Southeast Georgia Embayment were permanently separated by the end of Coosawhatchie time. The Coosawhatchie equivalent beds studied for this report were apparently deposited in waters derived from the Atlantic Ocean basin, rather than waters derived from the Gulf of Mexico. The nonmarine bed herein described probably was deposited during a relatively short-lived isolation of the Gulf Trough from free access to Atlantic waters and may perhaps be a precursor of its final separation from Atlantic waters.

## ACKNOWLEDGMENTS

A sample of fuller's earth from Thomas County, Georgia, was sent to the U. S. Geological Survey diatom laboratory, Washington, DC, by L. Ray Gremillion in 1963. Scanning electron micrographs were made of diatoms from this sample, because of their superior preservation. Charles E. Weaver, Department of Geology, Georgia Institute of Technology, Atlanta, Georgia, supplied a suite of samples and stratigraphic information on the Oil-Dri mine to W. H. Abbott. S. H. Patterson, U. S. Geological Survey, Reston, Virginia, and B. F. Buie, Department of Geology, Florida State University, Tallahassee, Florida, were our leaders on the Field Conference on Kaolin and Fuller's Earth held in November 1974. John L. Stone, Washington, DC, prepared slides in a high-index mounting medium and assisted in identification of specimens. John A. Barron, U. S. Geological Survey, Menlo Park, California, William C. Cornell, University of Texas at El Paso, El Paso, Texas, Paul F. Huddlestun, Georgia Geological Survey, Atlanta, Georgia, and J. P. Bradbury, U. S. Geological Survey, Denver, Colorado, have critically reviewed the manuscript. Suggestions made by Huddlestun and Bradbury have been incorporated into the

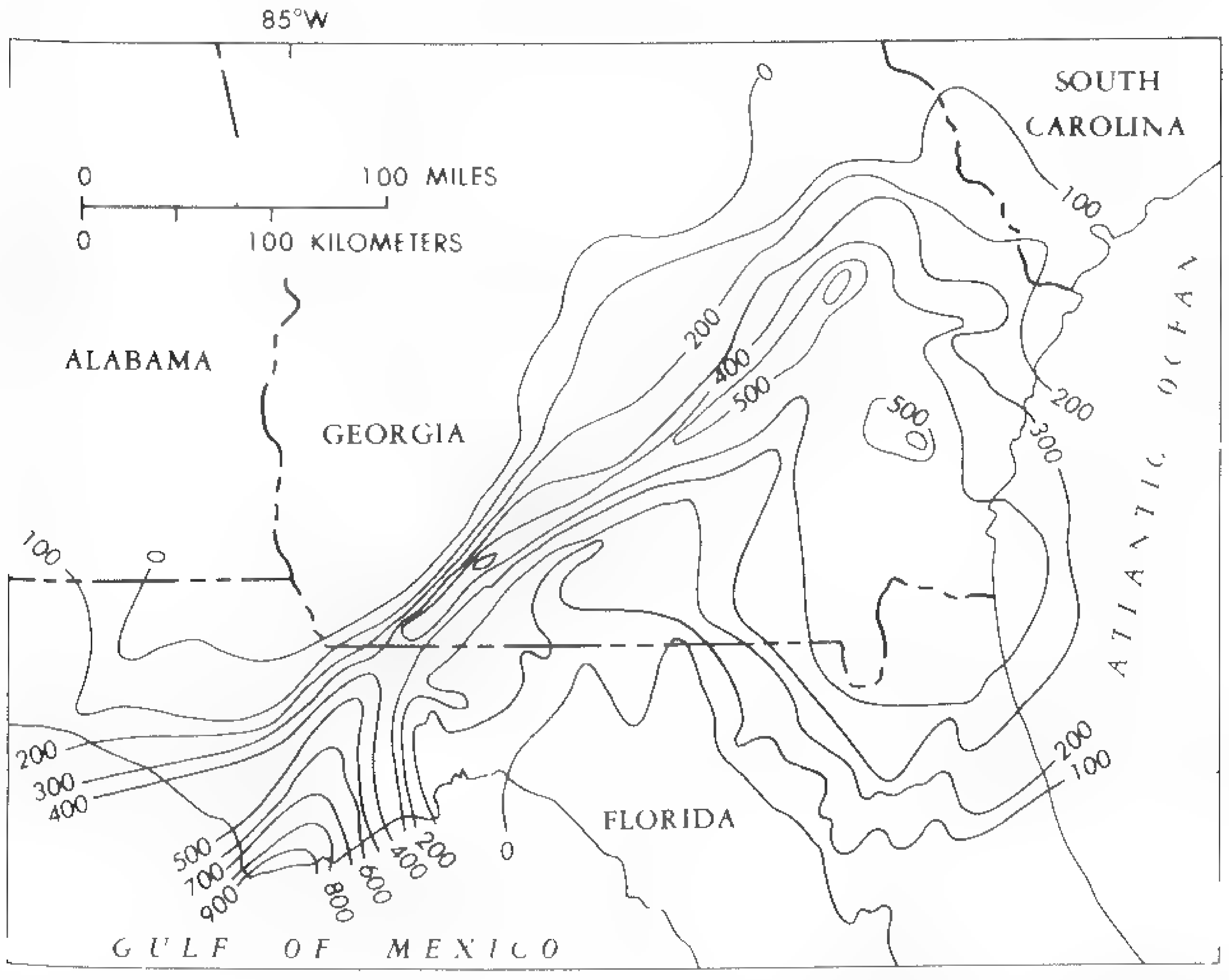



Text-figure 1.—Index map showing location of diatom locality in Thomas County, Georgia, and its relationship to the regional paleogeography.

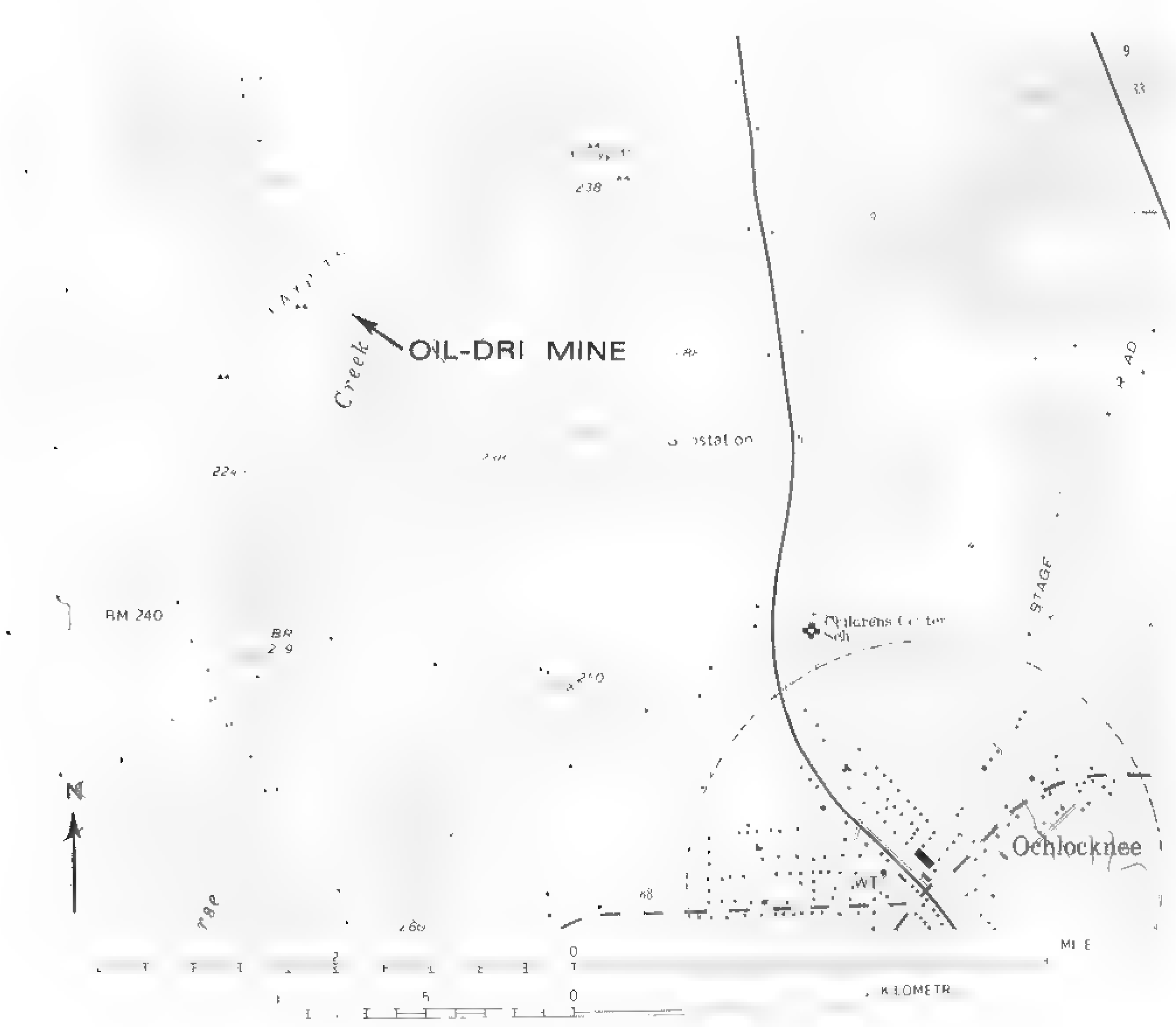
report. The kind assistance of all mentioned above in the preparation of this report is deeply appreciated.

## LOCATION OF DEPOSIT

The diatomaceous samples studied for this report were obtained from the Oil-Dri Corporation of America fuller's earth mine (formerly the Cairo Production Company mine), approximately 3.2 km (2 mi) northwest of Ochlocknee in northwest Thomas County, Georgia. The mine is shown as a group of "clay pits" near the north edge of the center of the U. S. Geological Survey (USGS) Ochlocknee, Georgia 7½′ quadrangle, part of which is herein reproduced as Text-figure 3.




Text-figure 2.—Isopach map of upper Oligocene and Miocene sedimentary rocks, showing major depocenters. Redrawn from Weaver and Beck (1977, fig. 2).




Text-figure 3.—Location of the Oil-Dri Corporation fuller's earth mine near Ochlocknee, Georgia. Base from U.S.G.S. Ochlocknee, Georgia 7½′ quadrangle.

The location of the Oil-Dri Corporation mine has been published by Patterson and Buie (1974, pp. 42–43) in the guidebook to the Field Conference on Kaolin and Fuller's Earth.

## STRATIGRAPHY OF DEPOSIT

The stratigraphy, lithology, and mineralogy of the Coosawhatchie equivalent beds in the Oil-Dri Corporation of America fuller's earth mine near Ochlocknee, Georgia have been described by Patterson (1974), Patterson and Buie (1974), and Weaver and Beck (1977). A measured stratigraphic section in the mine was published by Patterson (1974, pp. 36–37). Greatly simplified, the section consists of: (1) a lower deposit of commercial fuller's earth, approx. 7.3 m (24 ft) thick consisting of light-gray, massive, tough, jointed clay and a few thin sand-clay-pebble beds; (2) the overburden, approx. 11.9 m (39 ft) of interbedded pale-yellow soft plastic clays and light-gray clayey sands. The stratigraphic levels, associated lithology, and inferred paleoecology of diatomaceous samples studied for this report are shown in Text-figure 4.

According to Weaver and Beck (1977), the basal clay of the fuller's earth deposit is composed of approximately 50% palygorskite and sepiolite and 50% montmorillonite, the montmorillonite and kaolinite increasing toward the top. In addition to quartz and Na- and K-feldspar, the fuller's earth contains phosphate and clay grains, sponge spicules, silicoflagellates, and ebridians as well as diatoms. From the overburden sediments, Weaver and Beck (1977) reported 90% montmorillonite and 10% kaolinite in the basal clays, kaolinite becoming dominant 3 m below the surface. Quartz, K-feldspar, biotite, and muscovite occur in the sands of the overburden.

The correlation between the Weaver samples and the USGS diatom localities may not be exact. The compilation of Text-figure 4 was made by consideration of the stratigraphic section of Weaver and Beck (1977, text-fig. 54), showing the collection levels of the Weaver samples, the stratigraphic section of Patterson (1974, pp. 36–37), and our personal observations in the field. This compilation has been made carefully, however, and we believe that it reflects with reasonable accuracy the stratigraphic positions of the two sets of samples studied for diatoms.

## PREVIOUS DIATOM WORK

Although the presence of diatoms in the fuller's earth and associated strata of the Coosawhatchie equivalent beds in Thomas County, Georgia, was doubtlessly noted upon the first microscopic examination of these deposits, no systematic study of the diatoms was reported until 1965. A clay sample from the Cairo Production Company Mine near Ochlocknee, Georgia (the Oil-Dri Corporation of America mine of this report), was submitted by Gremillion (1965, pp. 44–45) for examination to Taro Kanaya, then at Tohoku University, Sendai, Japan. Kanaya identified 19 diatom taxa, all of which he regarded as marine. He suggested correlation with the Calvert Formation of Maryland, which he considered to be middle Miocene in age. Examination of Kanaya's species list indicates that he most probably examined a sample from the lower marine section studied in this report. Although the stratigraphic ranges of many species are now better understood and new stratigraphically significant diatom taxa have been defined, Kanaya's conclusions in no way conflict with this report. We can, however, now date this deposit more precisely by diatoms than could have been done in 1965.

Weaver and Beck (1977, pp. 107–110) published a list of diatom species determined by W. H. Abbott from the Cairo Production Company mine (Oil-Dri Corporation of America mine of this report). This list was a composite of several samples submitted by C. E. Weaver to W. H. Abbott and listed 51 taxa of diatoms. This study has been refined and is superseded by the present report, and the revised data are herein incorporated.

## SUMMARY OF INVESTIGATION

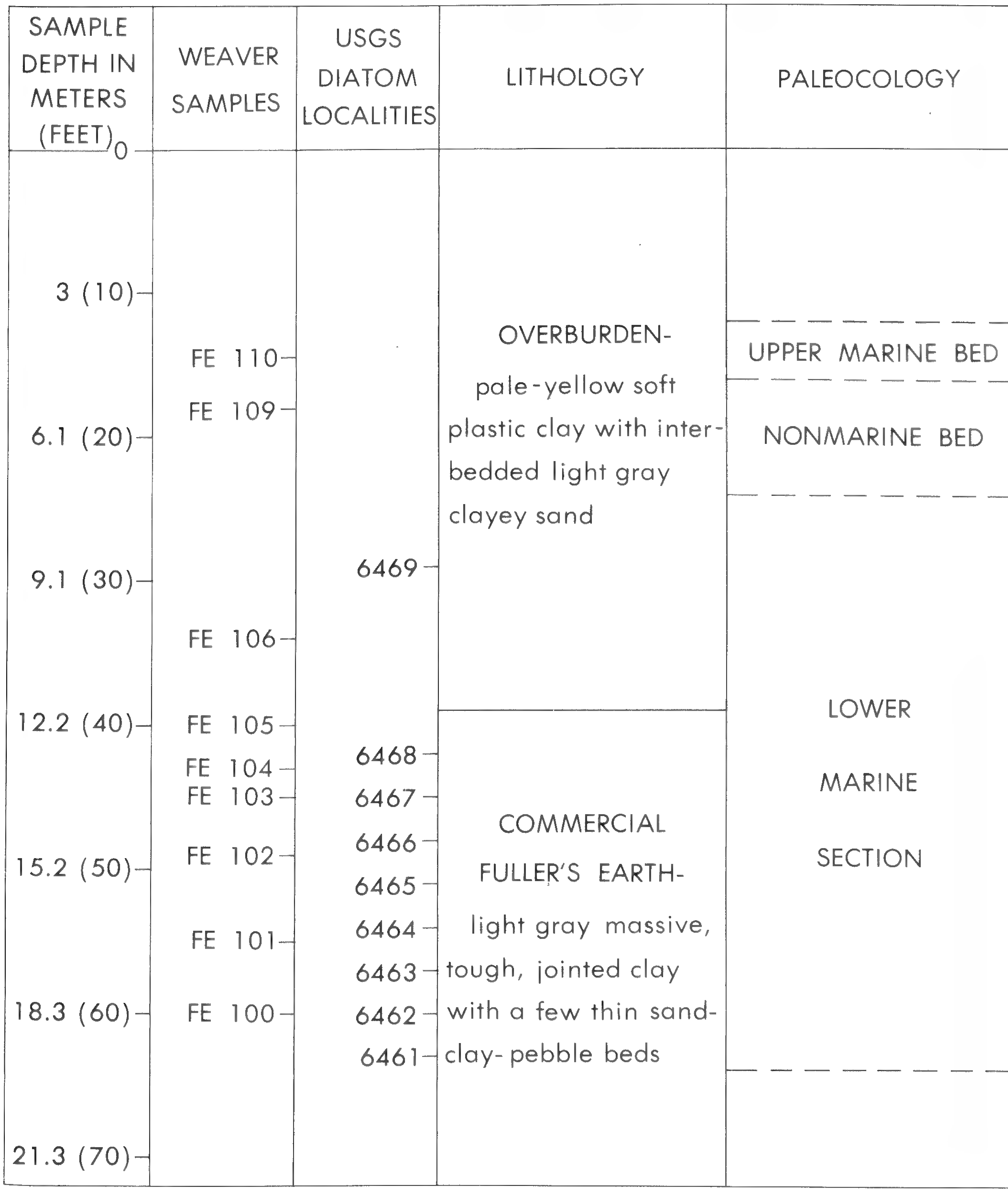
Two sequential suites of diatomaceous samples from the Oil-Dri Corporation mine were studied for this report: (1) a sequence of nine samples, at irregular intervals, taken by C. E. Weaver and presented to Abbott for study; (2) a sequence of nine samples, mostly at 1 m (3 ft) intervals, taken jointly by Abbott and Andrews during the Field Conference on Kaolin and Fuller's Earth on November 16, 1974. All the Weaver samples were studied in detail by Abbott; sample FE 100 was studied in detail by John Stone; samples FE 100, FE 106, FE 109, and FE 110 were studied in detail by Andrews to supplement those collected personally. The samples collected by Abbott and Andrews in 1974 were studied by both. Slides and photographs were exchanged on a regular basis in order to prepare as complete a taxonomic treatment as possible. In the preparation of this report, the two writers were jointly responsible for the stratigraphic and paleoecologic treatment as well as for the regional correlation. Although Andrews was primarily responsible for the taxonomic treatment, taxa observed only by Abbott have been incorporated into the report. Andrews has assumed sole responsibility for any revisions of nomenclature or descriptions of new species.

## DIATOM ASSEMBLAGES

Table 1 shows the distribution of diatom taxa in the strata exposed in the Oil-Dri mine. We will consider first the diatoms from the lower marine section and the upper marine bed (Text-fig. 4); the diatoms of the nonmarine bed will be considered subsequently. The compilation of Table 1 posed certain problems in that the writers, of necessity, had to work separately on the samples and because the samples came from two different sources—from C. E. Weaver, and from our own collections. We dare not claim 0.3 to 0.6 m (1 to 2 ft) accuracy in correlation of the Weaver samples with those personally collected. Therefore, in Table 1 we have indicated only those marine taxa observed by Andrews or by both writers at the appropriate levels. Those taxa observed only by Abbott in the Weaver samples have been placed in Table 3, a supplemental list at the end of this section. This placement in no way should be construed to denigrate the importance of these taxa; they are included in the section on systematic paleontology. It has only been necessary because of doubt of the exact stratigraphic correlation between the two suites of studied samples and possible differences in frequency estimates between the writers.

The diatom assemblage of the lower marine section is remarkably consistent throughout the fuller's earth deposit and on up into the overburden. The uppermost sample (USGS diatom locality 6469, depth 8.8 m [29 ft]), although it shows obvious floral similarity to the lower strata, is distinctly different in that it is dominated by a single species, *Actinoptychus aequalis*, n. sp. The other samples show relatively little variation in diatom content, other than those expected in sampling. One possible exception is the sample at the 43 ft level (Weaver sample FE 104) in which Abbott observed a slightly larger assemblage of marine diatoms than at any other level. This may perhaps be the result of either more normal marine depositional conditions or fortuitous preservation.

The diatom assemblages of the lower marine section, considered as a whole, but excepting the uppermost sample, seem to be relatively normal marine Miocene diatom assemblages. They are dominated by such species as *Paralia sulcata* (Ehrenberg, 1838), *P. sulcata* var. *coronata* (Ehrenberg, 1845c), and *Melosira westii* Smith, 1856, usually abundant in the Miocene strata of the southeastern United States. They have a relatively high component of benthic marine diatoms, suggesting deposition in relatively shallow marine waters. The assemblages show somewhat fewer species than one might expect in this region. We have listed 86 marine taxa in Table 1, whereas in the Coosawhatchie Clay Member of the Hawthorn Formation of eastern South Carolina and Georgia we observed 111 taxa (Ab-




Text-figure 4.—Stratigraphic position, associated lithology, and inferred paleoecology of diatomaceous samples of the Coosawhatchie equivalent beds in the Oil-Dri Corporation fuller's earth mine. Sample depth is measured from a surface elevation of approximately 85.3 m (280 ft), the level of the adjacent upland shown on the U.S.G.S. Ochlocknee, Georgia 7½′ quadrangle map. The "Weaver samples" were submitted by C. E. Weaver to Abbott for examination. The "USGS diatom localities" indicate samples collected in the field by the writers in 1974.

bott and Andrews, 1979). This may result more from poor preservation than from an initially restricted assemblage. Under the light microscope many of the diatoms appear to be reasonably well preserved, but most show varying degrees of corrosion and etching under the scanning electron microscope. Patterson (1974, p. 11) has reported the occurrence of opal in the Coosawhatchie Clay. We found that it was difficult to disaggregate the fuller's earth in order to free the diatoms for study, and lack of response to chemical treatment indicated siliceous cementation. This cementation is, of course, a characteristic that makes the fuller's earth commercially desirable, in that it does not readily disintegrate. Solution of silica probably has reduced the diatom assemblage in quality of preservation as well as in the quantity of specimens and variety of taxa.

The uppermost diatomaceous level of the lower marine section (USGS diatom locality 6469, 39 ft level) is distinct from the rest of the section. It has relatively few taxa and is dominated by *Actinoptychus aequalis,* n. sp. It shows affinities for the assemblage in the upper marine bed, which also has relatively few taxa and is dominated by *A. aequalis.* These levels seem affected by specialized ecologic conditions, which are discussed elsewhere in this paper.

The nonmarine diatom assemblage (Weaver sample FE 109) includes 16 taxa listed separately in Table 2. This assemblage, relatively sparse both in numbers of taxa and of specimens, includes two distinct groups of diatoms: (1) brackish-water taxa known from modern environments, which are numerically more abundant; and (2) freshwater taxa, many of which are known from Miocene rocks of the midcontinent region of the United States. Again, one cannot be certain what the original assemblage may have contained, for the preservation of this assemblage is relatively poor.

Table 2.—Relative frequency of occurrence of nonmarine diatom taxa in the Coosawhatchie equivalent beds, Thomas County, Georgia. Estimated relative frequency under an 18 mm cover glass viewed at ×250 is defined as follows: A = abundant (at least one specimen in all fields of view); C = common (one specimen in many, but not all, fields of view); F = frequent (several specimens observed on slide but seen only in a few fields of view); R = rare (about 1 or 2 specimens observed on a slide).

| NONMARINE ASSEMBLAGE | SAMPLE NUMBER FE 109 6.1 m (18 ft) |
|---|---|
| Achnanthes hungarica | R |
| Caloneis westii | F |
| Eunotia parallela | R |
| Eunotia pectinalis | R |
| Eunotia pectinalis var. minor | R |
| Gomphonema affine var. insigne | R |
| Gyrosigma aff. G. spencerii | R |
| Melosira juergensi | C |
| Navicula aff. N. radiosa | R |
| Nitzschia hybrida | R |
| Nitzschia tryblionella var. victoriae | F |
| Pinnularia brevicostata | R |
| Pinnularia fusana | R |
| Pinnularia aff. P. microstauron | R |
| Pinnularia torta | R |
| Stauroneis salina | R |

## CORRELATION

### Miocene Section in Maryland

The Coosawhatchie equivalent beds, as exposed in the Oil-Dri Corporation fuller's earth mine, appear to correlate with a part of the Calvert Formation of Maryland on the basis of marine diatoms. Marker diatoms of the Calvert and Choptank Formations along Chesapeake Bay have been studied by Andrews (1978), and a diatom zonation has been proposed for these deposits. Abbott (1978) has also established a diatom zonation for the Atlantic margin, which, though differing in details, does not disagree substantially with that of Andrews (1978). Abbott's zonation was based on materials from the entire Atlantic coastal region of the southeastern United States and primarily on offshore deposits. Andrews' zonation was based on materials from Maryland from a more nearshore section of the Miocene deposits, but it recognizes that the principles derived might be applicable farther afield. Neither zonation has been previously applied to Miocene deposits marginal to the Gulf of Mexico.

The Coosawhatchie equivalent beds of Thomas County, Georgia, contain the following marine marker diatoms in common with the Maryland section:

*Actinoptychus marylandicus* Andrews, 1976
*A. thumii* (Schmidt) Hanna, 1932
*A. virginicus* (Grunow) Andrews, 1976
*Delphineis angustata* (Pantocsek) Andrews, 1975
*D. novaecaesaraea* (Kain and Schultze) Andrews, 1977
*D. penelliptica* Andrews, 1977
*Rhaphoneis adamantea* Andrews, 1978
*R. elegans* (Pantocsek and Grunow) Hanna, 1932
*R. fusiformis* Andrews, 1978
*R. magnapunctata* Andrews, 1978
*R. parilis* Hanna, 1932

These marine diatoms suggest that the Coosawhatchie equivalent beds correlate with the upper part of East Coast Diatom Zone (ECDZ) 4 (the *Rhaphoneis*

Table 3.—Additional taxa of marine diatoms observed and identified by W. H. Abbott in samples supplied by C. E. Weaver.

| | |
|---|---|
| *Actinocyclus ingens* | *Diploneis bombus* |
| *Actinoptychus virginicus* | *Hemiaulus ambiguus* |
| *Anaulus birostratus* | *H. polymorphus* |
| *Coscinodiscus asteromphalus* | *Rhizosolenia styliformis* |
| *C. decrescens* | *Rossiella praepaleacea* |
| *C. gigas* var. *diorama* | *Sceptroneis grandis* |
| *C. marginatus* | *Stephanopyxis corona* |
| *C. stellaris* | *S. lineata* |
| *C. vetustissimus* | *Synedra jouseana* |
| *Debya insignis* | *Trochosira spinosa* |
| *Denticulopsis nicobarica* | *Xanthiopyxis* spp. |

*parilis* Partial Range Zone of Andrews, 1978) and with Atlantic Margin Siliceous Microfossil Zone (AMSMZ) IV (the *Delphineis penelliptica* Partial Range Zone of Abbott, 1978). These beds contain two diatom species—*Actinoptychus thumii* and *Rhaphoneis elegans*—that were observed only in the lower part of Miocene Lithologic Unit (MLU) 14 of the Calvert Formation by Andrews (1978). This suggests a fairly precise correlation of the Coosawhatchie equivalent beds with lower MLU 14, but, until stratigraphic ranges of marine diatoms are more thoroughly understood, such precision must be accepted with caution. In any event, these beds can be no younger than ECDZ 4, for the upper limit of that zone is defined on the last occurrence of *Rhaphoneis magnapunctata.*

Of the 11 marker diatoms listed, nine agree with this correlation completely. *Rhaphoneis adamantea* was last reported in the Maryland section at a slightly lower level in ECDZ 4, in the upper part of MLU 13. However, this discrepancy is relatively small, and *R. adamantea* is closely related to (and possibly a short variant of) *R. magnapunctata,* which ranges to the top of ECDZ 4. Probably, *R. adamantea* was by chance not observed at this stratigraphic level in the Maryland study. The only really vexing discrepancy is in the occurrence of *Rhaphoneis fusiformis* in the Coosawhatchie equivalent beds. This was recorded from about the middle of ECDZ 2 to about the middle of ECDZ 3 in the Calvert Formation of Maryland. *R. fusiformis* was never common in the Calvert Formation, so perhaps its range is greater than was observed. A more detailed study might indicate that the forms identified as *R. fusiformis* from the two areas are not conspecific. In all, the correlation between the marine diatoms of the Coosawhatchie herein studied with ECDZ 4 in the Calvert Formation is substantial and is quite remarkable, considering their wide geographic separation.

## HAWTHORN FORMATION OF THE RIDGELAND TROUGH

The marine diatom assemblage of the Coosawhatchie Clay Member of the Hawthorn Formation of the Ridgeland Trough was previously described by Abbott and Andrews (1979). The Coosawhatchie was originally named from beds exposed in the Ridgeland Trough of the East Georgia Basin in southern South Carolina and adjacent areas of Georgia. The Coosawhatchie diatoms of the Ridgeland Trough were correlated with those of ECDZ 6 (*Rhaphoneis gemmifera* Range Zone) of Andrews (1978) and with those of AMSMZ VI (*Coscinodiscus plicatus* Partial Range Zone) of Abbott (1978). The Ridgeland diatoms were, therefore, found to be distinctly younger than those of Thomas County, Georgia, studied for this report. The Ridgeland Trough deposit was correlated with approximately the upper half of MLU 16 of the Choptank Formation in the Chesapeake Bay region, whereas the Thomas County deposit of this study has been correlated approximately with the lower part of MLU 14. The marine diatoms clearly suggest that the Coosawhatchie equivalent beds in Thomas County are discernably older than the Coosawhatchie deposit in the Ridgeland Trough. Therefore, the Coosawhatchie deposits, as a whole, appear to be equivalent to MLU 14 through MLU 16 of the Calvert and Choptank Formations in Maryland.

## NONMARINE DIATOM ASSEMBLAGE

The nonmarine diatom assemblage in the Coosawhatchie equivalent beds is the first such Miocene assemblage to be reported from the southeastern United States. Comparison can be made only with nonmarine assemblages of the Great Plains region, which are both geographically and ecologically far removed from those of southwestern Georgia. The more abundant brackish-water component of this assemblage has not been recorded elsewhere in the Miocene and cannot be used in correlation. The three taxa of *Eunotia* Ehrenberg, 1837, a genus more common to acidic waters, were not observed in the alkaline lake waters of the Great Plains. The remaining six more cosmopolitan freshwater species in the Coosawhatchie have been observed in Miocene deposits of Nebraska. Of these, *Gomphonema affine* var. *insigne* (Gregory, 1856) Andrews, 1970 and *Pinnularia brevicostata* Cleve, 1891, were observed in both the lower Miocene Monroe Creek Sandstone in the Pine Ridge area, Nebraska (Andrews, 1971), and the lower to middle Miocene "Valentine Formation" at Kilgore, Nebraska (Andrews, 1970). *Pinnularia fusana* Andrews, 1971, and *P. microstauron* (Ehrenberg, 1843) Cleve, 1891 were observed only in the Monroe Creek Sandstone, and *Navicula radiosa* Kützing, 1844, and *Pinnularia torta* (Mann, 1924) Patrick *in* Patrick and Reimer, 1966 were observed only in the "Valentine Formation".

Six diatom taxa constitute too small a data base to attempt any precise correlation between the Coosawhatchie and the Miocene strata of the Great Plains. The Monroe Creek Sandstone is probably of early Miocene age, but the "Valentine Formation" would now be considered late early to early middle Miocene in age, rather than uppermost Miocene as stated by Andrews (1970). The small freshwater component of the nonmarine assemblage, although not highly definitive, in no way disagrees with the early middle Miocene age for the Coosawhatchie equivalent beds based on the marine diatom content; it does tend to confirm the observation (Andrews, 1970, 1971) that freshwater diatom assemblages of Miocene age are relatively less diverse than are similar assemblages in Pleistocene and Holocene deposits.

## AGE OF DIATOM ASSEMBLAGES

Although we are in complete agreement in assigning an early middle Miocene age to the Coosawhatchie equivalent of Thomas County, Georgia, and in its relative position in our respective diatom-zonation schemes, we hold slightly divergent opinions in the detailed age assignment of this part of the Miocene section. The following discussion is based on the timescale of Berggren and Van Couvering (1974). Abbott (1978, p. 26) stated that his AMSMZ IV was correlative with planktonic foraminiferal zone N9 or N10 of Blow (1969), but he preferred to assign his zone to N10. He placed his Zone IV in the lower part of the Serravallian Stage, with an absolute age of just less than 13 Ma (million years). Utilizing more recent correlation information, Abbott (unpub. data) still equates his Zone IV with planktonic foraminiferal zone N10, but he now places this zone in the upper part of the Langhian Stage. Andrews does not find the evidence to assign his ECDZ 4 to Blow's planktonic foraminiferal zone N10 to be compelling. He therefore prefers to correlate this diatom zone with Blow's zone N9. This would place the Thomas County deposit of the Coosawhatchie equivalent beds in the upper part of the Langhian Stage, with an approximate absolute age of 13.4 Ma (Andrews, 1978, p. 379). We regard this only as an interpretational difference of opinion; it does not affect the age assignment of these strata in any significant manner.

## PALEOECOLOGY

The sediments of the Coosawhatchie equivalent beds in Thomas County, Georgia may be logically divided into three parts for discussion of their paleoecology: (1) the lower marine section, exclusive of the uppermost level studied; (2) the uppermost level of the lower marine section and the upper marine bed; (3) the nonmarine bed. The relative stratigraphic position of these three paleoecologic elements is shown in Text-figure 4.

The lower marine section, exclusive of the upper part, shows a distinctly shallow-water marine diatom assemblage. At the time of deposition there must have been free access to open marine waters even if, as the paleogeography suggests, the strata were deposited in the far end of a narrow embayment extending southwestward from the Atlantic Ocean. The lower marine section, including the fuller's earth and approx. 5.2 m (17 ft) of overlying clastic sediments, shows an assemblage dominated by cosmopolitan marine diatoms, many common and widespread in modern marine environments. The most common forms are *Paralia sulcata* (Ehrenberg, 1838) Cleve, 1873 and *P. s.* var. *coronata* (Ehrenberg, 1845c) Andrews, 1976, and *Melosira westii* Smith, 1856. Many of the marker species are shallow-water benthic taxa, useful in correlation with strata as far away as Maryland and New Jersey. Although from the standpoints of location and diatom assemblage, these beds show evidence of shallow-water deposition, no evidence indicates any substantial deviation from normal marine salinity.

The second paleoecologic grouping presents a greater problem. This grouping includes the uppermost part of the lower marine section and the upper marine bed. These two diatomaceous horizons bracket the nonmarine bed. These two levels contain similar assemblages; the one near the top of the lower marine section includes a richer variety of marine species than does the upper marine bed. Both levels are dominated by *Actinoptychus aequalis* n. sp., which is of little help to us in ecological determination because *A. aequalis* has not been previously reported. Other more frequently occurring taxa in these beds are: *Biddulphia tuomeyi* (Bailey, 1844) Roper, 1859, *Hyalodiscus scoticus* (Kützing, 1844) Grunow, 1879, *Paralia sulcata,* and *P. sulcata* var. *coronata. Paralia* Heiberg, 1863, indicates little more than a marine environment. *Biddulphia tuomeyi* and *Hyalodiscus scoticus* are known to range from shallow-marine to brackish-water environments. *Aulacosira italica* (Ehrenberg, 1838) Simonsen, 1979, the only freshwater species identified in the marine deposits, was found rarely in the upper level of the lower marine section. Coupled with the fact that these beds bracket a distinctly brackish-freshwater diatom assemblage in the nonmarine bed, the evidence suggests a basically marine environment with somewhat lowered salinity. These beds may represent a transition between open marine and nonmarine environments during a temporary regression in the shallow Gulf Trough or because of blockage of marine waters from the Atlantic Ocean.

The nonmarine diatom assemblage shows two distinct elements, one preferring brackish or saline waters and the other fresh waters. The assemblage is dominated by *Melosira juergensi* Agardh, 1824, a distinctly brackish-water species. Other taxa tolerant of brackish water or of some salinity are: *Caloneis westii* (Smith, 1853) Hendey, 1964, *Gyrosigma* aff. *G. spencerii* (Quekett, 1848) Griffith and Henfrey, 1856, *Navicula* aff. *N. radiosa* Kützing, 1844, *Nitzschia hybrida* Grunow *in* Cleve and Grunow, 1880, *N. tryblionella* var. *victoriae* (Grunow, 1862) Grunow *in* Cleve and Grunow, 1880, and *Stauroneis* aff. *S. salina* Smith, 1853. Although there are more fresh- than brackish-water species in the nonmarine bed, the predominance of *Melosira juergensi* gives an edge to the brackish forms in the total number of specimens. The freshwater taxa include forms ranging in preference from acidic to alkaline waters and show no distinctive ecologic trend. The occurrence of *Eunotia* Ehrenberg, 1837, in the sample, however, suggests at least influx of some acidic fresh water. No distinctly marine species occurs in the nonmarine bed, and even the ubiquitous *Paralia sulcata* (Ehrenberg, 1838) Cleve, 1873 is absent. This suggests that the connection with the Atlantic Ocean was essentially closed, although some minor influx of brackish or marine water may have taken place from time to time. The mixed brackish- and freshwater diatom assemblage suggests deposition in waters of fluctuating salinity in a restricted bay or estuary. Apparently, relatively little new salt water was being added to the environment.

With regard to the sediments themselves, Weaver and Beck (1977) suggested that during the deposition of the fuller's earth, the presence of phosphate, clay grains, and Na- and K-feldspar indicates that the detritus was derived from the Ocala High to the east or southeast. They further suggested that the absence of these minerals and the presence of abundant K-feldspar, mica, kaolinite, and a zircon-rutile-tourmaline heavy-mineral suite in the upper part of the deposit indicates a source area in the southern Appalachian Mountains to the west or northwest.

## SYSTEMATIC PALEONTOLOGY

### INTRODUCTION

The genera and species of diatoms studied for this report are arranged in alphabetical order to facilitate use by the reader. A systematic arrangement has not been made because this paper is of interest primarily to the diatom biostratigrapher, to whom a suprageneric classification is of little consequence. The marine and nonmarine diatom assemblages are treated separately in the text, tables and plates, so that each group can be more readily examined and evaluated. The generic and infrageneric nomenclature generally follows that proposed by Hustedt (1927–1959) and Hendey (1964), but subsequent changes have been taken into account. Descriptions pertinent to the specimens of taxa observed in the Hawthorn Formation are included to increase the usefulness of this paper to the reader. More extensive descriptions can usually be found in the works cited in the synonymies.

There is no recognized standard for magnification in diatom illustrations, nor is it desirable that one should be imposed. Diatoms vary in maximum dimension from a few to several hundred micrometers. Requiring a constant magnification for all taxa in an ordinary diatom assemblage would result in absurdly small illustrations of the smallest diatoms, and illustrations of the largest diatoms could exceed the size of the plate. The selection of diatom magnification is pragmatic with the aim of producing a useful illustration. The light photomicrographs in this report are made at ×500 or ×1000; the electron microscope photographs vary as indicated, depending on the size of the specimen. The measurement of fine structures of diatom valves in number per 10 micrometers, long standard in diatom literature, is used throughout this report.

The format of discussion follows that used in earlier reports on fossil marine diatom assemblages of the southeastern United States. The first citation in each synonymy is to the basionym of the taxon. The second citation is to the name adopted for use in this report, with appropriate references in chronological order. Subsequent citations include synonyms, misidentifications, misspellings and incorrect attributions of authorship. These synonymies emphasize the reported fossil occurrences in the southeastern United States, and they are not intended to be exhaustive. Information is given in this paper on the known geologic range of all taxa because such information is useful in biostratigraphy. The terminology of relative abundance of the various taxa in the studied samples is given in the explanations of Tables 1 and 2. The terms "raised sector" and "depressed sector" used in describing taxa of the genus *Actinoptychus* shall by definition refer in this report to the external expression of those sectors.

### PHILOSOPHICAL CONSIDERATIONS

Scientific study of diatoms was initiated for North America by Jacob Whitman Bailey, who published his first paper on diatoms in 1838 and continued active in the field until his death in 1857. Much of Bailey's work was done on fossil diatoms, both marine and nonmarine, from widely scattered localities in the United States. The first studies of the Tertiary marine diatoms of the Atlantic coastal plain were made by Bailey, and he recognized early that diatoms were as useful for geologic correlation, *i.e.,* biostratigraphy, as were other groups of micro- and macrofossils (Bailey, 1845, p. 337). Bailey was a colleague and correspondent of Christian Gottfried Ehrenberg of Berlin, perhaps the best known European diatomist of the 19th century and certainly the most prolific writer of papers on diatoms, both fossil and recent. Many of Ehrenberg's works on fossil diatoms of North America were based on samples sent to him by Bailey for analysis. Both of these pioneer diatomists seem to have been men of considerable ability. Ehrenberg's work is better known and much more extensive; he was a recipient of handsome patronage by the kings of Prussia. Bailey, on the other hand, did such diatom work as he could incidental to his duties as a professor at the U. S. Military Academy at West Point, New York.

From these beginnings studies of fossil diatoms moved very slowly through the latter part of the 19th century and the early decades of the 20th century. These studies have increased considerably in recent years, so much that it is impossible to summarize the later fossil diatom work here. Fossil marine diatoms as old as Cretaceous were first reported from the Moreno Shale of California by Hanna (1927) and Long, Fuge, and Smith (1946). Well-authenticated diatoms of Cretaceous age have been reported more recently from the Soviet Union and deep-sea deposits in the ocean basins. Although reports have been made in the literature of fossil diatoms in rocks as old as pre-Cambrian in age, such claims have been generally received with deserved skepticism. The oldest known nonmarine diatom assemblage is that described by Lohman and Andrews (1968) from the late Eocene Wagon Bed Formation of Wyoming. The earliest diatom assemblages of both marine and nonmarine character are diverse in their component taxa, and this suggests that the diatoms have a much longer history than their recorded fossil occurrence indicates. Why then do we not find fossil diatoms in rocks older, and even substantially older, than Cretaceous in age? A major consideration appears to be preservation. Older rocks have simply been exposed for longer periods of time to highly varied kinds of percolating waters. The chance of survival of identifiable siliceous remains of diatoms is thus naturally decreased with the age of the rocks. Even though Cretaceous rocks are widespread and exposed in thick sections around the world, diatoms are exceedingly rare in Cretaceous deposits. Also, although the evidence is not clear from known early diatoms, it is possible that diatoms were not as robustly silicified early in their history as they are at present. We know that many species of diatoms living today are so very weakly silicified that they will not survive more than the mildest cleaning in preparation for study. Such assemblages as the one studied for this report have apparently had all weakly silicified and many moderately silicified diatoms destroyed by natural leaching, and they are poor in the more delicate planktonic forms that should be present. We can postulate that diatoms probably developed the ability to form siliceous tests from dissolved silica at some point in their history. At that time they became recognizable as diatoms and as distinct from similar and obviously related soft-bodied microorganisms. This assimilation of silica must have proceeded slowly at first. Because of weak silicification and extremely long times of weathering, it seems doubtful that the oldest diatoms will ever be discovered.

No classification of diatoms above the generic level has been presented in this paper. This is partly because of the alphabetic, rather than systematic, order of the genera and also because although such classification is of scientific interest, it has little practical use to the diatom biostratigrapher. Diatoms have been classified traditionally as single-celled organisms or cryptogams within the plant kingdom. They are indeed photosynthetic organisms, considered by most taxonomists as a definitive characteristic of plants. The Kingdom Protista was proposed by Haeckel (1866) for single-celled organisms with both plant and animal affinities, and more recently the paleontologist R. C. Moore (1954) suggested revival of this classification for the *Treatise on Invertebrate Paleontology.* The use of a third kingdom does not seem to have received much acceptance from biologists, and biostratigraphers seem almost completely indifferent to the question. Because we know nothing about the earliest evolution of the diatoms, this controversy can probably be solved only on a philosophical basis. Perhaps it is simpler to continue to consider the diatoms as plants, but we have no strong convictions on this subject.

The classification of diatoms at the family and lesser ranks has been reasonably well stabilized for many years. Generally accepted classifications are published in standard reference works by Hendey (1964) and Hustedt (1927–1959). These works do not always agree in detail, but they present the state of the art as developed under light microscopy. With the advent of electron microscopy a whole new world was revealed in the ultrastructure of diatoms. Transmission electron microscopy gave much greater magnification and resolution of pore structures. However, scanning electron microscopy has proved even more valuable in modelling the surface of the diatom valve with great resolution, higher magnification, and increased depth of field. The scanning electron microscope now allows the diatomist to see finer structures that were only vaguely discerned as light artifacts, or even not seen at all, under the light microscope. Scanning electron microscopy has greatly advanced our knowledge of the morphology of the diatom valve. Consequently, previous diatom classifications have been found to be somewhat inadequate in the light of this new knowledge. A revised classification has been made recently by Simonsen (1979), and further changes will doubtless be made as more information becomes available. Although the electron microscope is extremely useful in diatom research, it should by no means be considered as a replacement for the light microscope. We can increase our knowledge of detailed morphology of the diatom valve by techniques of electron microscopy in order to understand better what we see under the light microscope. No one should be excluded from the study of diatoms because he lacks access to one of these expensive and highly technical instruments.

Diatom research has suffered over the years from a patchwork system of classification (on the generic and subgeneric levels) inherited from a diverse group of 19th century workers. The early workers tended to be conservative and hence "lumpers" in that they did not have adequate microscopes to make significant distinctions nor did they have the experience to recognize significant distinctive features. There are no lack of generic names in the diatom literature, but too many of them were ill-conceived or synonyms for previously described genera. Some past workers were so conservative that they retained old classifications long after worthwhile revisions had been made. It seems to me that even today we have too few meaningful diatom genera. As new and distinct genera and species are recognized, even in previously described diatoms, they should be given proper taxonomic revision rather than continued "lumping" into inappropriate categories. Unfortunately, too little taxonomic revision is being done on diatoms at the present time. On the other hand, there seems to have been an excessive amount of "splitting" at the infraspecific level by some workers. Species of diatoms are often subdivided into "varieties" and these varieties are sometimes even further subdivided into "formas"; subspecies are seldom found in diatom literature. We believe that these infraspecific units may have meaning and utility to the biologist working on living diatoms. However, we do not find them to be useful to the paleontologist, for they imply relationships that are impossible to prove in fossil diatoms. Although in many instances we have retained the previously described varietal usage in diatom taxa, this is strictly because these varieties seem to show distinct morphology. If a fossil diatom taxon is distinctive enough to be recognized, it deserves the status of a species. Although the classification of fossil diatoms must be based on valve morphology, biologists continue to find examples of different morphologic formas, varieties and even species growing in the same clone of diatoms. It is important that that intraspecific variation be recognized and that diatom taxonomy be modified accordingly. This is a job that the biologist can do much more effectively than the paleontologist. Although diatom taxonomy has probably been more influenced by "lumping" than by "splitting", occasionally the "splitting" seems to have been excessive. Some of the work of Astrid Cleve-Euler comes to mind in this regard, wherein it seems that nearly every specimen observed has been given an infraspecific name or letter designation. When we recognize that diatom species show a degree of variability, such fine "splitting" as this seems to be inappropriate.

I have stated my reservations about the validity of quantitative studies on fossil diatoms in an earlier paper (Andrews, 1972). Quantification of diatom data has been in vogue in recent years, and some exponents of these techniques are enthusiastic about their results. Quantitative studies may have their value in biological specimens with excellent preservation, but the researcher must carefully consider the quality of the sample and the validity of the results produced. They may have value in certain carefully selected situations in paleontological studies, where taxa of relatively equal silicification are being compared. With regard to the samples studied for this report, and from similar shallow marine deposits of the southeastern United States, quantitative studies seem to be extremely inappropriate. We know that preservation is only fair in these samples from Thomas County, Georgia, and we have no way of knowing the kinds or quantities of diatoms that have been lost by selective leaching. Furthermore, in the majority of sandy and argillaceous coastal plain deposits there is always an abundance of broken and fragmental specimens, produced either by predepositional breakage in turbulent waters or by compaction between sand grains during lithification. These things preclude any validity to quantitative studies, not only in this region but also in many other fossil diatom deposits.

Research on diatoms at the present time is fragmented into several special interest groups, which are at times diverse in their techniques and purposes. There is a primary dichotomy between diatomists working in biology and in paleontology and another division between workers in marine and in nonmarine diatoms. Much recent work has been done by nonmarine biologists with interests in detecting polluted and enriched waters. An increasing interest has recently developed in the field of marine diatom biostratigraphy. There is, of course, excellent research also being carried out on the biology of marine diatoms as well as the biostratigraphy of nonmarine diatoms. Unfortunately, communication between these groups is not always as effective as it should be. We paleontologists particularly need more precise data on the ecology of living diatoms to interpret properly the paleoecology of our fossil diatoms. It is no longer adequate to know that a diatom taxon is, for example, "of common and widespread occurrence in shallow marine coastal waters of eastern North America." Additional information is urgently needed on precise geographic distribution and ecological preference of diatom taxa. Diatom biostratigraphers tend to avoid taxonomic problems, because taxonomy is not of pressing importance to meet their immediate needs. Basic considerations for useful diatom taxa for biostratigraphers are as follows: (1) the valves of the diatom taxon must be sufficiently silicified to be widely preserved as fossils; (2) the diatom taxon must be so morphologically distinct as to be readily recognizable; (3) the diatom taxon must have a restricted stratigraphic range that can be determined; (4) the diatom taxon should have a reasonably widespread geographic distribution, that is, it should not be a local endemic species. For routine biostratigraphic work most diatoms can be considered as distinctive objects and correct taxonomy is seemingly not an important consideration. But how can diatomists communicate with each other without a sound basis of taxonomic understanding? Effective taxonomic studies need to be made by both diatom biologists and paleontologists to a greater degree than is seen at present. Greater interchange of ideas between both groups would produce a body of knowledge on diatoms that would not only make for a more accurate science but would also increase the value of diatoms in the various fields of applied research.

## Marine Diatoms

### Genus **ACTINOCYCLUS** Ehrenberg, 1838

### **Actinocyclus ingens** Rattray

*Actinocyclus ingens* Rattray, 1890, pp. 149–150, pl. 11, fig. 7; Kanaya, 1959, pp. 97–99, pl. 7, figs. 6–9; pl. 8, figs. 1–4; Andrews, 1976, p. 13, pl. 3, fig. 10; Abbott and Andrews, 1979, pp. 230–231, pl. 1, fig. 3.

*Description.*—Valve round, nearly flat, but sharply bent at the margin. Margin with fine striations, about 18 in 10 $\mu$m, succeeded inwardly by a narrow ring of fine pores in a quincuncial pattern, about 16 in 10 $\mu$m. The main part of the valve is covered with radial rows of areolae, about four to six in 10 $\mu$m, more closely spaced near the margin than near the center, the lengths of the rows dividing the valve into sectors. Areolae near the margin show a slight tendency toward a secondary arrangement in curved decussating rows, are arranged radially in the midpart of valve and more or less randomly near the center. Center of valve is an irregular hyaline area. Pseudonodulus often difficult to observe, but consists of a single small cluster of fine but distinct pores near the shoulder of the valve.

*Discussion.*—This taxon is difficult to distinguish from *Coscinodiscus elegans* Greville, 1866, a similar appearing diatom without a discernible pseudonodulus. The relationship between several species of *Actinocyclus* and analogous morphological forms classified as *Coscinodiscus* Ehrenberg, 1838, because they show no pseudonodulus, is poorly understood at present. *A. ingens* was observed by Abbott as rare in sample FE 104 at approximately the 13.1 m (43 ft) level of the lower marine section.

*Known geologic range.*—Reported by Andrews (1976) from the Choptank Formation of Maryland and by Abbott and Andrews (1979) from the Coosawhatchie Clay Member of the Hawthorn Formation (middle Miocene). Restricted to the Miocene (Barron, 1980).

### **Actinocyclus octonarius** Ehrenberg
Plate 6, figure 1

*Actinocyclus octonarius* Ehrenberg, 1838, p. 172, pl. 21, fig. 7; Hendey, 1937, p. 262; Lohman, 1941, p. 77, pl. 16, fig. 4; Lohman, 1948, p. 167, pl. 8, fig. 8; Andrews, 1976, p. 14, pl. 3, fig. 7; Abbott and Andrews, 1979, p. 231, pl. 1, fig. 4; Andrews, 1980, p. 23, pl. 1, fig. 1; pl. 4, fig. 1.

*Actinocyclus ehrenbergii* Ralfs *in* Pritchard, 1861, p. 834; Hustedt, 1929, pp. 525–533, fig. 298.

*Description.*—Valve round, flat, thin and fragile, often fragmented or with damaged margin. Marginal zone covered with rows of fine areolae arranged in a quincuncial pattern, about 16 to 20 in 10 $\mu$m. Main part of valve divided into sectors by single radial rows of areolae extending from the marginal zone to the center. Each sector is filled with parallel rows of areolae, aligned normal to the margin of the valve but not parallel to the dividing rows of areolae. Each sector is thus filled by progressively shorter rows of areolae on both sides of the sector. About 10 rows of areolae in 10 $\mu$m; about seven areolae in 10 $\mu$m along the row. Pseudonodulus small, on the inner edge of the marginal zone.

*Discussion.*—Generally rare in the lower marine section.

*Known geologic range.*—Reported by Hajós (1976) from upper Eocene deposits in the southwestern Pacific and by Fenner (1977) from lower Oligocene deposits in the southern Atlantic. Common in Miocene deposits of the southeastern United States and widespread in modern oceans.

### **Actinocyclus tenellus** (Brébisson) Andrews
Plate 6, figures 2, 3

*Eupodiscus tenellus* Brébisson, 1854, p. 257, pl. 1, fig. 9.

*Actinocyclus tenellus* (Brébisson) Andrews, 1976, p. 14, pl. 3, figs. 8, 9; Abbott and Andrews, 1979, p. 231, pl. 1, fig. 9; Andrews, 1980, p. 23.

*Actinocyclus ehrenbergii* var. *tenella* (Brébisson). Hustedt, 1929, p. 530, fig. 302.

*Description.*—Valve small, round, nearly flat, but sharply bent at the margin. Margin with radial rows of very fine areolae, about 18 in 10 μm, followed inwardly by a narrow ring of fine areolae in a quincuncial pattern, about 16 in 10 μm. The main part of the valve is divided into about four to six sectors, and the sectors are filled with parallel rows of areolae normal to the margin of the valve as in *A. octonarius* Ehrenberg, 1838. About 10 rows of areolae in 10 μm; about 10 areolae in 10 μm along the row. Pseudonodulus at inner margin of quincuncial areolate zone.

*Discussion.*—This species has close affinities for *A. octonarius* but can be distinguished from that species by its somewhat more robust markings as well as its generally smaller size and fewer sectors. It is more frequently observed in this deposit than *A. octonarius.* Rare to frequent in the lower marine section and rare in the upper marine bed.

*Known geologic range.*—Miocene to Holocene, widespread in modern oceans.

### Genus **ACTINOPTYCHUS** Ehrenberg, 1841

**Actinoptychus aequalis** Andrews, new species
Plate 6, figures 4–7, 10–13; Plate 10, figures 17, 18; Plate 11, figures 1–6

*Description.*—Valve round with narrow slanting marginal rim surrounding a main area of raised and depressed sectors. Diameter of observed specimens 37–91 μm. Outer slanting rim (Pl. 11, fig. 1) ornamented with radial rows of fine pores, about 30 in 10 μm and also with external radial ridges of silica. At the shoulder of each externally raised sector with the rim is a single pore, centered, with a thickened rim or extended outward as a short tube (Pl. 11, fig. 3). These external pores or tubes connect with single labiate processes on the inside of the valve. The labiate processes, when preserved, are relatively long and curved (Pl. 11, fig. 4).

Main part of valve sharply divided into raised and depressed sectors, eight to 18 specimens observed. These sectors may be very nearly equal in width, but in some specimens alternate sectors are distinctly wider or narrower. There is no consistency as to which set of sectors is the widest. The raised sectors show a coarse areolate net on the outside of some specimens, which is much reduced or almost vestigial in others (see discussion below). Even when well-developed, the pattern of the areolate net is irregular. The depressed sectors show only vestiges of an areolate net, or more commonly, none at all.

The predominant ornamentation of the main part of the valve is the pore pattern, which can be observed well on both the inside and outside of the valve. The pores are arranged in a hexagonal net over both raised and depressed sectors, about 18 to 20 pores in 10 μm along the row, slightly more closely spaced in the depressed sectors. On the inside of the valve is a distinctly raised rim around each pore.

Central area hyaline, warped at margins to attach to undulating sectors. It is subpolygonal in outline and does not extend into the sectored part of the valve.

*Discussion.*—The specific name *aequalis* is given to this taxon because of the evenness of the pore pattern (both spacing and design) over both the raised and depressed sectors. All six-sectored specimens observed in this study have been assigned to *A. senarius* (Ehrenberg, 1838) Ehrenberg, 1843, although some of them show an evenness of pore pattern that approaches *A. aequalis.* What is considered to be *A. senarius* in this deposit frequently shows a variable placement in the labiate processes (see discussion of *A. senarius*), whereas *A. aequalis* as herein defined shows only the basic single labiate process centered on the shoulder of each raised sector. *A. aequalis* probably has evolved from *A. senarius,* but it is impossible to determine in a fossil assemblage whether or not these two morphologic species formed an interbreeding population.

*A. aequalis* was rare in the 18.3, 17.4, and 16.5 m (60, 57, and 54 ft) levels of the lower marine section, frequent in the 12.8 m (42 ft) and common in the 8.8 m (29 ft) (or uppermost) level. It was also common in the upper marine bed at the 4.6 m (15 ft) level. Specimens from the lower part of the lower marine section observed under the scanning electron microscope showed a more strongly developed external areolate net than did those from the top of the lower marine section. Whether this is an example of microevolution or a response to some undefined ecological factor is uncertain.

*Known geologic range.*—Not previously reported. Whether *A. aequalis* had a widespread distribution during the middle Miocene or whether it was restricted ecologically or geographically, perhaps even to this sedimentary basin, is not known. The species is most common in the assemblages that suggest deviation from normal marine ecological conditions.

*Holotype.*—USNM No. 372375 and USGS Diatom Catalog No. 3971-1 (Pl. 6, figs. 6, 7), diameter 57 μm. From USGS diatom locality 6469, the 8.8 m (29 ft) level (and uppermost studied sample) of the lower marine section, Oil-Dri fuller's earth pit, about 2 mi northwest of Ochlocknee, Thomas County, Georgia. The holotype is accessioned into the paleobotany collection located in the U. S. National Museum of Natural History, Washington, DC, 20560.

The holotype is deposited in the USGS diatom collection located in the U. S. National Museum of Natural History, Washington, DC. At such time as this collection ceases to be a working collection of the

U. S. Geological Survey, it will by law be formally accessioned to the U. S. National Museum.

**Actinoptychus marylandicus** Andrews
Plate 6, figures 8, 9

*Actinoptychus marylandicus* Andrews, 1976, p. 14, pl. 4, figs. 3–6; Andrews, 1978, p. 383, pl. 2, figs. 1, 2; Abbott and Andrews, 1979, p. 232, pl. 1, fig. 10.

*Description.*—Valve round, discoid, fragile, with margin often missing or poorly preserved. Main part of valve divided into sectors, usually about 14 to 18, alternately elevated and depressed, each group with distinctive fine markings. Group 1 (externally depressed, coarsely areolate sectors): single row of areolae at margin, succeeded inwardly by a narrow but distinct hyaline band; main part of sector covered with parallel rows of areolae, about 10 in 10 $\mu$m, normal to the margin and arranged in a quincuncial pattern; a bladelike hyaline area in the center of the sector extends from the hyaline central area about one-third to one-half the length of the sector; this bladelike hyaline area results from the absence of one to three rows of areolae in the center of the sector. Group 2 (externally elevated, finely punctate sectors): each sector has single labiate process centrally situated near the margin; main part of the sector covered with fine areolae, about 16 in 10 $\mu$m, arranged in a hexagonal pattern. Many specimens show a shorter, narrower hyaline blade analogous to the larger blades in alternate sectors. Central area hyaline, vaguely marked, warped near the margin to join alternate sectors on different planes.

*Discussion.*—This important marker species is similar in morphology to *A. virginicus* (Grunow *in* Van Heurck, 1883) Andrews, 1976, except that the hyaline areas in the depressed sectors are bladelike rather than irregular. Rare in the 14.6 m (48 ft) level of the lower marine section.

*Known geologic range.*—Middle Miocene, reported by Andrews (1978) from unit 12 of the Calvert Formation through unit 20 of the Choptank Formation in Maryland. Reported by Abbott and Andrews (1979) from the Coosawhatchie Clay Member of the Hawthorn Formation.

**Actinoptychus senarius** (Ehrenberg) Ehrenberg
Plate 6, figures 14, 15; Plate 12, figures 1, 2

*Actinocyclus senarius* Ehrenberg, 1838, p. 172, pl. 21, fig. 6.
*Actinoptychus senarius* (Ehrenberg) Ehrenberg, 1843, p. 400, pl. 1, fig. 27; Hendey, 1937, pp. 271–272; Lohman, 1941, pp. 80–81, pl. 16, fig. 9; Hendey, 1964, p. 95, pl. 23, figs. 1, 2; Andrews, 1976, p. 15, pl. 4, figs. 7, 8; Abbott and Andrews, 1979, p. 232, pl. 1, fig. 11; Andrews, 1980, p. 24, pl. 1, fig. 3.
*Actinoptychus undulatus* (Bailey) Ralfs. Hustedt, 1929, pp. 475–478, fig. 264.

*Description.*—Valve round, discoid, divided into 6 sectors, alternately elevated and depressed, each group showing different markings. Group 1 (externally depressed, coarsely areolate sectors): surface completely and regularly covered with a hexagonal network of fine areolae, about 17 in 10 $\mu$m. This layer is overlain by an indistinct net of larger hexagonal areolae, about four in 10 $\mu$m; each sector has a minimum of one labiate process on the margin of the valve at the center of the sector, and there may be others on the valve as indicated in the discussion below. Central area hyaline, vaguely marked, warped near margin to join alternate sectors on different planes.

*Discussion.*—Frequent throughout the lower marine section and rare in the upper marine bed. This species is the basic six-sectored form of *Actinoptychus,* which could perhaps be divided after further study. The long-ranging basic form shows a single internal labiate process centered on the margin of each externally raised sector. Specimens observed under the scanning electron microscope in this deposit show the following forms: (1) the basic form, having a single central labiate process on each raised sector; (2) a variety having an addition, inconsistently, of a single labiate process near the edge of the raised sectors; (3) a variety in which each raised sector shows three labiate processes, one central, one near each edge; (4) a variety that has, in addition to processes shown by variety three, the irregular occurrence of a single labiate process, not centered, in the depressed sectors; (5) the most advanced variety, having three labiate processes on each raised sector, two on each depressed sector, all subevenly distributed around the margin of the valve. These variations in placement of the labiate processes are reminiscent of those reported for *Actinoptychus heliopelta* Grunow *in* Van Heurck, 1883 by Andrews (1979). These variations are thought to represent only variation in a population and not to be of taxonomic significance.

*Known geologic range.*—Cretaceous to Recent (common in cool coastal waters of modern oceans). Common in the Neogene deposits of the southeastern United States.

**Actinoptychus thumii** (Schmidt) Hanna

*Actinoptychus stella* var. *thumii* Schmidt, 1886, pl. 90, figs. 3–5; Pantocsek, 1886, pt. 1, pp. 65–66, pl. 8, fig. 65.
*Actinoptychus thumii* (Schmidt) Hanna, 1932, p. 171, pl. 4, figs. 3, 4; Andrews, 1978, pp. 383–384, pl. 3, figs. 8, 9.

*Description.*—Valve round, discoid, divided into six alternately elevated and depressed sectors. The crimping of the valve is relatively sharp and deep. The whole valve has a stellate pattern of ornamentation, often not readily observed because of the disparity of focus in alternate sectors. Outer margin of valve has a narrow band of very fine areolate structure. Group 1 sectors (externally depressed): more coarsely marked than alternate sectors, with a triangular area covered with areolae arranged in a hexagonal pattern, about 22 in 10 μm, completely surrounded by a hyaline band about 2 μm wide. Group 2 sectors (externally elevated): covered with very fine areolae; a single prominent labiate process occurs in the center of its punctate rim segment; a narrow hyaline ray extends from area of labiate process to central area. Central area hyaline, about one-sixth width of valve.

*Discussion.*—Rare in the upper marine bed.

*Known geologic range.*—Reported by Andrews (1978) from lithologic unit 14 of the Calvert Formation in Maryland. Early middle Miocene age.

**Actinoptychus virginicus** (Grunow) Andrews

*Actinoptychus vulgaris* var. *virginica* Grunow *in* Van Heurck, 1883, pl. 121, fig. 7.
*Actinoptychus virginicus* (Grunow) Andrews, 1976, p. 15, pl. 4, figs. 9–12; Andrews, 1978, p. 384, pl. 2, figs. 2–5; Abbott and Andrews, 1979, pp. 232–233, pl. 1, fig. 12.

*Description.*—Valve round, discoid, fragile, with margin often missing or poorly preserved. Main part of valve divided into sectors, usually about 10 to 18, alternately elevated and depressed, each group showing different fine markings. Group 1 (externally depressed, coarsely areolate sectors): single row of areolae at margin, succeeded inwardly by a narrow but distinct hyaline band; main part of sector covered with parallel rows of areolae, about 10 in 10 μm, normal to the margin and arranged in a quincuncial pattern; an irregular hyaline area occurs in the center of each sector, seemingly an extension of the hyaline central area of the valve. Group 2 (externally elevated, finely areolate sectors): main part of sector covered with fine pores, about 16 in 10 μm, arranged in a hexagonal pattern; small bladelike hyaline extensions usually not present, or much less noticeable than in *A. marylandicus* Andrews, 1976; a single labiate process is centrally situated near the margin. Central area hyaline, vaguely marked, warped near the margin to join alternate sectors on different planes.

*Discussion.*—Although *A. virginicus* is usually more frequent than the related species *A. marylandicus* in Miocene deposits of the southeastern United States, here only a rare occurrence was found by Abbott in sample FE 104 at approximately the 13.1 m (43 ft) level of the lower marine section.

*Known geologic range.*—Middle Miocene, from the lower part of lithologic unit 13 of the Calvert Formation to at least the top of the Choptank Formation in Maryland (Andrews, 1978).

Genus **AMPHIPRORA** Ehrenberg, 1843

**Amphiprora** aff. **A. alata** (Ehrenberg) Kützing
Plate 6, figure 16

*Navicula alata* Ehrenberg, 1840, p. 212.
*Amphiprora alata* (Ehrenberg) Kützing, 1844, p. 107, pl. 3, fig. 63; Hustedt, 1930a, p. 340, fig. 625; Hendey, 1964, p. 253, pl. 39, figs. 14–16.

*Description.*—Valves linear, constricted in middle and twisted. Raphe enclosed in axial area raised to form a sigmoid keel. Surface of valve covered with rows of fine areolae with a primary longitudinal and secondary transverse orientation. Keel coarsely punctate.

*Discussion.*—Observed as rare in the 18.3 m (60 ft) level of the lower marine section. It appears to be close to *A. alata,* but absolute identification could not be made.

*Known geologic range.*—Not previously reported as a fossil species. Common in modern coastal waters having lowered salinity.

Genus **ANAULUS** Ehrenberg, 1844

**Anaulus birostratus** (Grunow) Grunow

*Biddulphia birostrata* Grunow, 1863, p. 158, pl. 13, fig. 23.
*Anaulus birostratus* (Grunow) Grunow *in* Van Heurck, 1882, pl. 103, figs. 1–3; Hustedt, 1930, p. 893, fig. 536; Abbott and Andrews, 1979, p. 233, pl. 1, fig. 13.

*Description.*—Valve fusiform, elongate, with slightly concave lateral margins. Ends subrostrate, attenuate, with bluntly rounded apices. Two transverse septa divide the valve into three chambers of subequal length, and maximum widths of valve are near crossing points of these septa. Valve surface covered with randomly distributed pores. A single internal labiate process is slightly off center in the central chamber.

*Discussion.*—Observed as rare by Abbott in sample FE 104 at approximately the 13.1 m (43 ft) level of the lower marine section.

*Known geologic range.*—Reported by Abbott and Andrews (1979) from the middle Miocene Coosawhatchie Clay Member of the Hawthorn Formation. This benthonic species is common in coastal environments of the warmer modern oceans.

Genus **AULACODISCUS** Ehrenberg, 1844

**Aulacodiscus argus** (Ehrenberg) Schmidt
Plate 7, figure 1

*Tripodiscus argus* Ehrenberg, 1841, p. 159, pl. 3, fig. 6.
*Aulacodiscus argus* (Ehrenberg) Schmidt, 1886, pl. 107, fig. 4; Rattray, 1888a, p. 373; Hustedt, 1929, pp. 503–505, fig. 281; Lohman, 1948, p. 171; Hendey, 1964, p. 97; Andrews, 1980, pp. 24–25.

*Description.*—Valves round, surface flat to slightly convex, completely covered with a coarse network of angular areolae that overlies a lower lamina with much finer pores. The valve appears to be heavy and dense and the areolation pattern is distinctive. Two to six processes are subequally spaced near the margin of the valve. Their external expression is as a siliceous tube, which is presumably connected to a labiate process on the inside of the valve.

*Discussion.*—Usually occurring as distinctive fragments; rare to frequent in the lower marine section and frequent in the upper marine bed.

*Known geologic range.*—Miocene to Holocene. A widespread neritic occurrence around the North Atlantic Ocean.

Genus **AULACOSIRA** Thwaites, 1848

**Aulacosira italica** (Ehrenberg) Simonsen
Plate 6, figure 17

*Gaillonella italica* Ehrenberg, 1838, p. 171, pl. 10, fig. 6.
*Aulacosira italica* (Ehrenberg) Simonsen, 1979, p. 55.
*Melosira italica* (Ehrenberg) Kützing, 1844, p. 55, pl. 2, fig. 6; Hustedt, 1927, pp. 257–262, fig. 109; Lohman and Andrews, 1968, p. E12, pl. 1, fig. 6; Andrews, 1970, p. A9, pl. 1, fig. 4; Andrews, 1971, p. E8, pl. 1, figs. 1, 2.

*Description.*—Valves cylindrical, bound in chains of frustules, usually greater in height than in diameter, so consequently more commonly seen in girdle view. Mantle finely areolate, about 14 areolae in 10 μm, arranged in longitudinal or slightly spiral rows, about 16 in 10 μm. Denticulate processes on face of valve link adjoining frustules.

*Discussion.*—The only distinctly freshwater taxon observed in these marine deposits. Rare in the 10.4 m (34 ft) level of the lower marine section; the diatom assemblage at this level seems to be affected by lower salinity. *A. italica* in this assemblage may well have been washed in from a freshwater environment.

*Known geologic range.*—Reported from deposits as old as early Miocene by Andrews (1971). A common and widespread pelagic form in modern freshwater environments.

Genus **AULISCUS** Ehrenberg, 1843

**Auliscus sculptus** (Smith) Ralfs
Plate 7, figures 2, 3

*Eupodiscus sculptus* Smith, 1853, p. 25, pl. 4, fig. 42.
*Auliscus sculptus* (Smith) Ralfs *in* Pritchard, 1861, p. 845; Greville, 1863, pp. 43–44, pl. 3, figs. 1–3; Rattray, 1888b, p. 883; Hustedt, 1929, pp. 516–518, fig. 290; Hendey, 1964, pp. 98–99, pl. 23, fig. 4.
*Auliscus caelatus* Bailey, 1854, p. 6, pl. 1, figs. 3, 4; Ralfs *in* Pritchard, 1861, p. 845; Greville, 1863, pp. 44–45, pl. 2, figs. 4–7; Hustedt, 1929, pp. 518–522, figs. 291–295.

*Description.*—Valves nearly circular to broadly elliptical. Two large, slightly produced ocelli located near the margin on a line slightly oblique to the longitudinal axis. Surface of valve ornamented with costae or thickenings radiating from the margin of the valve and from the ocelli to a distinct, rounded, hyaline central area.

*Discussion.*—Observed as rare in the 14.6 and 18.3 m (48 and 60 ft) levels of the lower marine section.

*Known geologic range.*—Not previously reported as a fossil species. Common in modern temperate coastal waters.

Genus **BIDDULPHIA** Gray, 1821

**Biddulphia aurita** (Lyngbye) Brébisson
Plate 7, figure 4

*Diatoma auritum* Lyngbye, 1819, p. 182, pl. 62, fig. D.
*Biddulphia aurita* (Lyngbye) Brébisson, 1838, p. 12; Hustedt, 1930, pp. 846–849, fig. 501; Hendey, 1964, p. 103, pl. 24, fig. 6; Abbott and Andrews, 1979, p. 233, pl. 2, fig. 1.

*Description.*—Valves elliptical-lanceolate in outline, convex in center and showing a single prominent horn on each end. Entire surface of valve, including horns, covered with large areolae, arranged in rows radiating from the center of the valve. Two or more long spines project from the raised center of the valve.

*Discussion.*—Rare and infrequent in the lower marine section and rare in the upper marine bed. Sometimes difficult to distinguish from *Triceratium spinosum* Bailey, 1844, in girdle view under the light microscope.

*Known geologic range.*—Reported by Abbott and Andrews (1979) from the Coosawhatchie Clay Member of the Hawthorn Formation (middle Miocene). Common in modern shallow coastal waters.

**Biddulphia tuomeyi** (Bailey) Roper
Plate 7, figures 5–8

*Zygoceros tuomeyi* Bailey, 1844, p. 138, pl. 3, figs. 3–9.
*Biddulphia tuomeyi* (Bailey) Roper, 1859, p. 8, pl. 1, figs. 1, 2; Grunow *in* Van Heurck, 1882, pl. 98, figs. 2, 3; Hustedt, 1930, pp. 834–836, fig. 491; Lohman, 1948, p. 174; Andrews, 1976, p. 17, pl. 5, fig. 11; Abbott and Andrews, 1979, p. 234, pl. 2, fig. 4; pl. 6, fig. 8; Andrews, 1980, pp. 25–26, pl. 1, figs. 10, 11; pl. 4, fig. 5.

*Description.*—Girdle view of valve shows base slightly extended beyond main part of valve, which consists of a large bulbous central process, two to eight smaller domed lateral processes and two elongate, tubular apical processes with closed ends. Surface of valve covered sparingly with large areolae, arranged radially on the bulbous central process but with near random distribution elsewhere. Mantle of valve covered with rows of fine areolae normal to the valve margin. The ends of the central process may show several protruding spine-like structures.

*Discussion.*—Rare to frequent in the lower marine section and frequent in the upper marine bed. Many specimens show four or more lateral bulbous processes, and a few show remnants of a finely punctate siliceous membrane, draped marginally between the tubular apical processes. This membrane is rarely observed in fossil specimens.

*Known geologic range.*—Cretaceous to Holocene, according to Lohman (1948). Occurs with varying frequency throughout the Neogene deposits of the southeastern United States. Frequent in modern coastal waters of warmer oceans and ranges into brackish environments.

## Genus **COSCINODISCUS** Ehrenberg, 1838

### **Coscinodiscus asteromphalus** Ehrenberg

*Coscinodiscus asteromphalus* Ehrenberg, 1844, p. 77; Hustedt, 1928, pp. 452–454, fig. 250; Hendey, 1964, p. 78, pl. 24, fig. 2; Abbott and Andrews, 1979, p. 235, pl. 2, fig. 8.

*Description.*—Observed only as fragmental material. The large size of the disk, central rosette, coarse areolae and the secondary structures within the areolae are sufficient to identify the species.

*Discussion.*—Observed as rare by Abbott in sample FE 104 at approximately the 13.3 m (43 ft) level of the lower marine section.

*Known geologic range.*—Frequently observed as fragments in Miocene to Holocene deposits of the southeastern United States and elsewhere. This planktonic species has a worldwide distribution in modern oceans.

### **Coscinodiscus curvatulus** Grunow
Plate 7, figure 9

*Coscinodiscus curvatulus* Grunow *in* Schmidt, 1878, pl. 57, fig. 33; Hustedt, 1928, pp. 406–410, fig. 214; Lohman, 1941, p. 74, pl. 15, fig. 8; Lohman, 1948, p. 160; Hendey, 1964, p. 81; Andrews, 1976, p. 10, pl. 2, fig. 4; Abbott and Andrews, 1979, p. 236, pl. 2, fig. 12; Andrews, 1980, p. 27, pl. 4, fig. 4.

*Description.*—Valve round, flat, divided into about 11 to 12 curved sectors. Each sector defined by a curved row of areolae extending from margin to center, the remainder of the sector filled by progressively shorter rows of areolae, decreasing in length toward the margin of the adjacent sector. About five to six areolae in 10 μm, arranged in curved radial rows as well as secondarily in a decussating pattern. No distinct central area. Narrow marginal rim finely areolate, about 12 areolae in 10 μm.

*Discussion.*—Rare in some samples from the lower marine section.

*Known geologic range.*—Throughout the Neogene deposits of the southeastern United States; a frequent pelagic form in modern oceans.

### **Coscinodiscus decrescens** Grunow

*Coscinodiscus decrescens* Grunow *in* Schmidt, 1878, pl. 61, figs. 8, 9; Rattray, 1889, p. 525; Hustedt, 1928, p. 430, fig. 233; Hendey, 1964, p. 77; Abbott and Andrews, 1979, p. 236, pl. 2, fig. 12.

*Description.*—Valves round, markedly convex, covered with a coarse areolate net. Areolae arranged in a crudely spiral arrangement emanating from the center of the valve. About four areolae in 10 μm near the center, decreasing in size to about six in 10 μm near the margin. No central area or rosette. A few fine pores are scattered randomly in the areolate net.

*Discussion.*—Observed by Abbott as frequent in sample FE 101, at approximately the 16.7 m (55 ft) level of the lower marine section.

*Known geologic range.*—Reported from the Coosawhatchie Clay Member of the Hawthorn Formation by Abbott and Andrews (1979); hence, at least as old as middle Miocene to modern cool-water marine environments.

### **Coscinodiscus gigas** var. **diorama** (Schmidt) Grunow

*Coscinodiscus diorama* Schmidt, 1878, pl. 64, fig. 2.
*Coscinodiscus gigas* var. *diorama* (Schmidt) Grunow, 1884, p. 76; Rattray, 1889, p. 542; Abbott and Andrews, 1979, pp. 236–237, pl. 2, fig. 14.

*Description.*—Valve round, large, slightly convex. Valve ornamented with wavy radial rows of areolae near the center, becoming more closely packed into an areolate net a short distance out, and so extending to the margin. About seven areolae in 10 μm near the center, increasing in size to about three-and-one-half in 10 μm near the margin. Margin with rows of fine areolae. Areolate net predominantly oriented in radial rows with a much less prominent secondary orientation in wavy decussating rows. Central area hyaline; short hyaline rays extend outward between rows of pores.

*Discussion.*—*C. gigas* var. *diorama* was observed as rare by Abbott in samples FE 101, FE 103 and FE 104 at the approximate 18.3, 13.7 and 13.1 m (60, 45 and 43 ft) levels of the lower marine section.

*Known geologic range.*—Reported by Rattray (1889) from the Miocene "Santa Monica" and "Monterey" diatom assemblages of California and by Abbott and Andrews (1979) from the middle Miocene Coosawhatchie Clay Member of the Hawthorn Formation. Not reported in Holocene marine environments.

### **Coscinodiscus lacustris** Grunow
Plate 7, figure 10

*Coscinodiscus lacustris* Grunow *in* Cleve and Grunow, 1880, p. 114; Hustedt, 1928, pp. 432–433, fig. 235; Abbott and Andrews, 1979, p. 237, pl. 2, fig. 17.

*Description.*—Valve round, irregularly warped, markedly convex at margin. Valve covered with irregular radial rows of areolae, about 12 rows in 10 μm. Some areolae are elongate in a radial direction. Margin narrow, finely areolate, with irregularly placed small processes along its inner edge.

*Discussion.*—Rare in the 13.7 m (45 ft) level of the lower marine section.

*Known geologic range.*—Reported previously from rocks as old as Miocene by Abbott (1980), and widely observed in nonmarine fossil deposits of the Great Plains area. Apparently tolerates salinity ranging from shallow marine coastal waters and brackish waters into essentially freshwater environments.

### **Coscinodiscus marginatus** Ehrenberg

*Coscinodiscus marginatus* Ehrenberg, 1843, p. 329, 371; Ehrenberg, 1854, p. 18, fig. 44; pl. 33, XII, fig. 13; pl. 38, XXII, fig. 8; Hustedt, 1928, pp. 416–418, fig. 223; Hendey, 1964, p. 78, pl. 22, fig. 2; Andrews, 1976, p. 11, pl. 2, figs. 6, 7; Abbott and Andrews, 1979, p. 238, pl. 3, fig. 2.

*Description.*—Valve round, slightly convex. Surface of valve covered with a net of strong and large hexagonal areolae, about three-and-one-half in 10 μm. Areolae arranged irregularly in roughly radial rows and increasing in size toward the center from the margin. Prominent marginal rim covered with fine radial striae. Areolate net covers the center of the valve.

*Discussion.*—Observed as rare by Abbott in samples FE 102 and FE 104 and as frequent in sample FE 106 at levels of approximately 15.2, 13.1 and 10.7 m (50, 43 and 35 ft) respectively, of the lower marine section; he observed it as rare in sample FE 110 at a level of 4.6 m (15 ft) in the upper marine bed.

*Known geologic range.*—Cretaceous to Holocene, according to Abbott and Andrews (1979).

### **Coscinodiscus oculus-iridis** Ehrenberg

*Coscinodiscus oculus-iridis* Ehrenberg, 1841, p. 147; Ehrenberg, 1854, pl. 18, fig. 42; pl. 19, fig. 2; Hustedt, 1928, pp. 454–456, fig. 252; Hendey, 1964, p. 78; Andrews, 1976, p. 11, pl. 2, fig. 8; Abbott and Andrews, 1979, p. 238, pl. 3, fig. 4.

*Description.*—Valve round, large, flat. Marginal rim marked by short striae, about four to five in 10 μm. Main part of valve covered by areolae primarily ordered in radial rows and secondarily ordered in curved decussating rows. Areolae fill the valve surface by intercalation of progressively shorter radial rows toward the valve margin. About three areolae in 10 μm, but somewhat smaller near the margin. Center of valve shows a rosette of elongate radiating areolae.

*Discussion.*—Observed as rare in the 13.7 m (45 ft) level of the lower marine section. A large and fragile diatom, which may be easily broken and hence not readily identified.

*Known geologic range.*—Throughout the Tertiary into modern marine environments, according to Lohman (1948).

### **Coscinodiscus perforatus** Ehrenberg
Plate 7, figures 11–13

*Coscinodiscus perforatus* Ehrenberg, 1844, p. 78; Ehrenberg, 1854, pl. 18, fig. 46; Hustedt, 1928, pp. 445–449, fig. 245; Lohman, 1948, p. 163; Hendey, 1964, pp. 77–78; Andrews, 1976, p. 11, pl. 2, fig. 9; Abbott and Andrews, 1979, p. 239, pl. 3, fig. 5.

*Description.*—Valve round, flat, surface covered by areolae with a primary orientation in radial rows and a secondary orientation in curved decussating rows. Areolae fill the valve surface by intercalation of progressively shorter rows toward the valve margin, each row terminated centrally by a single small pore. Areolae for the most part distinctly round and not commonly squeezed into a polygonal shape by close packing. About six areolae in 10 μm at half-radius position, slightly finer near center and margin. A small hyaline central area is commonly present.

*Discussion.*—Rare to frequent in most samples from the lower marine section. Two of the specimens included herein (Pl. 7, figs. 11, 12) are small specimens that are somewhat atypical for the species. They resemble the form in the Petersburg assemblage (Andrews, 1980, p. 27, pl. 1, fig. 18) described as *Coscinodiscus nitidus* Gregory, 1857. This taxon has since been properly recognized as a pseudocentric diatom with affinities for *Rhaphoneis* Ehrenberg, 1845, and renamed as *Psammodiscus nitidus* (Gregory, 1857) Round and Mann, 1980. These Miocene forms are clearly a species of *Coscinodiscus* Ehrenberg, 1838, and they seem to be most closely allied to *C. perforatus.*

*Known geologic range.*—Miocene (Calvert Formation of Maryland) to Recent (common in modern marine environments).

### **Coscinodiscus perforatus** var. **cellulosus** Grunow
Plate 7, figure 14

*Coscinodiscus perforatus* var. *cellulosa* Grunow, 1884, p. 75; Hustedt, 1928, p. 447, fig. 246; Lohman, 1948, pp. 163–164, pl. 8, fig. 3; Andrews, 1976, p. 11, pl. 2, fig. 10; Abbott and Andrews, 1979, p. 239, pl. 3, fig. 6.

*Description.*—The variety *cellulosus* is similar to the typical variety, except that the areolae are polygonal in outline because of tight packing, rather than large discrete round openings.

*Discussion.*—Rare to frequent in the lower marine section.

*Known geologic range.*—Miocene to Holocene marine environments.

**Coscinodiscus rothii** (Ehrenberg) Grunow
Plate 7, figure 15; Plate 8, figure 1

*Heterostephania rothii* Ehrenberg, 1854, pl. 35A, XIIIB, figs. 4, 5.
*Coscinodiscus rothii* (Ehrenberg) Grunow, 1878, p. 125; Hustedt, 1928, pp. 400–406, fig. 211; Andrews, 1976, p. 12, pl. 3, figs. 1, 2; Abbott and Andrews, 1979, p. 239, pl. 3, fig. 9.

*Description.*—Valve round, concentrically undulate, raised upward from margin to an annular ring, but depressed in center. Surface of valve divided into many sectors, each defined by a relatively straight row of areolae from the margin to the center, then by progressively shorter rows to the edge of the adjacent sector. Areolae round, about seven in 10 $\mu m$ with a primary orientation in the subradial sectoral pattern and a secondary orientation in curved decussating rows. The center may have a narrow hyaline ring enclosing a few areolae.

*Discussion.*—Rare to frequent throughout the lower marine section. This species has obvious affinities for the genus *Actinocyclus* Ehrenberg, 1838, and indeed the varieties *normani* and *subsalsa* have been reclassified as *Actinocyclus normanii* and *A. normanii* forma *subsalsa* by Hustedt (1957a, pp. 218–220) and this classification has been confirmed by Hasle (1977). Both of these taxa show a definite pseudonodulus. With regard to *Coscinodiscus rothii* sensu stricto, Hustedt (1957a, p. 219), although he recognized the close similarity to *Actinocyclus* in morphology, examined many specimens of *C. rothii* and was unable to find the pseudonodulus necessary for its reclassification as *Actinocyclus.* Hence, I am retaining this diatom as a species of *Coscinodiscus,* recognizing that there are difficulties in separating some species of *Coscinodiscus* from *Actinocyclus* under the currently accepted classification.

*Known geologic range.*—From the lower to middle Miocene Calvert Formation of Maryland to Recent (common in modern marine environments).

**Coscinodiscus stellaris** Roper

*Coscinodiscus stellaris* Roper, 1858, p. 21, pl. 3, fig. 3; Hustedt, 1928, pp. 396–398, fig. 207; Lohman, 1941, pp. 68–69, pl. 13, fig. 2; 1948, p. 164; Hendey, 1964, p. 81; Abbott and Andrews, 1979, p. 240, pl. 3, fig. 10.

*Description.*—Valves round, convex, thin. Surface of valve covered with a net of fine areolae in radial and curved decussating rows, warped in certain areas to produce irregularly sized fascicles. Irregularly shaped hyaline central area with about three to six extended arms, forming a roughly starlike pattern.

*Discussion.*—Observed as rare in sample FE 104 at approximately the 13.1 m (43 ft) level of the lower marine section.

*Known geologic range.*—Calvert Formation (lower to middle Miocene) of Maryland (Lohman, 1948); Coosawhatchie Clay Member of the Hawthorn Formation (middle Miocene) of South Carolina and Georgia (Abbott and Andrews, 1979). A common planktonic species with worldwide distribution in modern oceans.

**Coscinodiscus vetustissimus** Pantocsek

*Coscinodiscus vetustissimus* Pantocsek, 1886, pt. 1, p. 71, pl. 20, fig. 186; Hustedt, 1928, pp. 412–414, fig. 220; Lohman, 1938, p. 86, pl. 20, fig. 7; Andrews, 1976, p. 12, pl. 3, fig. 3; Abbott and Andrews, 1979, p. 240, pl. 3, fig. 11.

*Description.*—Valve round, flat. Surface covered with areolae, closely packed in a polygonal net; about five areolae in 10 $\mu m$. Areolate net has a primary radial orientation and a poorly defined secondary orientation in curved decussating rows. Areolate net is fasciculate, dividing the valve into many ill-defined sectors, each limited by a relatively straight row of areolae from margin to center, then by progressively shorter parallel rows to edge of adjacent sector. The center of the valve contains a small cluster of areolae surrounded by an irregular hyaline ring. Margin of valve finely striate, about 12 in 10 $\mu m$.

*Discussion.*—Observed by Abbott as rare in samples FE 101, FE 104, and FE 106 at the approximate 16.8, 13.1 and 10.4 m (55, 43 and 34 ft) levels of the lower marine section.

*Known geologic range.*—Middle Miocene to Pliocene, according to Abbott and Andrews (1979).

Genus **CYMATOGONIA** Grunow, 1883

**Cymatogonia amblyoceros** (Ehrenberg) Hanna
Plate 8, figures 2, 3

*Triceratium amblyoceros* Ehrenberg, 1844, p. 88; Ehrenberg, 1854, pl. 18, fig. 51.
*Cymatogonia amblyoceros* (Ehrenberg) Hanna, 1932, p. 186, pl. 10, fig. 5; Lohman, 1948, pp. 170–171, pl. 9, fig. 7; Abbott and Andrews, 1979, p. 241, pl. 3, fig. 16.
*Actinoptychus amblyoceros* (Ehrenberg) Schmidt, 1874, pl. 1, fig. 25.

*Description.*—Valve triangular with broadly rounded corners. Surface undulatory between six sectors, alternate sectors on the same plane. Sectors ornamented with rows of fine areolae, about 13 to 14 in 10 $\mu m$, arranged in a hexagonal pattern. A labiate process occurs at one side of the bisector of each angle and close to the margin. Narrow marginal area depressed and marked by somewhat finer pore structure. Hyaline central area irregular in size and shape, commonly roughly triangular.

*Discussion.*—Generally rare in the lower marine section and in the upper marine bed. An excellent marker fossil because it can be identified from any fragment showing the small hyaline central area.

*Known geologic range.*—Although this distinctive species is widely known, its precise range within the Miocene has yet to be determined. Hanna (1932) has stated that it is not known from late Miocene or younger deposits. Lohman (1948) reported the species from the Calvert Formation (lower to middle Miocene) of Maryland and Abbott and Andrews (1979) reported it from the Coosawhatchie Clay Member of the Hawthorn Formation (middle Miocene).

### Genus **CYMATOSIRA** Grunow, 1862

#### **Cymatosira belgica** Grunow
Plate 8, figures 4, 5

*Cymatosira belgica* Grunow *in* Van Heurck, 1881, pl. 45, figs. 38–41; Hustedt, 1931, pp. 127–128, fig. 649; Hendey, 1964, p. 160.

*Description.*—Valve linear-lanceolate with small, slightly produced, rounded apices. Valve surface with short, irregularly transverse rows of areolae. Hyaline central area is indistinct. Margin of valve with small spines, about seven in 10 $\mu$m, projecting normal to the plane of the valves.

*Discussion.*—The specimens observed in this study show pores scattered throughout the central area and lack the small circular hyaline area at the center of the valve. Hence, they seem to be more closely conformable to *C. belgica* than to *C. biharensis* Pantocsek, 1889. *C. belgica* is frequent throughout the lower marine section and rare in the upper marine bed.

*Known geologic range.*—Not previously reported as fossil, though a related form, *Cymatosira* aff. *C. biharensis,* was found in the Coosawhatchie Clay Member of the Hawthorn Formation by Abbott and Andrews (1979). *C. belgica* is a common littoral species in temperate oceans.

#### **Cymatosira immunis** (Lohman) Abbott
Plate 8, figure 6

*Rhaphoneis immunis* Lohman, 1948, p. 182, pl. 11, fig. 6; Andrews, 1975, p. 215, pl. 3, figs. 45, 46.
*Cymatosira immunis* (Lohman) Abbott *in* Abbott and Andrews, 1979, p. 242, pl. 3, fig. 18.

*Description.*—Valve flat, lanceolate with attenuate apices. A single row of areolae alternate with spinose marginal processes, oriented perpendicular to the plane of the valves. These spinose marginal processes have T-shaped ends and interlock with similar processes on the adjacent valve in a chain of frustules, forming a positive yet flexible connection. About eight marginal areolae and eight intercalated processes in 10 $\mu$m along the margin. A second row of areolae, about six in 10 $\mu$m, lies parallel to and inside the marginal row and shows no ordered relationship to the marginal row. Hyaline axial area lanceolate, filling the center of the valve but not extending toward the attenuate apices.

*Discussion.*—This distinctive species with its single row of marginal pores is rare in the 12.8 and 18.3 m (42 and 60 ft) levels of the lower marine bed.

*Known geologic range.*—Lower to middle Miocene of the Calvert Formation of Maryland (Lohman, 1948); observed by Abbott in the Pungo River Formation of North Carolina; in the Coosawhatchie Clay Member of the Hawthorn Formation (Abbott and Andrews, 1979).

#### **Cymatosira lorenziana** Grunow
Plate 8, figures 7, 8

*Cymatosira lorenziana* Grunow, 1862, p. 378, pl. 4, fig. 25; Grunow *in* Van Heurck, 1881, pl. 45, fig. 42; Hustedt, 1931, p. 127, fig. 648.

*Description.*—Valve small, flat, rounded-lanceolate with long narrowly protracted apices. Surface of valve covered with relatively large round areolae, about four in 5 $\mu$m, with a primary orientation in continuous transverse rows and a secondary orientation parallel to the margin of the valve. No hyaline central or axial areas.

*Discussion.*—A small but distinctive species, observed as rare in the 18.3 m (60 ft) level of the lower marine section.

*Known geologic range.*—Reported by Schrader and Fenner (1976) from lower Miocene deposits in the Norwegian Sea. A common coastal form in Recent warmer marine waters.

### Genus **DEBYA** Pantocsek, 1886

#### **Debya insignis** Pantocsek
Plate 12, figure 3

*Debya insignis* Pantocsek, 1886, p. 65, pl. 29, fig. 298; Pantocsek, 1889, p. 109; Hendey, 1964, p. 95, pl. 22, fig. 4.

*Description.*—Valve round, with three low subrounded external swellings. Surface of valve covered by a network of very fine areolae, overlain on the exterior by a coarser network of faint siliceous ribbing. The three subrounded swellings are separated by three depressed rays extending from the center to the margin. A single labiate process is located near the marginal end of each depressed ray. The external pore connected to the labiate process shows a raised rim on the surface of the valve.

*Discussion.*—Hendey (1964, p. 95) stated that *Debya insignis* is an auxospore valve of *Actinoptychus senarius* (Ehrenberg, 1838) Ehrenberg, 1843; we agree that he is most probably correct. The affinities of *D. insignis* for *A. senarius* are obvious. However, a single labiate process is located marginally from the end of each *depressed* ray, in contrast to the normal condition of *A. senarius,* in which a single labiate process is centered on the margin of each externally *raised* sector. *Debya* *insignis* was noted only in scanning electron microscope preparations from a sample near the base of the lower marine section.

*Known geologic range.*—Originally described by Pantocsek (1886) from a Miocene deposit in Hungary. Presumably its range is the same as that of *Actinoptychus senarius.*

Genus **DELPHINEIS** Andrews, 1977

**Delphineis angustata** (Pantocsek) Andrews
Plate 8, figures 9, 10

*Rhaphoneis angustata* Pantocsek, 1886, pt. 1, p. 33, pl. 11, fig. 97; pl. 30, fig. 313; Lohman, 1948, pp. 180–181, pl. 11, fig. 11; Lohman, 1974, p. 352, pl. 5, fig. 14; Andrews, 1975, pp. 203–204, pl. 1, figs. 5, 6; Andrews, 1976, p. 20, pl. 7, figs. 1, 2.
*Delphineis angustata* (Pantocsek) Andrews, 1977, pp. 250–251, pl. 1, figs. 1–4; pl. 2, figs. 21, 23; pl. 3, figs. 29, 30; Andrews, 1978, pp. 389–390, pl. 5, figs. 1, 2; pl. 8, figs. 1, 2; Abbott and Andrews, 1979, p. 242, pl. 4, fig. 1.

*Description.*—Valve linear and elongate, tapering only slightly from near center to bluntly rounded apices. Transverse striae short, five in 10 $\mu$m, consisting of external grooves with two areolae. Pores are secondarily arranged in longitudinal rows. Transverse striae parallel for almost the length of the valve, slightly radiate near the apices, and fine apical striae curve completely around the ends of the valve. Pairs of transverse striae are well aligned across the hyaline axial area. Apical ornamentation consists of two very fine pores penetrating each end of the valve and single internal labiate processes arranged diagonally to the longitudinal axis.

*Discussion.*—A distinctive marker diatom, which is rare in the 10.4, 12.8, and 15.5 m (34, 42, and 51 ft) levels of the lower marine section.

*Known geologic range.*—Reported by Andrews (1978) to range from the lower part of unit 13 of the Calvert Formation to the upper part of unit 19 of the Choptank Formation, middle Miocene of Maryland. Occurs in the Coosawhatchie Clay Member of the Hawthorn Formation (Abbott and Andrews, 1979).

**Delphineis novaecaesaraea**
(Kain and Schultze) Andrews
Plate 8, figure 14

*Dimeregramma novaecaesaraea* Kain and Schultze, 1889, p. 74, pl. 89, figs. 1, 1b; Lohman, 1948, pp. 184–185, pl. 11, figs. 4, 5.
*Delphineis novaecaesaraea* (Kain and Schultze) Andrews, 1977, pp. 251–252, pl. 1, figs. 8–11; pl. 2, figs. 23, 24; pl. 3, figs. 31, 32; Andrews, 1978, p. 392, pl. 5, figs. 9–11; pl. 8, fig. 7; Abbott and Andrews, 1979, pp. 242–243, pl. 4, fig. 3; pl. 7, figs. 5, 6.

*Description.*—Valve linear, usually having a slight expansion in the center and slightly to distinctly inflated acute apices. Transverse striae short, seven to eight in 10 $\mu$m, formed by external grooves with two areolae at the base. Striae parallel, becoming radiate near the apices, where they grade imperceptibly into finer apical striae around the ends of the valve. Hyaline axial area about 2.5 to 3 $\mu$m in width, and pairs of striae are aligned across it. Two very fine pores are found on each end of the valve as well as single internal labiate processes oriented diagonally to the longitudinal axis.

*Discussion.*—A distinctive marker diatom having readily identifiable inflated acute apices. Observed as rare only in the 16.5 m (54 ft) level of the lower marine section.

*Known geologic range.*—Middle Miocene, reported by Andrews (1978) from the middle of unit 12 of the Calvert Formation to the middle of unit 18 of the Choptank Formation in Maryland. Further study has suggested to Andrews that the species may range at least as high as unit 19 of the Choptank Formation. Also reported by Abbott and Andrews (1979) from the Coosawhatchie Clay Member of the Hawthorn Formation.

**Delphineis penelliptica** Andrews
Plate 8, figures 11–13; Plate 13, figure 1

*Delphineis penelliptica* Andrews, 1977, pp. 253–254, pl. 1, figs. 16–20; pl. 2, figs. 27, 28; pl. 4, figs. 35, 36; Andrews, 1978, pp. 395–396, pl. 5, figs. 15–17; pl. 8, fig. 8.

*Description.*—Valve elliptical-lanceolate to lanceolate with lateral margins tapering with but slight curvature toward rounded apices. Transverse striae contain three or four areolae near the center, but only one or two near the apices. About five-and-one-half to seven transverse striae in 10 $\mu$m, parallel in the center, but becoming slightly radiate and finer near the apices. Fine apical striae curve around the ends of the valve. Hyaline axial area narrow, up to only about 1 $\mu$m in width, and pairs of transverse striae are well aligned across it. Apical ornamentation consists of two fine pores penetrating the valve and single internal labiate processes arranged diagonally to the longitudinal axis.

*Discussion.*—A distinctive marker fossil, which is rare to frequent throughout the lower marine section.

*Known geologic range.*—Lower to middle Miocene. From the top of unit 9 of the Calvert Formation to the middle of unit 16 of the Choptank Formation of Maryland (Andrews, 1978).

Genus **DENTICULOPSIS** Simonsen, 1979

**Denticulopsis nicobarica** (Grunow) Simonsen

*Denticula nicobarica* Grunow, 1870, p. 97, pl. 1A, fig. 5; Grunow *in* Van Heurck, 1881, pl. 49, fig. 3; Simonsen and Kanaya, 1961, p. 503, pl. 1, figs. 11–13; Schrader, 1973a, p. 705, pl. 1, figs. 31–35; Schrader, 1973b, pp. 419–420, pl. 1, figs. 25–27.
*Denticulopsis nicobarica* (Grunow) Simonsen, 1979, p. 65.

*Description.*—Valves narrowly linear to linear-elliptical with bluntly rounded ends. Four to five pseudosepta in 10 μm with intercalated short riblike wall thickenings that extend from valve edge to raphe, about 16 in 10 μm. Secondary pseudosepta not present. Transverse rows of coarse areolae, about 16 in 10 μm, arranged in quincuncial pattern. Raphe marginal.

*Discussion.*—Observed as rare by Abbott in sample FE 105 at approximately the 12.2 m (40 ft) level in the lower marine section.

*Known geologic range.*—Reported by Schrader (1973b) from North Pacific Diatom Zones 20 through 24, approximately early middle Miocene in age. Gombos (1975) observed this species in Pacific deposits from early Miocene to late middle Miocene in age.

Genus **DIPLONEIS** Ehrenberg, 1840

**Diploneis bombus** (Ehrenberg) Cleve

*Pinnularia* (*Diploneis*) *bombus* Ehrenberg, 1844, p. 84.
*Diploneis bombus* (Ehrenberg) Cleve, 1894, p. 90; Hustedt, 1937, pp. 704–709, fig. 1086; Hendey, 1964, p. 227, pl. 32, fig. 2; Abbott and Andrews, 1979, p. 243, pl. 4, fig. 6.

*Description.*—Valve panduriform with central constriction dividing the valve into two suborbicular or elliptical segments. Hyaline central area longitudinally rectangular, extending into horns that enclose the raphe. The horns diverge in the middle of each segment but converge toward the apices. Valve surface covered with transverse rows of areolae alternating with costae, about eight in 10 μm. The areolae show a secondary orientation in longitudinal rows.

*Discussion.*—Observed as rare by Abbott throughout the lower marine section.

*Known geologic range.*—Reported by Abbott and Andrews (1979) from the middle Miocene Coosawhatchie Clay Member of the Hawthorn Formation. A common species in modern coastal waters.

**Diploneis crabro** (Ehrenberg) Ehrenberg
Plate 8, figures 15, 16

*Pinnularia* (*Diploneis*) *crabro* Ehrenberg, 1844, p. 85.
*Diploneis crabro* (Ehrenberg) Ehrenberg, 1854, pl. 19, fig. 29; Cleve, 1894, pp. 100–102; Hustedt, 1937, pp. 616–626, fig. 1028; Hendey, 1964, p. 225, pl. 32, figs. 1, 3; Andrews, 1976, p. 23, pl. 7, figs. 22, 23; Abbott and Andrews, 1979, pp. 243–244, pl. 4, fig. 7.

*Description.*—Valve panduriform with elliptical-cuneate segments; apices obtusely rounded. Central nodule quadrate to slightly elongate longitudinally, extended to form siliceous horns on either side of the raphe. A row of large pores borders very narrow furrows. About seven transverse striae in 10 μm, radiate, consisting of double transverse rows of fine areolae alternating with costae.

*Discussion.*—A complex species, showing much variation in external outline. Frequent throughout the lower marine section and rare in the upper marine bed.

*Known geologic range.*—Lower to middle Miocene of Maryland to Recent (common in modern marine environments of high salinity); in the Coosawhatchie Clay Member of the Hawthorn Formation (Abbott and Andrews, 1979).

**Diploneis** aff. **D. suborbicularis** (Gregory) Cleve
Plate 8, figure 17

*Navicula smithii* var. *suborbicularis* Gregory, 1857, p. 487, pl. 9, fig. 17.
*Diploneis suborbicularis* (Gregory) Cleve, 1894, p. 81; Hustedt, 1937, pp. 612–613, fig. 1026; Hendey, 1964, p. 224.

*Description.*—Valve broadly elliptical or oblong elliptical with rounded apices and almost parallel sides. Central nodule quadrate, extended into two curved horns on either side of the raphe. Furrows linear, crossed by a faint continuation of the costae that ornament the valve surface. Costae about six to eight in 10 μm, parallel in the middle but radiating toward the apices.

*Discussion.*—This form seems to conform with *D. suborbicularis* in most respects, but the ends are somewhat more blunt than those shown in the figures of Hustedt (1937). Frequent in the 12.8 m (42 ft) level and rare in the 15.5 and 16.5 m (51 and 54 ft) levels of the lower marine section.

*Known geologic range.*—Not previously reported as a fossil. A common shallow marine species in Recent warm to temperate waters.

Genus **ENDICTYA** Ehrenberg, 1845b

**Endictya oceanica** Ehrenberg
Plate 8, figure 18

*Endictya oceanica* Ehrenberg, 1845b, p. 76; Ehrenberg, 1854, pl. 35A, XVIII, figs. 6, 7; Hustedt, 1928, pp. 297–299, fig. 136; Hendey, 1964, p. 82; Abbott and Andrews, 1979, p. 244, pl. 4, fig. 10.

*Description.*—Frustules cylindrical with large flat circular valves and a relatively wide perpendicular mantle. Observed in this deposit only as large mantle fragments with straight sides and covered with relatively fine areolae in transverse straight lines.

*Discussion.*—Occurs intermittently as rare fragments in the lower marine section and was observed in the upper marine bed.

*Known geologic range.*—Previously reported from the Coosawhatchie Clay Member of the Hawthorn Formation by Abbott and Andrews (1979). Widespread in modern oceans.

### Genus **GRAMMATOPHORA** Ehrenberg, 1841

**Grammatophora marina** (Lyngbye) Kützing
Plate 8, figure 20

*Diatoma marinum* Lyngbye, 1819, pl. 62A.
*Grammatophora marina* (Lyngbye) Kützing, 1844, p. 128, pl. 17, figs. XXIV, 1–6; pl. 18, figs. I, 1–5; Hustedt, 1931, pp. 43–44, fig. 569; Hendey, 1964, p. 170; Andrews, 1976, p. 22, pl. 7, figs. 14, 15; Abbott and Andrews, 1979, p. 245, pl. 4, fig. 14; Andrews, 1980, p. 30, pl. 2, fig. 14.

*Description.*—Valve elongate with bluntly rounded apices. Fine structure not usually preserved. Robust internal septa are nearly flat. Single elliptical central opening is the most striking feature of the valve.

*Discussion.*—Intermittently of rare occurrence in the lower marine section.

*Known geologic range.*—Miocene to Holocene; a benthic form common in modern oceans.

### Genus **GYROSIGMA** Hassall, 1845

**Gyrosigma** species
Plate 8, figure 19

*Description.*—Valve sigmoid-lanceolate tapering to narrowly rounded apices. Surface of valve covered with very fine areolae, arranged in both transverse and longitudinal rows. Raphe thin, in center of the valve through most of its length but skewed toward the concave sides of the sigmoidally flexed ends. Hyaline central area small, irregular in outline.

*Discussion.*—This form of *Gyrosigma* was rare in the 12.8 m (42 ft) level of the lower marine bed. It could not be readily identified with any described species, and the few specimens observed did not justify formal taxonomic treatment.

*Known geologic range.*—Until this form can be specifically identified, it must be considered as known only from this deposit.

### Genus **HEMIAULUS** Ehrenberg, 1844

**Hemiaulus ambiguus** Grunow

*Hemiaulus ambiguus* Grunow, 1884, p. 62, pl. 2, figs. 25, 26; Hustedt, 1930, pp. 876–877, fig. 520.

*Description.*—Valve irregularly elliptical-lanceolate with apices terminating in prominent horns, normal to the plane of the valves. Central part of valve shows a slight swelling. Valve surface covered with irregularly radiating rows of fine areolae, about nine to 10 in 10 μm, extending from the face of the valve to the mantle. Apical horns show a short curved spine on ends.

*Discussion.*—Observed by Abbott as rare in the 18.3 m (60 ft) and the 12.2 m (40 ft) levels and frequent in the 10.4 m (34 ft) level of the lower marine section.

*Known geologic range.*—Previously reported only from modern arctic marine environments.

**Hemiaulus bipons** (Ehrenberg) Grunow
Plate 8, figures 21, 22

*Zygoceros bipons* Ehrenberg, 1845a, p. 273.
*Hemiaulus bipons* (Ehrenberg) Grunow *in* Van Heurck, 1882, pl. 103, figs. 6–9; Lohman, 1948, p. 177, pl. 10, fig. 7; Lohman, 1974, p. 348.

*Description.*—Valve elliptical and moderately convex, with apices extended to a small sharp point. Surface of valve covered with large pores distributed irregularly. Length of observed specimens, 32 to 35 μm; width about 18 μm. Interior of valve has two transverse septa, each located about halfway between the center and respective ends of the valve. These septa are sometimes warped and not always oriented in an exactly transverse direction.

*Discussion.*—Intermittently rare in the lower marine section.

*Known geologic range.*—Lohman (1948) reported this species as occurring in the Miocene Calvert Formation of Maryland and ranging into modern arctic marine environments.

**Hemiaulus polymorphus** Grunow

*Hemiaulus polymorphus* Grunow, 1884, p. 66; Hustedt, 1930, pp. 880–881.

*Description.*—Valve usually oriented in girdle view, with a single slightly bulbous center and two prominent tubular apical horns. Bulbous central part divided from ends of valve by two internal transverse septa. Mantle and horns of valve covered with irregularly radial rows of areolae.

*Discussion.*—Observed by Abbott as frequent in sample FE 100 and rare in sample FE 104, approximately the 18.3 and 13.1 m (60 and 43 ft) levels, of the lower marine section.

*Known geologic range.*—A variety of *H. polymorphus* was reported by Grunow (1884) from lower Eocene deposits in Denmark and by Abbott and Andrews (1979) from the middle Miocene Coosawhatchie Clay Member of the Hawthorn Formation. It is known from modern arctic marine waters.

### Genus **HYALODISCUS** Ehrenberg, 1845b

**Hyalodiscus scoticus** (Kützing) Grunow
Plate 8, figure 23

*Cyclotella scotica* Kützing, 1844, p. 50, pl. 1, figs. 2, 3.
*Hyalodiscus scoticus* (Kützing) Grunow, 1879, p. 690, pl. 21, fig. 5; Hustedt, 1928, pp. 293–294, fig. 133; Hendey, 1964, p. 90; Andrews, 1980, pp. 30–31, pl. 2, fig. 11.

*Description.*—Valve round, convex, with center flattened or slightly depressed. Surface of valve shows a roughly circular umbilicus at about half the radius. Valve covered with fine areolae, but pattern and spacing were too fine to resolve under the light microscope. Narrow marginal rim is finely striate.

*Discussion.*—Rare throughout the lower marine section and frequent in the marine beds immediately above and below the nonmarine strata.

*Known geologic range.*—Reported by Andrews (1980) from the upper Miocene or lower Pliocene deposit at Petersburg, Virginia. Reported from Holocene marine and brackish-water environments.

## Genus **LIRADISCUS** Greville, 1865

### **Liradiscus bipolaris** Lohman
Plate 8, figure 24

*Liradiscus bipolaris* Lohman, 1948, p. 164, pl. 7, fig. 5; Abbott and Andrews, 1979, p. 245, pl. 4, fig. 19.

*Description.*—Valve oblong with broadly rounded ends, sometimes slightly concave along lateral margins. Surface of valve nearly flat, but showing two low raised areas from which radiate curved to linear anastomosing markings that form an irregular network. Interspaces between markings are hyaline.

*Discussion.*—Rare in the 16.5 m (54 ft) level of the lower marine section.

*Known geologic range.*—Originally described by Lohman (1948) from the lower to middle Miocene Calvert Formation of Maryland. Reported by Abbott and Andrews (1979) from the Coosawhatchie Clay Member of the Hawthorn Formation.

## Genus **LITHODESMIUM** Ehrenberg, 1840

### **Lithodesmium ehrenbergii** (Grunow) Forti
Plate 8, figure 25

*Triceratium* (*Ditylium*?) *ehrenbergii* Grunow *in* Van Heurck, 1883, pl. 115, figs. 7, 8.
*Lithodesmium ehrenbergii* (Grunow) Forti, 1912, p. 83; Forti, 1913, pp. 1613–1614.

*Description.*—Valve rounded-triangular with rounded obtuse angles. Surface of valve covered with radial rows of areolae, about 14 in 10 μm. Small irregular hyaline areas at the angles and a large irregular hyaline central area. Single large "punctum" at center of valve is probably a labiate process that cannot be resolved under the light microscope.

*Discussion.*—Rare in the 18.3 m (60 ft) level of the lower marine section.

*Known geologic range.*—Originally described by Grunow *in* Van Heurck, 1883 from the lower Miocene part of the Calvert Formation at Nottingham, Maryland. Reported by Forti (1912) from middle Miocene limestone in Italy.

### **Lithodesmium undulatum** Ehrenberg
Plate 8, figure 26

*Lithodesmium undulatum* Ehrenberg, 1841, p. 155, pl. 4, fig. 13; Grunow *in* Van Heurck, 1883, pl. 116, figs. 8–11; Hustedt, 1930, pp. 789–791, fig. 461; Hendey, 1964, p. 111, pl. 6, fig. 6; Abbott and Andrews, 1979, p. 246, pl. 4, fig. 21.

*Description.*—Valve triangular, each side with a median swelling forming an undulate margin. This median swelling is caused by a more or less circular central part of the valve being separated from the angles by indentations in the valve surface. Angles are bluntly rounded. Valve covered with radiate rows of areolae, about 10 rows in 10 μm. Valve mantle sharply deflected from surface and relatively wide. Small hyaline central area with a centered prominent "punctum", which is probably a labiate process that cannot be resolved under the light microscope.

*Discussion.*—Rare in the 18.3 m (60 ft) level of the lower marine section.

*Known geologic range.*—Reported by Abbott and Andrews (1979) from the middle Miocene Coosawhatchie Clay Member of the Hawthorn Formation. A common neritic species in warmer modern coastal waters.

## Genus **MELOSIRA** Agardh, 1824

### **Melosira westii** Smith
Plate 8, figure 27

*Melosira westii* Smith, 1856, p. 59, pl. 52, fig. 333; Hustedt, 1927, pp. 268–269, fig. 113; Hendey, 1964, p. 73, pl. 1, fig. 4; pl. 22, fig. 8; Andrews, 1976, p. 8, pl. 1, figs. 1, 2; Abbott and Andrews, 1979, p. 246, pl. 4, fig. 23; Andrews, 1980, p. 31, pl. 2, fig. 15.

*Description.*—Valve disciform with heavy mantle, rarely seen because of common orientation in valve view. Immediately inside the mantle rim is a row of very short, fine striae. Center of valve dominated by relatively large, irregularly distributed blobs of silica showing a patchy appearance.

*Discussion.*—Intermittently rare to frequent through the lower marine section.

*Known geologic range.*—Cretaceous to Holocene according to Fenner (1977); modern occurrence in marine coastal waters.

## Genus **NAVICULA** Bory, 1822

### **Navicula arenaria** Donkin
Plate 8, figures 28, 29

*Navicula arenaria* Donkin, 1861, p. 10, pl. 1, figs. 8, 9; Hendey, 1964, p. 196, pl. 30, fig. 15.

*Description.*—Valve small, lanceolate, with subacute apices. Axial area narrow, indistinct with small, ill-defined, rounded central area. Transverse rows of areolae about nine to 10 in 10 μm, radiate in the middle of the valve to transverse or slightly convergent toward the apices.

*Discussion.*—Observed as rare at the 12.8 m (42 ft) level of the lower marine section.

*Known geologic range.*—Not previously reported as a fossil. A marine littoral species in modern oceans and tolerant of a considerable range in salinity.

**Navicula maculata** (Bailey) Edwards
Plate 8, figure 30

*Stauroneis maculata* Bailey, 1850, p. 40, pl. 2, fig. 32.
*Navicula maculata* (Bailey) Edwards, 1860, p. 128; Hustedt, 1966, pp. 707–711, fig. 1698.

*Description.*—Valve broadly elliptical with rounded, slightly subrostrate apices. Transverse rows of large round areolae, about seven in 10 μm, divergent throughout the length of the valve, secondarily arranged in irregular longitudinal rows. Hyaline axial area narrow. Hyaline central area moderately large, subround to transversely elliptical.

*Discussion.*—Rare in both the 18.3 m (60 ft) level of the lower marine section and the upper marine bed.

*Known geologic range.*—Hustedt (1966, p. 710) reported the occurrence of this taxon as: "Especially widespread and common in brackish and sea water on the Atlantic coast of America. In the European region not observed in the Recent, found as fossil in Hungary and Italy." This is a curious distribution, suggesting that perhaps *N. maculata* may be a fossil species reworked from Miocene deposits along the east coast of the United States into modern marine sediments.

## Genus **NITZSCHIA** Hassall, 1845

**Nitzschia** species A
Plate 8, figures 31, 32

*Description.*—Valve smoothly lanceolate with pointed apices and only a trace of central constriction. Length of observed specimens, 53 to 62 μm, width about 10 μm. Either the surface of valve is hyaline or the rows of pores are too fine to be resolved under the light microscope. About eight marginal keel puncta in 10 μm.

*Discussion.*—If the valves are indeed hyaline, this form may be related to *Nitzschia imperforata* Andrews, 1980, described from Neogene strata in Virginia. This form is definitely not *N. imperforata,* however, and because of its scarcity, formal taxonomic treatment is not here attempted. This species of *Nitzschia* is rare in the 12.8 and 16.5 m (42 and 54 ft) levels of the lower marine section.

*Known geologic range.*—Known only from this deposit.

## Genus **PARALIA** Heiberg, 1863

**Paralia complexa** (Lohman) Andrews
Plate 8, figure 33

*Melosira complexa* Lohman, 1948, p. 156, pl. 5, figs. 1–7.
*Paralia complexa* (Lohman) Andrews, 1976, p. 8, pl. 1, figs. 3, 4; Abbott and Andrews, 1979, p. 247, pl. 4, fig. 26.

*Description.*—Valve round, convex. Ornamentation varies in concentric zones: outer zone dominated by highly irregular but generally radiate striae; second zone by a ring of concentric areolae; third zone, 3 to 5 μm wide, with fine pores arranged in a quincuncial pattern. Center of valve highly convex, with many irregularly distributed large areolae; at selected focus, it may also show radiate striae.

*Discussion.*—Noted as rare in the 13.7 and 18.3 m (45 and 60 ft) levels of the lower marine section and in the upper marine bed.

*Known geologic range.*—Lower to middle Miocene. Reported by Abbott and Andrews (1979) in the middle Miocene Coosawhatchie Clay Member of the Hawthorn Formation.

**Paralia sulcata** (Ehrenberg) Cleve
Plate 9, figure 1

*Gaillonella sulcata* Ehrenberg, 1838, p. 170, pl. 21, fig. 5.
*Paralia sulcata* (Ehrenberg) Cleve, 1873, p. 7; Hendey, 1964, p. 73, pl. 23, fig. 5; Andrews, 1976, pp. 8–9, pl. 1, figs. 5, 6; Abbott and Andrews, 1979, p. 247, pl. 4, figs. 27, 28; Andrews, 1980, pp. 31–32, pl. 2, fig. 23.
*Melosira sulcata* (Ehrenberg) Kützing, 1844, p. 55, pl. 2, fig. 7; Hustedt, 1928, pp. 276–279, fig. 119; Lohman, 1941, p. 64, pl. 12, fig. 1; Lohman, 1948, pp. 156–157.

*Description.*—Valve round, nearly flat. Outer rim complexly loculate with about five chambers in 10 μm. Rim is succeeded inwardly by a narrow band of fine pores, about 14 in 10 μm, arranged in a quincuncial pattern, then by a hyaline band less than 1 μm in width, then by a ring of prominent radial striae, about 10 in 10 μm, which taper toward the hyaline center.

*Discussion.*—Frequent to common in all the marine strata studied for this report.

*Known geologic range.*—A variety as old as Cretaceous is known (Lohman, 1948), and the species ranges throughout the Tertiary and Quaternary to a common occurrence in Holocene marine coastal waters. *P. sulcata* and the related variety, *P. sulcata* var. *coronata* (Ehrenberg, 1845c) Andrews, 1976, are the most common marine diatoms to be found in the Cenozoic deposits of the Atlantic Coastal Plain. They seem to be relatively resistant to dissolution and are sometimes the only identifiable diatoms in a poorly preserved assemblage. Although valuable as indicators of marine deposition, their long range makes them useless for correlation or age determination.

**Paralia sulcata** var. **coronata** (Ehrenberg) Andrews
Plate 9, figure 2

*Gaillonella coronata* Ehrenberg, 1845c, p. 154, pl. 38, XXII, fig. 5.
*Paralia sulcata* var. *coronata* (Ehrenberg) Andrews, 1976, p. 9, pl. 1, figs. 7, 8; Abbott and Andrews, 1979, pp. 247–248, pl. 4, fig. 29; Andrews, 1980, p. 32, pl. 3, fig. 1.
*Melosira* (*Paralia*) *sulcata* var. *coronata* (Ehrenberg) Grunow *in* Van Heurck, 1882, pl. 91, fig. 17.
*Melosira sulcata* forma *coronata* Grunow. Hustedt, 1928, p. 278, fig. 119d.

*Description.*—Valve round, nearly flat. Outer rim complexly loculate, similar to that of the typical variety, succeeded inwardly by a hyaline band about 2 μm in width, then by a ring of knobby and irregular siliceous processes, three to four in 10 μm, directed outward from a broad, flat hyaline center.

*Discussion.*—Frequent to common in all the marine strata studied for this report. Recent research suggests that this variety is the separation valve and that the typical variety is the linking valve in chains of frustules of the same diatom.

*Known geologic range.*—Same as the typical variety.

Genus **PERIPTERA** Ehrenberg, 1845a

**Periptera petiolata** Andrews
Plate 9, figure 3

*Periptera petiolata* Andrews *in* Abbott and Andrews, 1979, pl. 4, figs. 30–34; pl. 8, fig. 1.

*Description.*—Valve usually seen in girdle view, roughly rectangular in outline, but prominently flexed at both apices and the center. A single row of areolae, about six to eight in 10 μm, is irregularly spaced along one flexed margin. On the same side of the valve, extending from the center is a prominent projection or boss, eight to 10 μm high, tapering slightly from the valve surface to a flat top with a narrow flange around it.

*Discussion.*—Observed as rare in the 8.8 and 18.3 m (29 and 60 ft) levels of the lower marine section. This is probably a diatom spore, but the diatom to which it pertains has not yet been identified.

*Known geologic range.*—Previously reported only from the middle Miocene Coosawhatchie Clay Member of the Hawthorn Formation by Abbott and Andrews (1979).

Genus **PLEUROSIGMA** Smith, 1852

**Pleurosigma** aff. **P. aestuarii** (Brébisson) Smith
Plate 9, figures 4, 5

*Navicula aestuarii* Brébisson *in* Kützing, 1849, p. 890.
*Pleurosigma aestuarii* (Brébisson) Smith, 1853, p. 65, pl. 31, fig. 275; Hendey, 1964, p. 247, pl. 36, fig. 5; pl. 41, fig. 5.

*Description.*—Valve lanceolate to broadly lanceolate with a gently sigmoid outline. Ends attenuate, ending in sharply rounded apices. Raphe considerably more sigmoid than the valve margin, central in the middle of the valve, but close to the margin near the apices. Valve surface covered by very fine areolae, arranged in both transverse and oblique rows. Axial area narrow; central area small, rounded.

*Discussion.*—Appears to be close to *P. aestuarii*, though the apices are somewhat more attenuate and the ends of the raphe are closer to the margin than are those in the specimen illustrated by Hendey (1964, pl. 36, fig. 5). The form is rare in most of the samples from the lower marine section.

*Known geologic range.*—*P. aestuarii* has not previously been reported as a fossil. A common species in temperate marine coastal waters of modern oceans.

Genus **PYRGUPYXIS** Hendey, 1969

**Pyrgupyxis johnsoniana** Hendey
Plate 9, figure 6

*Pyrgupyxis johnsoniana* Hendey, 1969, p. 3.
*Pyxilla johnsoniana* Grove and Sturt, 1887, p. 71, pl. 5, fig. 10 (*non* Greville, 1865); Laporte and Lefébure, 1929, pl. 7, fig. 48.

*Description.*—Valve usually seen in girdle view, cylindrical in shape. Base straight, extending to a slightly bulbous main part of valve, extending upward into a long, hollow horn. This horn has a single siliceous spine directed outward from the end. Valve covered with irregular radial rows of areolae, about seven to eight in 10 μm, finer on the projecting horn.

*Discussion.*—This form seems to be identifiable as *P. johnsoniana*, although the published figures cited above do not show the spine at the end of the apical horn. The species was noted as rare in the 12.8 m (42 ft) level of the lower marine section and also observed as rare by Abbott in sample FE 104 at approximately the 13.1 m (43 ft) level.

*Known geologic range.*—Reported by Grove and Sturt (1887) from the upper Eocene deposit at Oamaru, New Zealand. Not previously known from Miocene strata in the southeastern United States.

Genus **RHAPHONEIS** Ehrenberg, 1844

**Rhaphoneis adamantea** Andrews
Plate 9, figures 7, 8; Plate 13, figures 2, 3

*Rhaphoneis adamantea* Andrews, 1978, pp. 384–385, pl. 2, figs. 9–11.

*Description.*—Valve lozenge-shaped with obtusely rounded lateral margins and narrowly rounded, sometimes slightly produced apices. Transverse rows of large, round areolae, about three to four in 10 μm, parallel in the center to slightly radiate near the apices. Areolae show a secondary arrangement in slightly curved longitudinal rows. Transverse rows of areolae not aligned across the very narrow hyaline axial area. A single labiate process subcentered in each end of the valve. Pseudocellus consists of a small field of fine pores at the very tip of the valve. Vela supported by two struts and show a roughly concentric pattern of fine openings.

*Discussion.*—Rare to frequent throughout the lower marine section.

*Known geologic range.*—Reported by Andrews (1978) from the middle part of lithologic unit 11 to the upper part of lithologic unit 13 of the Calvert Formation (upper lower to lower middle Miocene) of Maryland.

**Rhaphoneis elegans**
(Pantocsek and Grunow) Hanna
Plate 9, figures 9, 10; Plate 13, figure 4

*Rhaphoneis gemmifera* var. *elegans* Pantocsek and Grunow *in* Pantocsek, 1886, pt. 1, p. 34, pl. 2, fig. 21; pl. 20, fig. 179; pl. 27, fig. 264; pl. 30, fig. 317.
*Rhaphoneis elegans* (Pantocsek and Grunow) Hanna, 1932, p. 213, pl. 15, figs. 6–8; Lohman, 1948, p. 182, pl. 11, fig. 2; Lohman, 1974, p. 353, pl. 6, fig. 1; Andrews, 1975, p. 208, pl. 2, figs. 25–27; Andrews, 1978, p. 386, pl. 3, figs. 10, 11.

*Description.*—Valve subrhomboid with obtusely rounded lateral margins at center and elongate, protracted apices. Areolae large, arranged in slightly radiating transverse rows, five in 10 $\mu$m. Areolae show secondary orientation in somewhat poorly organized longitudinal rows. Hyaline axial area 1.5 to 2 $\mu$m wide at center, narrowing toward the apices. Transverse rows of areolae not aligned across the axial area. Apical pseudonodulus consists of transverse rows of fine pores.

*Discussion.*—Rare in the 13.7 and 15.5 m (45 and 51 ft) levels of the lower marine section.

*Known geologic range.*—Reported by Andrews (1978) from the lower part of lithologic unit 14 of the Calvert Formation (lower middle Miocene) in Maryland.

**Rhaphoneis fusiformis** Andrews
Plate 9, figures 11–13; Plate 13, figure 5

*Rhaphoneis fusiformis* Andrews, 1978, p. 386, pl. 3, figs. 14–16.

*Description.*—Valve lanceolate with smoothly rounded lateral margins. Apices protracted, narrowly rounded to bluntly pointed, somewhat asymmetrical and often slightly bent in relation to the longitudinal axis. Five to six transverse rows of large, relatively few areolae in 10 $\mu$m. Hyaline axial area narrow, and rows of areolae are not aligned across it. Apical fine structures not observed.

*Discussion.*—Rare to frequent throughout the lower marine section, except for the uppermost and lowermost beds.

*Known geologic range.*—Reported by Andrews (1978) from the upper part of lithologic unit 3 to the middle of unit 11 in the Calvert Formation (upper lower Miocene) of Maryland.

**Rhaphoneis magnapunctata** Andrews
Plate 9, figures 14–16; Plate 13, figure 7

*Rhaphoneis magnapunctata* Andrews, 1978, pp. 387–388, pl. 4, figs. 1–4; pl. 7, fig. 2.

*Description.*—Valve large, variable in shape from subrhomboidal to narrowly lanceolate with protracted attenuate apices. Ends of valve very narrowly rounded. Transverse rows of areolae three to four in 10 $\mu$m, parallel, composed of very large areolae with a secondary arrangement in slightly wavy longitudinal lines. Although the areola spacing remains constant except at the very tip of the valve, in large specimens the pores increase in size toward the attenuate apices. Valves sometimes slightly asymmetrical longitudinally and a bit bent near the apices. Hyaline axial area narrow and transverse rows of areolae not aligned across it. Single internal labiate process on each end of valve. Pseudocellus consists of a small field of fine pores at the tip of the valve.

*Discussion.*—Frequent throughout the lower marine section but rare in the uppermost bed.

*Known geologic range.*—Reported by Andrews (1978) from lithologic unit 10 through the lower part of unit 14 of the Calvert Formation (upper lower to lower middle Miocene) of Maryland.

**Rhaphoneis parilis** Hanna
Plate 9, figures 17–19; Plate 13, figure 6

*Rhaphoneis parilis* Hanna, 1932, p. 214, pl. 16, figs. 2–4; Lohman, 1948, p. 182, pl. 11, fig. 10; Andrews, 1975, pp. 214–215, pl. 3, figs. 41–44; Andrews, 1978, p. 388, pl. 3, figs. 22, 23; pl. 7, fig. 3.

*Description.*—Valve narrowly lanceolate, long and slender, tapering to protracted apices and with very obtusely rounded lateral margins. Transverse rows of evenly spaced areolae are straight, about six to seven in 10 $\mu$m. Areolae arranged secondarily in straight longitudinal rows, and valve shows a distinctly quadrate areolate pattern. Hyaline axial area very narrow, but usually distinct. Transverse rows of areolae are aligned across the axial area. The apices show pseudocelli formed of very fine pores and a single internal labiate process on each end.

*Discussion.*—Frequent throughout the lower marine section, except for the 19.2 m (63 ft) level and a rare occurrence in the 8.8 m (29 ft) level.

*Known geologic range.*—Reported by Andrews (1978) from the middle of lithologic unit 11 to near the top of unit 15 of the Calvert Formation (upper lower to lower middle Miocene) in Maryland.

### Genus **RHIZOSOLENIA** Ehrenberg, 1843

**Rhizosolenia styliformis** Brightwell

*Rhizosolenia styliformis* Brightwell, 1858, p. 94, pl. 5, fig. 5; Hustedt, 1929, p. 584, fig. 333; Hendey, 1964, p. 150, pl. 2, fig. 1; Abbott and Andrews, 1979, pp. 251–252, pl. 5, figs. 24, 25.

*Description.*—Only the more heavily silicified pen-point-like tip observed in these assemblages. Apical spine is hollow with two small lateral wings at base. Tip is hyaline; center of base marked by scattered areolae; wings ornamented by fine striations flaring outward from base.

*Discussion.*—Observed by Abbott as rare in samples FE 104 and FE 106 at approximately the 13.1 and 10.4 m (43 and 34 ft) levels of the lower marine section.

*Known geologic range.*—Reported by Abbott and Andrews (1979) from the middle Miocene Coosawhatchie Clay Member of the Hawthorn Formation. It is widespread in modern marine environments.

### Genus **ROSSIELLA** Desikachary and Maheshwari, 1958

**Rossiella paleacea** (Grunow) Desikachary and Maheshwari
Plate 9, figures 20–22

*Stoschia*? *paleacea* Grunow *in* Van Heurck, 1883, pl. 128, fig. 6.
*Rossiella paleacea* (Grunow) Desikachary and Maheshwari, 1958, pp. 28–29, fig. 1.
*Coscinodiscus paleaceus* (Grunow) Rattray, 1889, p. 597; Schrader, 1973a, p. 703, pl. 3, figs. 10–12.
*Cussia paleacea* (Grunow) Schrader, 1974a, p. 914; Abbott and Andrews, 1979, p. 241, pl. 3, fig. 14.
*Bogorovia paleaceus* (Rattray) Jousé, 1976, pp. 1233–1234, figs. 5, 6.

*Description.*—Valve flat, lanceolate with slightly attenuate pointed apices. Single row of large areolae, about six in 10 μm, around margins. Similar large rounded to subpolygonal pores fill the inner part of the valve and show a random orientation. No hyaline central or axial areas.

*Discussion.*—Desikachary and Maheshwari (1958) apparently complied with the rules of nomenclature in establishing the genus *Rossiella* with *Stoschia*? *paleacea* Grunow as its generotype. Despite the rather obscure publication of the name *Rossiella,* it seems advisable to regard both *Cussia* Schrader, 1974b and *Bogorovia* Jousé, 1973 as junior synonyms. *R. paleacea* is intermittently rare or frequent in the lower marine section.

*Known geologic range.*—Reported by Schrader (1973a) from his North Pacific Diatom Zones XVI–XXIII and by Abbott and Andrews (1979) from the Coosawhatchie Clay Member of the Hawthorn Formation.

**Rossiella praepaleacea** (Schrader) Andrews new combination

*Coscinodiscus praepaleaceus* Schrader, 1973a, p. 703, pl. 3, figs. 1–9.
*Cussia praepaleacea* (Schrader) Schrader, 1974a, p. 914; Abbott and Andrews, 1979, p. 241, pl. 3, fig. 15.

*Description.*—Valve flat, smoothly lanceolate, with pointed apices. Surface of valve areolate; strong marginal ribs extend to center of valve between areolae. Transverse ribs not aligned across center of valve, but joined at center by a weak, crudely zigzag central apical rib. No central or axial area.

*Discussion.*—Observed by Abbott as rare to frequent in samples FE 103, FE 104, FE 105, and FE 106 at approximate levels of 13.7, 13.1, 12.2, 10.4 m (45, 43, 40, and 34 ft), respectively, in the lower marine section.

*Known geologic range.*—According to Abbott and Andrews (1979), this species is possibly restricted to the Miocene, but the first occurrence is not known with certainty.

### Genus **SCEPTRONEIS** Ehrenberg, 1844

**Sceptroneis grandis** Abbott

*Sceptroneis grandis* Abbott *in* Abbott and Ernissee, 1983, pp. 302–303, pl. 11, fig. 7; pl. 12, fig. 1.

*Description.*—Valve clavate, elongate, heavily silicified, with a broader rounded head-pole and narrower pointed foot-pole. Valve covered with short transverse rows of areolae, not aligned across the narrow axial area. Apical structures not observed.

*Discussion.*—*Sceptroneis grandis* was described by Abbott (1983) from the Pungo River Formation in North Carolina. The species was observed by Abbott as frequent in samples FE 102, FE 103 and FE 106 and rare in FE 105 at levels of approximately 15.2, 13.7, 10.4, and 12.2 m (50, 45, 34, and 40 ft), respectively, in the lower marine section.

*Known geologic range.*—Atlantic Miocene Siliceous Microfossil Zones I and III of Abbott (1978) and upper lower Miocene to lower middle Miocene.

### Genus **STEPHANOPYXIS** Ehrenberg, 1844

**Stephanopyxis corona** (Ehrenberg) Grunow

*Systephania corona* Ehrenberg, 1845a, p. 272; Ehrenberg, 1854, pl. 33, XV, fig. 22.
*Stephanopyxis corona* (Ehrenberg) Grunow *in* Van Heurck, 1882, pl. 83 ter, figs. 10, 11; Andrews, 1976, p. 9, pl. 1, figs. 11, 12; Abbott and Andrews, 1979, p. 252, pl. 5, fig. 27.

*Description.*—Valve round, convex, hemispherical, but markedly flattened in the center. Margin loculate, convex part of valve covered with areolae arranged in an orderly hexagonal pattern. Three to four large hexagonal areolae in 10 μm. A ring of prominent thornlike siliceous spines radiates from a zone near the margin, but these spines do not extend beyond the margin. A second ring of prominent siliceous spines occurs at about half radius on the valve.

*Discussion.*—Observed as rare by Abbott in sample FE 104 at approximately the 13.1 m (43 ft) level of the lower marine section.

*Known geologic range.*—Calvert and Choptank Formations (lower to middle Miocene) of Maryland and the middle Miocene Coosawhatchie Clay Member of the Hawthorn Formation (Abbott and Andrews, 1979).

**Stephanopyxis lineata** (Ehrenberg) Forti

*Stephanodiscus? lineatus* (= *Peristephania lineata*) Ehrenberg, 1854, pl. 33, XIII, fig. 22.

*Stephanopyxis lineata* (Ehrenberg) Forti, 1912, p. 83; Forti, 1913, p. 1547, pl. 11, figs. 21–23; pl. 12, fig. 3; Andrews, 1976, pp. 9–10, pl. 1, figs. 13, 14; Abbott and Andrews, 1979, p. 252, pl. 5, fig. 28.

*Description.*—Valve round, almost flat to slightly domed. Surface of valve shows generally regular hexagonal net of areolae, about four-and-one-half in 10 μm. Margin loculate, and a ring of thornlike siliceous spines, somewhat irregularly spaced, occurs 2 to 3 μm inward from the outer margin.

*Discussion.*—Observed as frequent by Abbott in sample FE 104 at approximately the 13.1 m (43 ft) level of the lower marine section.

*Known geologic range.*—Koizumi (1973, fig. 10) indicated that this species ranges throughout the middle Miocene. It has been reported in the Choptank Formation of Maryland and the Coosawhatchie Clay Member of the Hawthorn Formation of South Carolina and Georgia, both of middle Miocene age.

**Stephanopyxis turris** (Greville) Ralfs
Plate 9, figure 23

*Creswellia turris* Greville *in* Gregory, 1857, p. 538, pl. 14, fig. 109.

*Stephanopyxis turris* (Greville) Ralfs *in* Pritchard, 1861, p. 826, pl. 5, fig. 74; Hendey, 1964, p. 92; Abbott and Andrews, 1979, pp. 252–253, pl. 6, figs. 1, 2; pl. 8, fig. 6; Andrews, 1980, p. 34, pl. 3, fig. 15.

*Stephanopyxis turris* (Greville and Arnott) Ralfs; Hustedt, 1928, pp. 304–307, fig. 140; Lohman, 1948, p. 185; Andrews, 1976, p. 10, pl. 2, figs. 1, 2.

*Description.*—Valve round, highly domed. Height usually greater than diameter, hence more often seen in girdle view. Valve shows flat or slightly concave base, expanded into a narrow flange, then tapering to almost parallel sides, arching over the top as a rounded or flattened dome. Surface of valve covered with a somewhat irregular hexagonal net of areolae, four to six in 10 μm. Bases of siliceous spines on domed end are commonly present.

*Discussion.*—The valves observed in this deposit seem to be more nearly hemispherical than some described specimens, and many lack distinct spines. Perhaps some of these forms might be classified as *Pyxidicula cruciata* Ehrenberg, 1843, but most seem to be closer to *S. turris*. Intermittently rare in the lower marine section.

*Known geologic range.*—From Cretaceous to Holocene; frequent pelagic occurrence in modern marine environments.

Genus **STICTODISCUS** Greville, 1861

**Stictodiscus kittonianus** Greville
Plate 9, figure 27

*Stictodiscus kittonianus* Greville, 1861, pp. 79–80, pl. 10, figs. 2, 3; Schmidt, 1882, pl. 74, figs. 16–18; Hanna, 1932, p. 219, pl. 16, fig. 12; Lohman, 1948, pp. 167–168, pl. 9, fig. 2; Abbott and Andrews, 1979, p. 253, pl. 6, fig. 3.

*Description.*—Valve irregularly round and markedly umbonate. Surface of valve covered with irregularly radial rows of areolae, about eight in 10 μm. Each group of two or three rows of pores separated by a siliceous ray extending from the margin part way to the center. Areolae cover center of valve in an unorganized pattern. Narrow hyaline marginal rim.

*Discussion.*—Observed as rare in the 17.4 m (57 ft) level of the lower marine section.

*Known geologic range.*—Lower to middle Miocene, including the Coosawhatchie Clay Member of the Hawthorn Formation, according to Abbott and Andrews (1979).

Genus **SYNEDRA** Ehrenberg, 1832

**Synedra jouseana** Sheshukova-Poretskaya

*Synedra jouseana* Sheshukova-Poretskaya, 1962, p. 208, fig. 4; Schrader, 1973a, p. 710, pl. 23, figs. 21–23, 25, 38.

*Description.*—Valve narrow, lanceolate with acute apices. Transverse striae 12 to 13 in 10 μm, originating in marginal areolae and projecting 2 to 3 μm into valve. Axial area hyaline, very wide, lanceolate, divided into three parts by two longitudinal lines.

*Discussion.*—Observed by Abbott as rare to frequent throughout the lower marine section. The species is difficult to distinguish from *Thalassionema obtusum* (Grunow *in* Van Heurck, 1881) Andrews, 1976.

*Known geologic range.*—Reported by Schrader (1973a) from his North Pacific Diatom Zones XVII to XXIV, of middle to late Miocene age. Reported by Schrader and Fenner (1976) from upper Oligocene to lower Miocene deposits in the Norwegian Sea.

## Genus **THALASSIONEMA** Grunow *in* Van Heurck, 1881

### **Thalassionema nitzschioides** (Grunow) Hustedt Plate 9, figure 24

*Synedra nitzschioides* Grunow, 1862, p. 403.
*Thalassionema nitzschioides* (Grunow) Hustedt, 1932, pp. 244–246, fig. 725; Hendey, 1964, p. 165; Abbott and Andrews, 1979, p. 253, pl. 6, fig. 11; Andrews, 1980, p. 34, pl. 3, fig. 17.

*Description.*—Valve narrowly linear, with almost parallel sides tapering only slightly toward bluntly rounded apices. Valve marked with a single row of marginal areolae, 10 to 11 in 10 μm. Hyaline axial area covers most of valve surface.

*Discussion.*—Rare through most of the lower marine section.

*Known geologic range.*—A long-ranging species, at least from Miocene to Holocene. A common and widespread neritic species in modern coastal waters.

### **Thalassionema obtusum** (Grunow) Andrews Plate 9, figure 25

*Thalassiothrix*? *nitzschioides* var. *obtusa* Grunow *in* Van Heurck, 1881, pl. 43, fig. 6.
*Thalassionema obtusum* (Grunow) Andrews, 1976, p. 21, pl. 7, figs. 6–8; Abbott and Andrews, 1979, p. 253, pl. 6, fig. 11.

*Description.*—Valve narrowly lanceolate with rounded apices. A single row of areolae, about nine-and-one-half to 11 in 10 μm along the margin of the valve. Wide hyaline lanceolate axial area fills the center.

*Discussion.*—Rare in the 12.8 m (42 ft) level of the lower marine section.

*Known geologic range.*—Middle Miocene, including the Coosawhatchie Clay Member of the Hawthorn Formation, as reported by Abbott and Andrews (1979).

## Genus **THALASSIOSIRA** Cleve, 1873

### **Thalassiosira eccentrica** (Ehrenberg) Cleve Plate 9, figure 28

*Coscinodiscus eccentricus* Ehrenberg, 1841, p. 146; Ehrenberg, 1854, pl. 18, fig. 32; pl. 21, fig. 6; Hendey, 1964, pp. 80–81, pl. 24, fig. 7.
*Thalassiosira eccentrica* (Ehrenberg) Cleve, 1904; Fryxell and Hasle, 1972, pp. 297–317, pls. 1–4; Abbott and Andrews, 1979, p. 254, pl. 6, fig. 12; Andrews, 1980, pp. 34–35, pl. 3, fig. 16.
*Coscinodiscus excentricus* Ehrenberg. Hustedt, 1928, pp. 388–391, fig. 201; Lohman, 1941, pp. 67–68, pl. 12, fig. 7; pl. 13, fig. 8; Lohman, 1948, p. 161.

*Description.*—Valve round, flat or nearly so. Valve covered by an areolate net showing a regular hexagonal pattern over much of the valve. This net is disordered somewhere on the valve by a single areola surrounded by seven, rather than six, areolae. Areolae about four-and-one-half in 10 μm, round, very even in size and spacing. Valve shows a narrow, finely granular margin.

*Discussion.*—Rare throughout most of the lower marine section.

*Known geologic range.*—From the Calvert Formation (lower and middle Miocene) in Maryland to a common and widespread occurrence in modern neritic plankton.

### **Thalassiosira leptopus** (Grunow) Hasle and Fryxell Plate 9, figures 29, 30

*Coscinodiscus* (*lineatus* var.?) *leptopus* Grunow *in* Van Heurck, 1883, pl. 131, figs. 5, 6.
*Thalassiosira leptopus* (Grunow) Hasle and Fryxell, 1977, pp. 20–22, pls. 1–4; pl. 18, figs. 94–96.
*Coscinodiscus lineatus* Ehrenberg, 1838, p. 129; Ehrenberg, 1854, pl. 18, fig. 33; pl. 22, fig. 6; pl. 35A, figs. XVI-3, XVII-7; Hustedt, 1929, pp. 392–394, fig. 204; Hendey, 1964, p. 76; Abbott and Andrews, 1979, p. 238, pl. 3, fig. 1.
*Coscinodiscus leptopus* Grunow. Rattray, 1889, p. 476.

*Description.*—Valve round, flat or nearly so. Covered with an areolate net showing a regular hexagonal pattern. Areolae about five-and-one-half in 10 μm, round to hexagonal, even in size and spacing. Margin is narrow and finely striate. Small spinelike processes sometimes seen along inner edge of margin.

*Discussion.*—Rare throughout most of the lower marine section.

*Known geologic range.*—From the Calvert Formation (lower and middle Miocene) of Maryland to a common and widespread occurrence in the plankton of modern oceans.

### **Thalassiosira** species A Plate 9, figure 31

*Description.*—Valve round, flat, slightly warped in at least some specimens. Diameter of observed specimen, 26 μm. Surface of valve covered by a net of polygonal areolae, about six in 10 μm in the radius of the valve. These areolae are oriented in an irregularly radiate pattern; many are distinctly elongate parallel to the radius of the valve.

*Discussion.*—This form seems to resemble *Thalassiosira* somewhat more than it does *Coscinodiscus* Ehrenberg, 1838, but too few specimens were observed to justify formal taxonomic treatment. Rare in the 16.5 m (54 ft) level of the lower marine section.

## Genus **THALASSIOTHRIX** Cleve and Grunow, 1880

### **Thalassiothrix longissima** Cleve and Grunow Plate 9, figure 26

*Synedra thalassiothrix* Cleve, 1873, p. 22, pl. 4, fig. 24.
*Thalassiothrix longissima* Cleve and Grunow, 1880, p. 108; Hustedt, 1932, p. 247, fig. 726; Lohman, 1948, p. 185; Andrews, 1976, p. 21, pl. 7, figs. 9, 10; Abbott and Andrews, 1979, p. 254, pl. 6, fig. 13; Andrews, 1980, p. 35.

*Description.*—Valve extremely elongate and narrow, with parallel sides and bluntly rounded apices. Transverse rows of areolae short, marginal, about 12 in 10 μm. Hyaline axial area about one-third the width of the valve, narrowing near the apices.

*Discussion.*—Rare in the 18.3 m (60 ft) level of the lower marine section.

*Known geologic range.*—Miocene to Holocene. Especially abundant in the colder waters of modern oceans.

### Genus **TRICERATIUM** Ehrenberg, 1841

**Triceratium condecorum** Ehrenberg
Plate 9, figure 32

*Triceratium condecorum* Ehrenberg, 1845a, p. 272; Grunow *in* Schmidt, 1882, pl. 76, fig. 28; Hustedt *in* Schmidt, 1959, pl. 478, figs. 14–21; Andrews, 1976, p. 18, pl. 5, figs. 18, 19; Abbott and Andrews, 1979, p. 254, pl. 6, figs. 14, 15.
*Triceratium interpunctatum* Grunow *in* Schmidt, 1882, pl. 76, fig. 7; Lohman, 1948, p. 175, pl. 10, fig. 2.

*Description.*—Valve triangular with raised rim and depressed triangular center. Sides vary from slightly concave to straight, or slightly convex. Angles vary from obtusely rounded to a rounded point. Surface of valve covered with large areolae, arranged primarily in a radial pattern and secondarily in a roughly concentric pattern. About five areolae in 10 μm near the center, somewhat more closely spaced at the margin. Radial rows of large areolae terminate inwardly with a single small pore. A pseudonodulus consisting of fine pores is found on each of the angles.

*Discussion.*—Rare to frequent throughout most of the lower marine section.

*Known geologic range.*—Hustedt (1959) reported this species from the upper Eocene of New Zealand. Frequent to common in the Calvert and Choptank Formations (lower to middle Miocene) of Maryland. Not known from deposits younger than Miocene.

**Triceratium spinosum** Bailey
Plate 9, figures 33, 34; Plate 12, figure 4

*Triceratium spinosum* Bailey, 1844, p. 139, pl. 3, fig. 12; Schmidt, 1885, pl. 87, figs. 2, 3; Hustedt, 1930, pp. 804–806, fig. 467; Hendey, 1964, pp. 108–109.

*Description.*—Valve triangular with commonly slightly concave or straight, but sometimes slightly convex, sides. Angles of the valve are produced into narrow, tapering, horn-like processes. Valve surface convex, covered with fine areolae arranged in a warped hexagonal pattern. Several spines, both short and long, are scattered over the surface of the valve. No hyaline central area.

*Discussion.*—Intermittently rare throughout the lower marine section.

*Known geologic range.*—Originally described by Bailey (1844) from the Neogene deposit at Petersburg, Virginia, but not observed in a later study by Andrews (1980) of a similar deposit. A widespread and common littoral form on the coasts of warmer seas.

### Genus **TROCHOSIRA** Kitton, 1871

**Trochosira spinosa** Kitton

*Trochospira spinosa* Kitton, 1871, p. 170, pl. 14, figs. 6, 7; Sheshukova-Poretskaya, 1967, pp. 137–138, pl. 11, figs. 6a, b; pl. 13, figs. 4a, b; Schrader, 1973a, p. 713, pl. 12, figs. 18, 19; Abbott and Andrews, 1979, p. 255, pl. 6, fig. 19.

*Description.*—Frustules in chains connected by several short processes. Valves convex, central part flat. Processes connecting the frustules emanate from margin of the flattened central part of the valve.

*Discussion.*—Observed by Abbott as common to frequent throughout the lower marine section and in the upper marine bed. Usually seen in girdle view and may be readily confused with girdle orientations of *Paralia sulcata* (Ehrenberg, 1838) Cleve, 1873.

*Known geologic range.*—Lower Eocene to middle Miocene. Reported by Kitton (1871) from the lower Eocene deposit at Mors, Denmark; by Schrader (1973a) from his North Pacific Diatom Zone XXIII; by Abbott and Andrews (1979) from the middle Miocene Coosawhatchie Clay Member of the Hawthorn Formation.

### Genus **XANTHIOPYXIS** Ehrenberg, 1845a

**Xanthiopyxis** species

*Discussion.*—Specimens attributable to *Xanthiopyxis* were observed as frequent throughout the lower marine section and in the upper marine bed. As is common in the Miocene deposits of the southeastern United States, the forms are highly varied, mostly small, ovate or elliptical-elongate and either hyaline or showing varying degrees of spinosity. Each form is very rare, and because of the doubtful value of these forms to biostratigraphy, no attempt has been made to undertake their taxonomic treatment.

Genus and species indeterminate
Plate 9, figure 35

*Description.*—Elongate valves or girdle bands, markedly flexed in the center. Sides straight, except for flexure normal to the flat surface; ends rounded and slightly asymmetrical. One longitudinal row of large marginal areolae, about five-and-one-half in 10 μm, on one side only. Areolae continue to the ends.

*Discussion.*—This object is similar to the siliceous microfossil reported without taxonomic treatment by Abbott and Andrews (1979) from the Coosawhatchie Clay Member of the Hawthorn Formation of South Carolina and eastern Georgia. These objects show the same flexed shape but differ in having a single longitudinal row of large pores, rather than two as in the previously observed form. These objects are equally problematical in origin. They may be girdle fragments of some diatom, possibly *Rhaphoneis magnapunctata* Andrews, 1978. They could possibly be valves of a flexed and imperforate species of *Nitzschia* Hassall, 1845, the row of pores being analogous to keel puncta. However, the similar forms having two rows of pores indicate that this interpretation is unlikely.

## NONMARINE DIATOMS

### Genus **ACHNANTHES** Bory, 1822

#### **Achnanthes hungarica** (Grunow) Grunow
Plate 10, figure 1

*Achnanthidium hungaricum* Grunow, 1863, p. 146, pl. 4, figs. 8a–c.
*Achnanthes hungarica* (Grunow) Grunow *in* Cleve and Grunow, 1880, p. 20; Hustedt, 1933, pp. 383–384, fig. 829; Patrick and Reimer, 1966, p. 259, pl. 16, figs. 27, 28.

*Description.*—Valve linear-elliptical to linear-lanceolate with bluntly rounded, slightly subrostrate apices. Raphe valve with narrow linear hyaline axial area. Central area a narrow stauros reaching both margins, but broadening considerably toward one margin only. Raphe very thin. Striae fine, about 24 in 10 $\mu$m, slightly radiate. Rapheless valve not observed.

*Discussion.*—The single raphid valve observed in the nonmarine assemblage seems to conform well to *A. hungarica.*

*Known geologic range.*—Not, to our knowledge, previously reported as fossil. This is an alkaliphilous species with widespread occurrence in modern lakes, ponds and flowing waters. Reported by Hustedt (1933) to occur in fresh and slightly saline waters.

### Genus **CALONEIS** Cleve, 1894

#### **Caloneis westii** (Smith) Hendey
Plate 10, figure 12

*Navicula westii* Smith, 1853, p. 49, pl. 16, fig. 135.
*Caloneis westii* (Smith) Hendey, 1964, pp. 230–231, pl. 44, figs. 5–10; pl. 45, figs. 1–13.
*Navicula formosa* Gregory, 1856b, p. 42, pl. 5, fig. 6.
*Caloneis formosa* (Gregory) Cleve, 1894, p. 57; Hustedt, 1930a, pp. 232–233, fig. 350.

*Description.*—Valve lanceolate with obtusely rounded apices. Axial area narrowly lanceolate, irregular, with a slight asymmetric dilation at the center of the valve. Valve surface shows about 14 transverse striae in 10 $\mu$m, slightly radiate throughout the length of the valve. Longitudinal lines somewhat nearer the valve margin than the raphe.

*Discussion.*—Although the figured specimen (Pl. 10, fig. 12) is somewhat more broadly lanceolate than any figured by Hendey (1964), this taxon conforms to *C. westii* in all other respects. Occurs frequently in the nonmarine diatom assemblage.

*Known geologic range.*—Not, to our knowledge, previously reported as a fossil. A brackish water species, known from littoral marine environments as well as saline inland waters.

### Genus **EUNOTIA** Ehrenberg, 1837

#### **Eunotia parallela** Ehrenberg
Plate 10, figure 2

*Eunotia parallela* Ehrenberg, 1843, p. 414; Hustedt, 1932, p. 302, fig. 768; Patrick and Reimer, 1966, p. 193, pl. 10, fig. 12; Andrews, 1970, p. A12, pl. 1, fig. 24.

*Description.*—Valve elongate, varying from almost straight to slightly arched. Ventral and dorsal margins of the valve very nearly parallel. Apices bluntly rounded. Fine structures poorly preserved in this assemblage.

*Discussion.*—A distinctive species that is rare in the nonmarine deposit.

*Known geologic range.*—Reported by Andrews (1970, p. A12) from a Nebraska deposit of early to middle Miocene age. Common in modern cool to cold freshwaters.

#### **Eunotia pectinalis** (Müller) Rabenhorst
Plate 10, figure 3

*Conferva pectinalis* Müller, 1788, p. 91, pl. 1, figs. 4–7; Dillwyn, 1809, pl. 24.
*Eunotia pectinalis* (Müller) Rabenhorst; Patrick and Reimer, 1966, pp. 204–205, pl. 12, figs. 8, 10.
*Eunotia pectinalis* (Dillwyn) Rabenhorst, 1864, p. 73.
*Eunotia pectinalis* (Dillwyn? Kützing) Rabenhorst; Hustedt, 1932, pp. 296–299, fig. 763a.

*Description.*—Valve elongate, slightly curved. Ventral margin straight to slightly concave; dorsal margin straight to slightly convex, nearly parallel to ventral margin. Valve narrows to slightly bent, attenuated, rounded ends. Transverse striae 12 in 10 $\mu$m, slightly finer near the end of the valve.

*Discussion.*—Fragments of specimens referable to *E. pectinalis* were observed as rare in the nonmarine assemblage.

*Known geologic range.*—The type variety has not been previously reported as a fossil. Commonly recorded in modern cool waters having a low mineral content.

#### **Eunotia pectinalis** var. **minor** (Kützing) Rabenhorst
Plate 10, figure 4

*Himatidium minus* Kützing, 1844, p. 39, pl. 16, fig. 10.
*Eunotia pectinalis* var. *minor* (Kützing) Rabenhorst, 1864, p. 74; Hustedt, 1932, p. 298, figs. 763d–f; Patrick and Reimer, 1966, p. 207, pl. 12, figs. 12, 13; Andrews, 1970, pp. A12–A13, pl. 1, fig. 25.

*Description.*—Valve elongate, ventral margin slightly concave, dorsal margin distinctly convex. Valve narrows toward ends; apices bluntly rounded. Striae 12 in 10 $\mu$m at center, where they are perpendicular to the ventral margin; somewhat finer and slightly curved near the ends.

*Discussion.*—*E. pectinalis* var. *minor* is rare in the nonmarine assemblage.

*Known geologic range.*—Reported by Andrews (1970, pp. A12–A13) from a Nebraska deposit of early to middle Miocene age. Occurs in acid to circumneutral modern fresh waters but shows a greater tolerance for calcium carbonate than do many species of *Eunotia.*

### Genus **GOMPHONEMA** Agardh, 1824

**Gomphonema affine** var. **insigne** (Gregory) Andrews
Plate 10, figure 5

*Gomphonema insigne* Gregory, 1856a, p. 12, pl. 1, fig. 39; Grunow *in* Van Heurck, 1880, pl. 24, figs. 39–41.
*Gomphonema affine* var. *insigne* (Gregory) Andrews, 1970, p. A20, pl. 3, figs. 12–16; Andrews, 1971, p. E14, pl. 2, figs. 16–18; Patrick and Reimer, 1975, pp. 133–134, pl. 17, fig. 4.
*Gomphonema lanceolatum* var. *insignis* (Gregory) Cleve, 1894, p. 183; Hustedt, 1930a, p. 376, fig. 701.

*Description.*—Valve lanceolate-clavate to nearly lanceolate, rounded on the head-pole but somewhat more acutely pointed on the foot-pole. Hyaline axial area about one-fourth the width of the valve. Central area asymmetrical, formed by shortening of a single transverse row of areolae on one side of the valve. A single stigma on opposite side of valve from the shortened row of areolae. Transverse striae fine, about 10 in 10 μm, composed of rows of fine areolae. Raphe thin, filamentous.

*Discussion.*—Rare in the nonmarine deposit.

*Known geologic range.*—Reported by Andrews (1971, p. E14) from lower Miocene deposits in Nebraska and also by Andrews (1970, p. A20) from lower to middle Miocene deposits in Nebraska. It has a widespread modern occurrence in hard to circumneutral freshwaters.

### Genus **GYROSIGMA** Hassall, 1845

**Gyrosigma** aff. **G. spencerii** (Quekett) Griffith and Henfrey
Plate 10, figure 6

*Navicula spencerii* Quekett, 1848, p. 440, pl. 9.
*Gyrosigma spencerii* (Quekett) Griffith and Henfrey, 1856, p. 303, pl. 11, fig. 17; Patrick and Reimer, 1966, pp. 315–316, pl. 23, fig. 4.
*Gyrosigma spencerii* (Smith) Cleve. Hustedt, 1930a, pp. 225–226, fig. 336.

*Description.*—Valve moderately sigmoid, lanceolate, tapering to narrowly rounded apices. Raphe approximately centered throughout the length of the valve. Small longitudinally elliptical central area. Fine structure not observed because of poor preservation.

*Discussion.*—Observed as a single poorly preserved specimen that seemed to conform to *G. spencerii.*

*Known geologic range.*—*G. spencerii,* so far as is known, has not been previously recorded as a fossil. It has been reported from modern alkaline freshwaters and is able to tolerate some salinity.

### Genus **MELOSIRA** Agardh, 1824

**Melosira juergensi** Agardh
Plate 10, figure 7

*Melosira juergensi* Agardh, 1824, p. 9; Hustedt, 1927, pp. 238–240, fig. 99.

*Description.*—Cylindrical frustules linked in chains. Valves cylindrical with rounded ends. Section through valve wall shows slight thickening toward open end, giving the frustule a distinctive, somewhat "hourglass" internal outline. Valve mantle may be finely marked but appears to be hyaline under the light microscope. Linking processes between frustules small, indistinct.

*Discussion.*—Common in the nonmarine assemblage.

*Known geologic range.*—Reported as occurrring in the middle Miocene Hualapai Limestone of Arizona by Bradbury (written commun., 1983). Hustedt (1927) stated that *M. juergensi* is a widespread and common brackish-water species that may range into shallow marine waters.

### Genus **NAVICULA** Bory, 1822

**Navicula** aff. **N. radiosa** Kützing
Plate 10, figure 8

*Navicula radiosa* Kützing, 1844, p. 91, pl. 4, fig. 23; Hustedt, 1930a, p. 299, fig. 513; Patrick and Reimer, 1966, p. 509, pl. 48, fig. 15; Andrews, 1970, p. A16, pl. 2, fig. 15.

*Description.*—Valve linear-lanceolate with acute, narrowly rounded ends. Valve surface with transverse rows of areolae, about 10 in 10 μm, highly radiate near the center grading to parallel or slightly convergent near the apices. Hyaline axial area narrow, little or no widening at center in specimens observed.

*Discussion.*—The transverse rows of areolae are somewhat finer and less divergent in the center of the valve than most descriptions of modern representatives of this taxon suggest. This species is rare in the nonmarine assemblage.

*Known geologic range.*—Reported by Andrews (1970, p. A16) from deposits of early to middle Miocene in Nebraska. Common in a wide variety of modern circumneutral fresh waters and tolerant of some salinity.

## Genus **NITZSCHIA** Hassall, 1845

### **Nitzschia hybrida** Grunow
Plate 10, figure 9

*Nitzschia hybrida* Grunow *in* Cleve and Grunow, 1880, p. 79, pl. 5, fig. 95; Hustedt, 1930a, p. 406, fig. 778.

*Description.*—Valve linear with concave to nearly straight sides. End of valve asymmetrical, smoothly and broadly rounded on keel side of valve but more sharply truncated on girdle side. Surface of valve covered with fine transverse striae, about 16 in 10 μm. Keel puncta obscure in specimens observed.

*Discussion.*—Specimens in this assemblage are somewhat more coarsely marked than has been reported for modern representatives. Occurs rarely as fragments in the nonmarine assemblage.

*Known geologic range.*—Not known to have been reported previously from fossil deposits. It is a salt water species, known from modern coastal waters and inland saline waters.

### **Nitzschia tryblionella** var. **victoriae** (Grunow) Grunow
Plate 10, figure 10

*Tryblionella victoriae* Grunow, 1862, p. 553, pl. 12, fig. 34.
*Nitzschia tryblionella* var. *victoriae* (Grunow) Grunow *in* Cleve and Grunow, 1880, p. 69; Hustedt, 1930a, pp. 399–400, fig. 758.

*Description.*—Valve relatively short, elliptical, with rounded ends. Surface of valve covered with robust transverse striae, about seven in 10 μm. Keel puncta about 16 in 10 μm.

*Discussion.*—Occurs frequently in the nonmarine assemblage.

*Known geologic range.*—Not previously known as a fossil species. The most common modern occurrence is in somewhat saline waters, but the species and its varieties range into freshwater environments.

## Genus **PINNULARIA** Ehrenberg, 1843

### **Pinnularia brevicostata** Cleve
Plate 10, figure 11

*Pinnularia brevicostata* Cleve, 1891, p. 25, pl. 1, fig. 5; Hustedt, 1930a, pp. 329–330, fig. 609; Patrick and Reimer, 1966, p. 623, pl. 60, fig. 1; Andrews, 1970, p. A17, pl. 3, fig. 3; Andrews, 1971, p. E11, pl. 1, figs. 18, 19.

*Description.*—Valve linear with a slight expansion at the center and rounded ends. Hyaline axial area wide, about half the width of the valve. Transverse striae short, 12 in 10 μm, slightly radiate.

*Discussion.*—Rare in the nonmarine assemblage.

*Known geologic range.*—Reported by Andrews (1971) from the early Miocene Pine Ridge assemblage of Nebraska and also by Andrews (1970) from the early to middle Miocene Kilgore assemblage of Nebraska. Common in modern cool waters having a low mineral content.

### **Pinnularia fusana** Andrews
Plate 10, figure 13

*Pinnularia fusana* Andrews, 1971, pp. E11–E12, pl. 1, figs. 25–27.

*Description.*—Valve fusiform, lanceolate-elliptical with somewhat produced, rostrate apices. Ends of valve rounded. Strong transverse costae, 10 in 10 μm, radiate near the center, but convergent near the apices. Hyaline axial area narrow at the apices, irregular in outline and expanding to about one-third the width of the valve by a slight lateral swelling at the central area. Raphe straight, terminating in pronounced central nodules.

*Discussion.*—This taxon seems to be close to the original description of *P. fusana,* except that the apices are much narrower, and the valve is relatively somewhat narrower. Rare in the nonmarine deposit.

*Known geologic range.*—Previously reported only from the lower Miocene Monroe Creek Sandstone at Pine Ridge, Nebraska, by Andrews (1971).

### **Pinnularia** aff. **P. microstauron** (Ehrenberg) Cleve
Plate 10, figure 15

*Stauroptera microstauron* Ehrenberg, 1843, p. 423, pl. 1, fig. IV, 1.
*Pinnularia microstauron* (Ehrenberg) Cleve, 1891, p. 28; Hustedt, 1930a, p. 320, fig. 582; Patrick and Reimer, 1966, pp. 597–598, pl. 55, fig. 12; Andrews, 1971, p. E12, pl. 1, figs. 22–24.

*Description.*—Valve linear-lanceolate, tapering to rounded apices. About nine transverse costae in 10 μm, radiate at center, but becoming convergent near the apices. Hyaline axial area narrow at the ends, tapering to the central area where it expands to the margins of the valve.

*Discussion.*—The figured specimen (Pl. 10, fig. 15) shows little indication of rostrate apices but seems to conform reasonably well to a specimen figured by Andrews (1971, pl. 1, fig. 24). It was observed only as rare fragments in the nonmarine assemblage.

*Known geologic range.*—Reported by Andrews (1971, p. E12) from a deposit of early Miocene age in Nebraska. Known from a variety of modern freshwater environments but is thought to prefer oligotrophic, slightly acid waters.

### **Pinnularia torta** (Mann) Patrick
Plate 10, figure 14

*Navicula torta* Mann, 1924, p. 31, pl. 4, fig. 6.
*Pinnularia torta* (Mann) Patrick *in* Patrick and Reimer, 1966, p. 634, pl. 63, fig. 3; Andrews, 1970, p. A18, pl. 3, figs. 4, 5.
*Pinnularia major* var. *asymmetrica* Cleve, 1895, p. 89, pl. 1, fig. 22.

*Description.*—Valve linear with rounded ends and a slight lateral expansion at the center. About seven costae in 10 μm, radiate at the center to convergent near the apices, some flexed to an attenuated S-shape. Hyaline axial area about one-fourth to one-third the width of the valve, markedly asymmetric to the center line of the valve. Raphe about centrally located in the axial area, filamentous, oblique to the plane of the valves. Central area rounded, slightly more expanded in direction of deflection of the central nodules of the raphe.

*Discussion.*—Observed as rare in the nonmarine assemblage.

*Known geologic range.*—Reported by Andrews (1970, p. A18) from the "Valentine Formation" (lower to middle Miocene) of Nebraska. Modern occurrence in standing acid waters of low mineral content.

Genus **STAURONEIS** Ehrenberg, 1843
**Stauroneis** aff. **S. salina** Smith
Plate 10, figure 16

*Stauroneis salina* Smith, 1853, p. 60, pl. 19, fig. 188; Hustedt, 1959, pp. 786–789, fig. 1133.

*Description.*—Valve lanceolate with rounded ends. Transverse striae very fine, parallel or slightly radiate throughout the length of the valve. Hyaline axial area narrow, expanded at the center of the valve to a narrow transversely rectangular stauros extending to the margins of the valve.

*Discussion.*—This taxon shows somewhat more bluntly rounded apices and a less distinctly defined stauros than do the specimens illustrated by Hustedt (1959); otherwise, it appears to be similar to *S. salina.* Rare in the nonmarine assemblage.

*Known geologic range.*—Not previously reported as a fossil, to the writers' knowledge. *S. salina* is known from modern saline and brackish-water environments.

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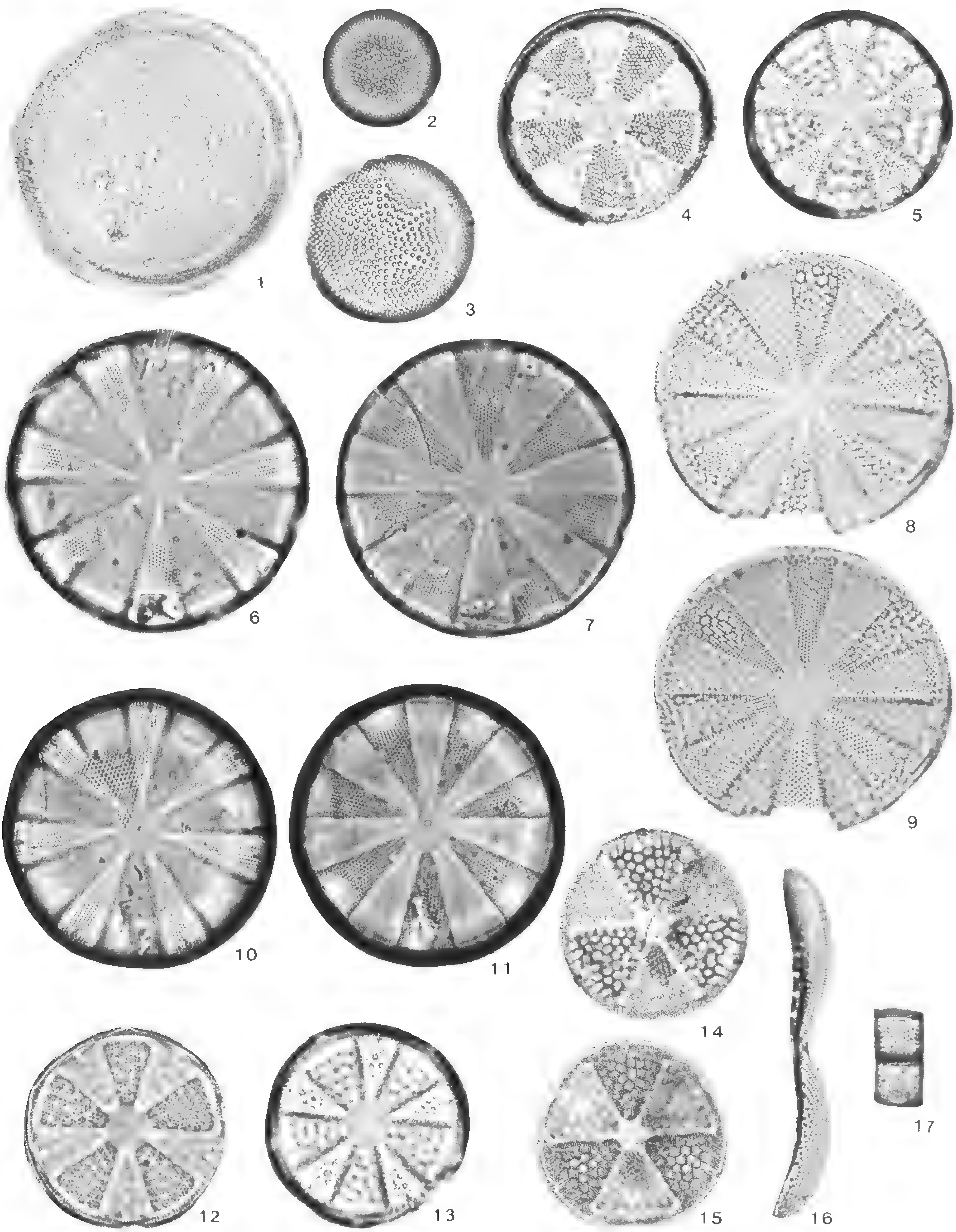
# PLATES

## EXPLANATION OF PLATE 6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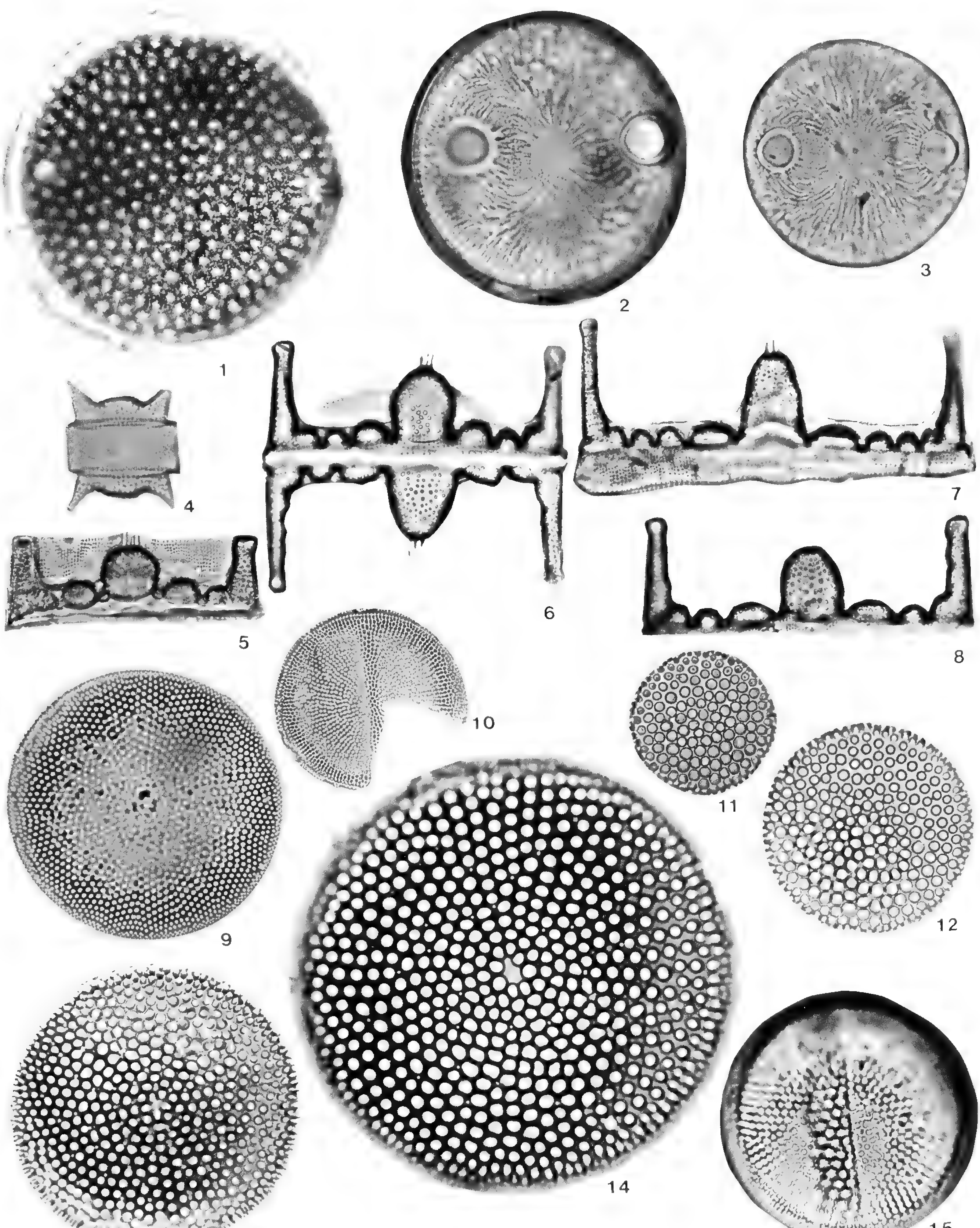
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## EXPLANATION OF PLATE 7

## EXPLANATION OF PLATE 8

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| 1. | ***Coscinodiscus rothii*** (Ehrenberg) Grunow | 75 |
| | USGS Diatom Cat. no. 3959-19, ×1000, diameter 57 μm. | |
| 2, 3. | ***Cymatogonia amblyoceros*** (Ehrenberg) Hanna | 75 |
| | 2. USGS Diatom Cat. no. 3959-39, ×1000, height 42 μm. | |
| | 3. USGS Diatom Cat. no. 3963-33, ×1000, height 39 μm. | |
| 4, 5. | ***Cymatosira belgica*** Grunow | 76 |
| | 4. USGS Diatom Cat. no. 3969-28, ×1000, length 59 μm. | |
| | 5. USGS Diatom Cat. no. 3969-56, ×1000, length 70 μm. | |
| 6. | ***Cymatosira immunis*** (Lohman) Abbott | 76 |
| | USGS Diatom Cat. no. 3969-9, ×1000, length 35 μm. | |
| 7, 8. | ***Cymatosira lorenziana*** Grunow | 76 |
| | 7. USGS Diatom Cat. no. 3989-17, ×1000, length 20 μm. | |
| | 8. USGS Diatom Cat. no. 3990-18, ×1000, length 18 μm. | |
| 9, 10. | ***Delphineis angustata*** (Pantocsek) Andrews | 77 |
| | 9. USGS Diatom Cat. no. 3970-44, ×1000, length 52 μm. | |
| | 10. USGS Diatom Cat. no. 3963-37, ×1000, length 69 μm. | |
| 11–13. | ***Delphineis penelliptica*** Andrews | 77 |
| | 11. USGS Diatom Cat. no. 3961-1, ×1000, length 35 μm. | |
| | 12. USGS Diatom Cat. no. 3969-89, ×1000, length 38 μm. | |
| | 13. USGS Diatom Cat. no. 3959-18, ×1000, length 44 μm. | |
| 14. | ***Delphineis novaecaesaraea*** (Kain and Schultze) Andrews | 77 |
| | USGS Diatom Cat. no. 3961-32, ×1000, length of fragment 59 μm. | |
| 15, 16. | ***Diploneis crabro*** (Ehrenberg) Ehrenberg | 78 |
| | 15. USGS Diatom Cat. no. 3989-19, ×1000, length 52 μm. | |
| | 16. USGS Diatom Cat. no. 3953-2, ×1000, length 43 μm. | |
| 17. | ***Diploneis*** aff. ***D. suborbicularis*** (Gregory) Cleve | 78 |
| | USGS Diatom Cat. no. 3969-47, ×1000, length 23 μm. | |
| 18. | ***Endictya oceanica*** Ehrenberg | 78 |
| | USGS Diatom Cat. no. 3969-80, ×1000, width of fragment 31 μm. | |
| 19. | ***Gyrosigma*** species | 79 |
| | USGS Diatom Cat. no. 3969-92, ×500, length of fragment 114 μm. | |
| 20. | ***Grammatophora marina*** (Lyngbye) Kützing | 79 |
| | USGS Diatom Cat. no. 3961-9, ×1000, length 58 μm. | |
| 21, 22. | ***Hemiaulus bipons*** (Ehrenberg) Grunow | 79 |
| | 21. USGS Diatom Cat. no. 3969-83, ×1000, length 32 μm. | |
| | 22. USGS Diatom Cat. no. 3959-20, ×1000, length 35 μm. | |
| 23. | ***Hyalodiscus scoticus*** (Kützing) Grunow | 79 |
| | USGS Diatom Cat. no. 3969-94, ×1000, diameter 49 μm. | |
| 24. | ***Liradiscus bipolaris*** Lohman | 80 |
| | USGS Diatom Cat. no. 3961-29, ×1000, length 27 μm. | |
| 25. | ***Lithodesmium ehrenbergii*** (Grunow) Forti | 80 |
| | USGS Diatom Cat. no. 3953-36, ×1000, length 39 μm. | |
| 26. | ***Lithodesmium undulatum*** Ehrenberg | 80 |
| | USGS Diatom Cat. no. 3989-21, ×1000, length 39 μm. | |
| 27. | ***Melosira westii*** Smith | 80 |
| | USGS Diatom Cat. no. 3969-58, ×1000, diameter 18 μm. | |
| 28, 29. | ***Navicula arenaria*** Donkin | 80 |
| | 28. USGS Diatom Cat. no. 3969-27, ×1000, length 38 μm. | |
| | 29. USGS Diatom Cat. no. 3969-82, ×1000, length 67 μm. | |
| 30. | ***Navicula maculata*** (Bailey) Edwards | 81 |
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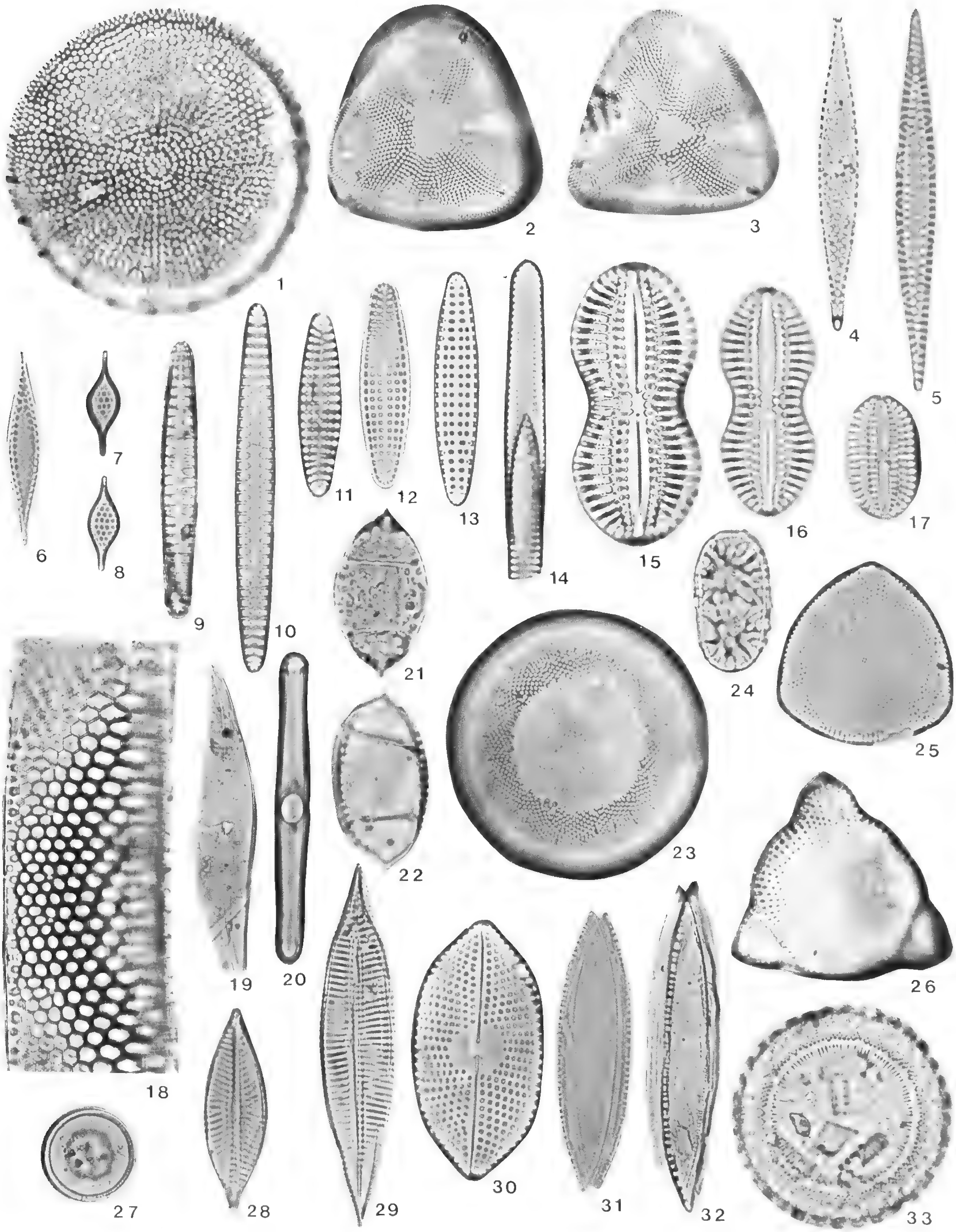
| 31, 32. | ***Nitzschia*** species A | 81 |
| | 31. USGS Diatom Cat. no. 3963-7, ×1000, length 53 μm. | |
| | 32. USGS Diatom Cat. no. 3970-17, ×1000, length 62 μm. | |
| 33. | ***Paralia complexa*** (Lohman) Andrews | 81 |
| | USGS Diatom Cat. no. 3971-11, ×1000, diameter 41 μm. | |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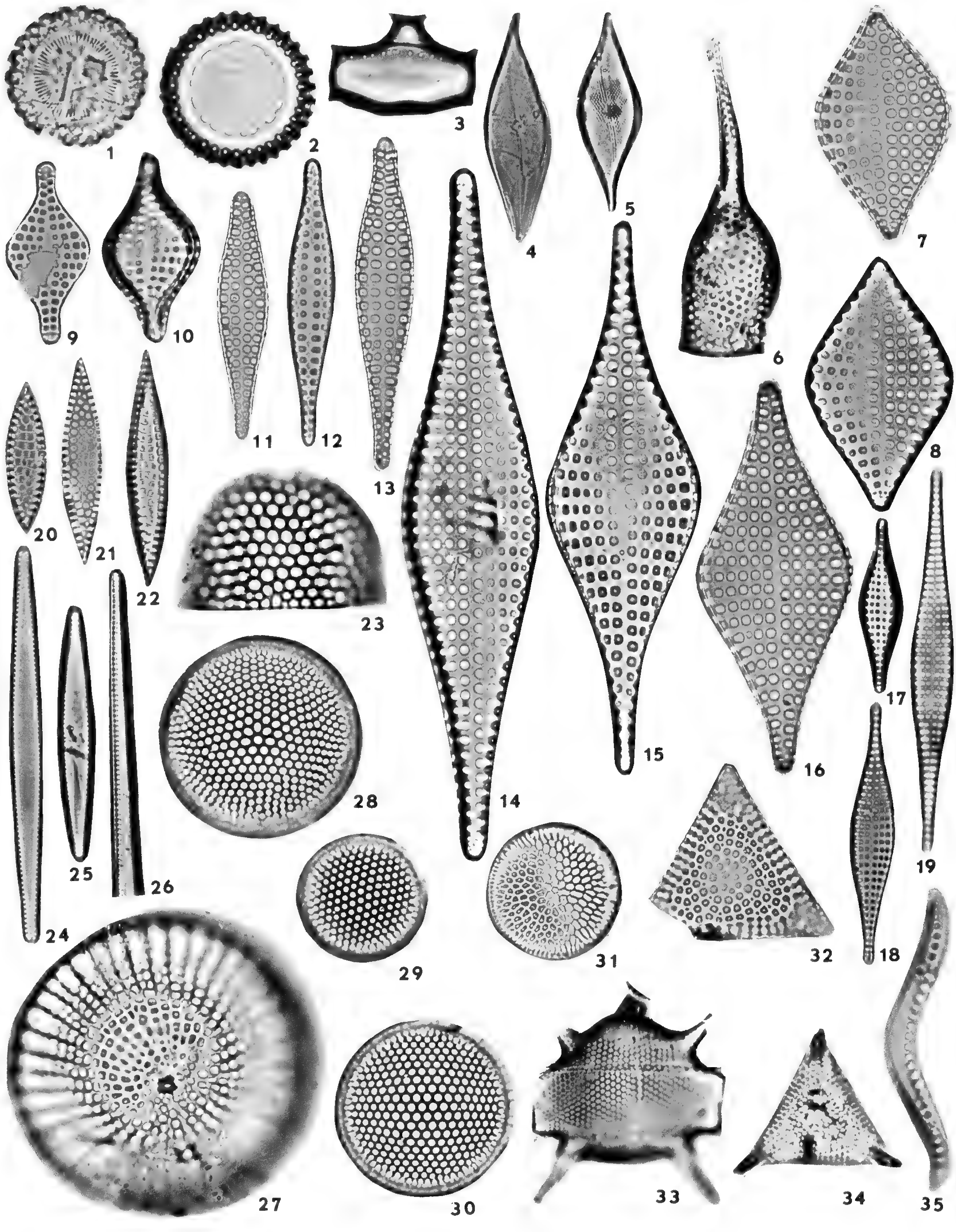
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| 6. | ***Pyrgupyxis johnsoniana*** Hendey<br>USGS Diatom Cat. no. 3970-38, ×1000, length 66 μm. | 82 |
| 7, 8. | ***Rhaphoneis adamantea*** Andrews<br>7. USGS Diatom Cat. no. 3969-19, ×1000, length 45 μm.<br>8. USGS Diatom Cat. no. 3969-55, ×1000, length 48 μm. | 82 |
| 9, 10. | ***Rhaphoneis elegans*** (Pantocsek and Grunow) Hanna<br>9. USGS Diatom Cat. no. 3963-7, ×1000, length 35 μm.<br>10. USGS Diatom Cat. no. 3967-27, ×1000, length 36 μm. | 83 |
| 11–13. | ***Rhaphoneis fusiformis*** Andrews<br>11. USGS Diatom Cat. no. 3969-17, ×1000, length 41 μm.<br>12. USGS Diatom Cat. no. 3953-7, ×1000, length 54 μm.<br>13. USGS Diatom Cat. no. 3953-42, ×1000, length 63 μm. | 83 |
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| 24. | ***Thalassionema nitzschioides*** (Grunow) Hustedt<br>USGS Diatom Cat. no. 3959-10, ×1000, length 75 μm. | 86 |
| 25. | ***Thalassionema obtusum*** (Grunow) Andrews<br>USGS Diatom Cat. no. 3969-45, ×1000, length 48 μm. | 86 |
| 26. | ***Thalssiothrix longissima*** Cleve and Grunow<br>USGS Diatom Cat. no. 3990-35, ×1000, length of fragment 61 μm. | 86 |
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| 28. | ***Thalassiosira eccentrica*** (Ehrenberg) Cleve<br>USGS Diatom Cat. no. 3953-5, ×1000, diameter 37 μm. | 86 |
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| 33, 34. | ***Triceratium spinosum*** Bailey<br>33. Girdle view, USGS Diatom Cat. no. 3969-78, ×1000, width 35 μm.<br>34. Valve view, USGS Diatom Cat. no. 3970-15, ×1000, height 26 μm. | 87 |
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| 2. | ***Eunotia parallela*** Ehrenberg<br>USGS Diatom Cat. no. 4165-15, ×500, length 108 μm. | 88 |
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| 9. | ***Nitzschia hybrida*** Grunow<br>USGS Diatom Cat. no. 4165-5, ×1000, length of fragment 52 μm. | 90 |
| 10. | ***Nitzschia tryblionella*** var. ***victoriae*** (Grunow) Grunow<br>USGS Diatom Cat. no. 4165-22, ×1000, length 55 μm. | 90 |
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| 12. | ***Caloneis westii*** (Smith) Hendey<br>USGS Diatom Cat. no. 4165-4, ×1000, length 60 μm. | 88 |
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| 16. | ***Stauroneis*** aff. ***S. salina*** Smith<br>USGS Diatom Cat. no. 4165-17, ×1000, length 41 μm. | 91 |
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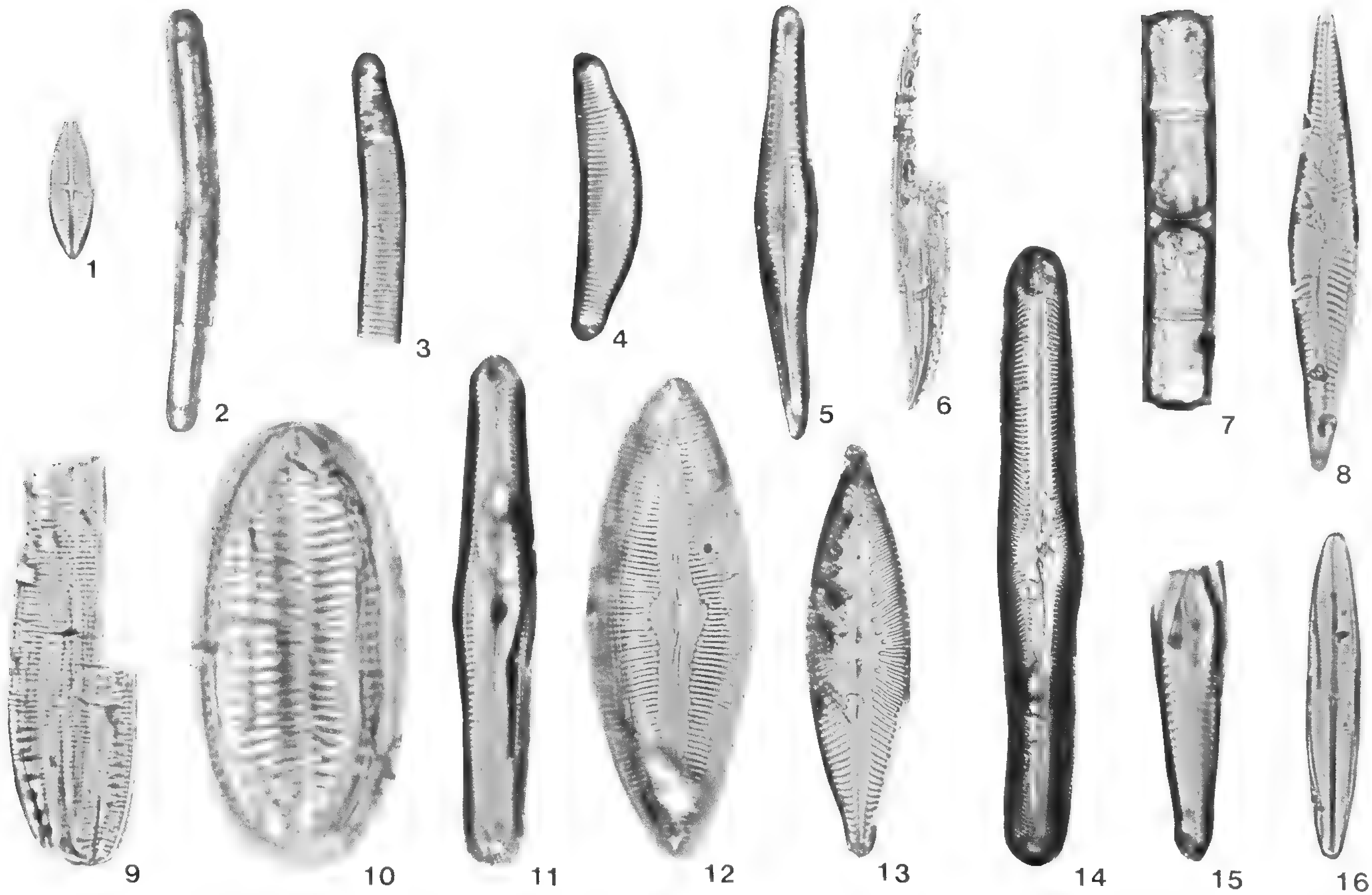


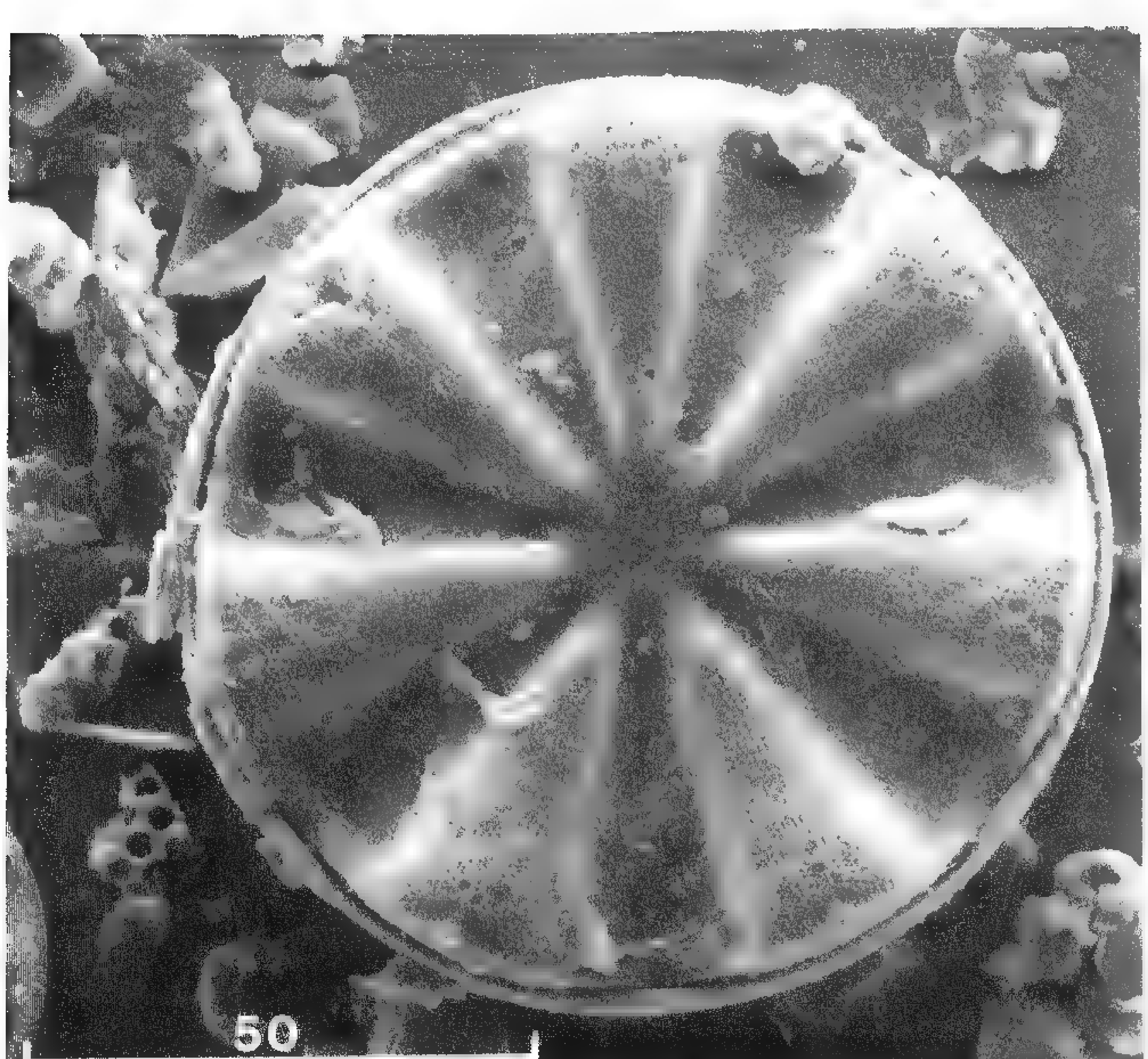


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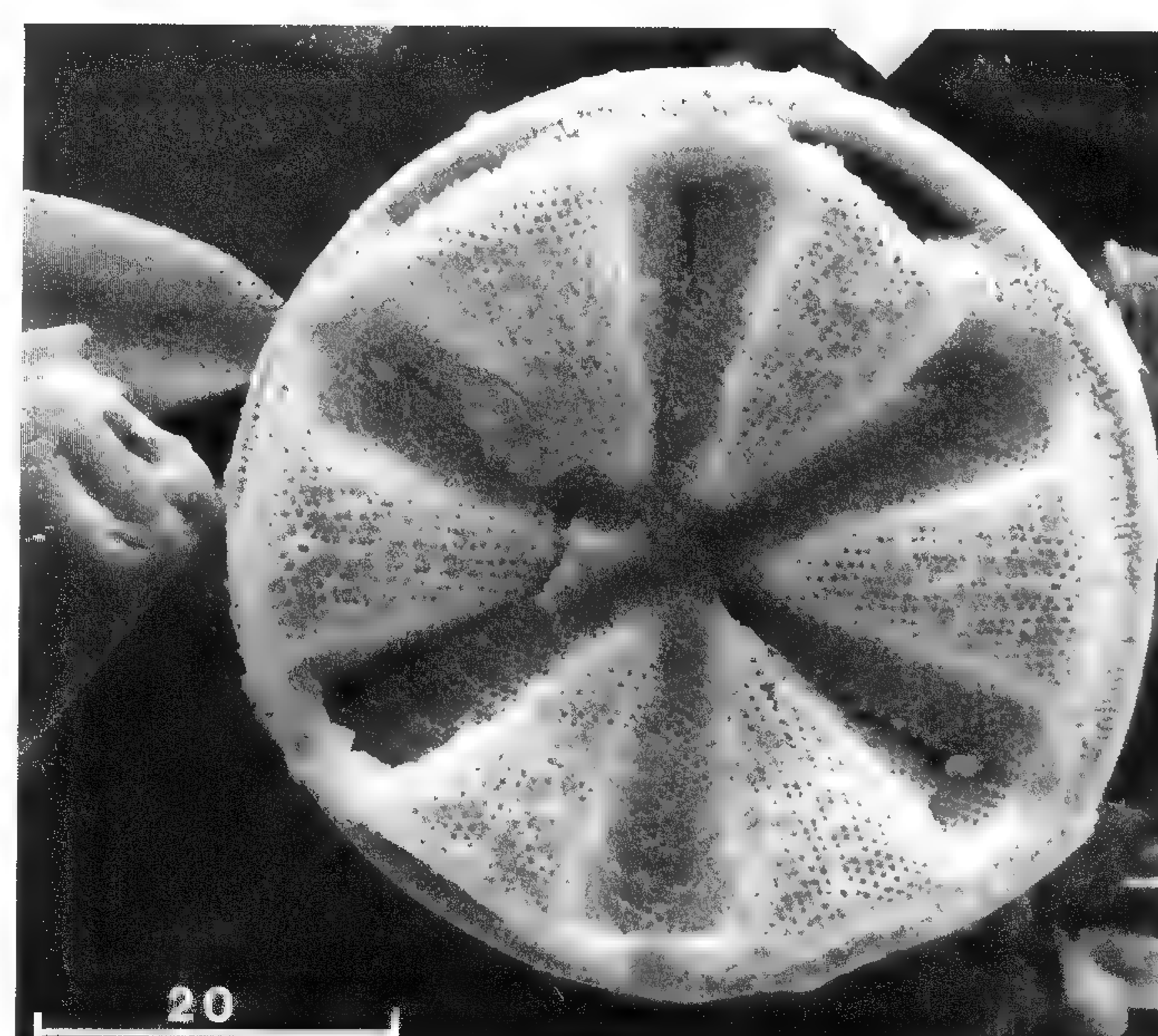


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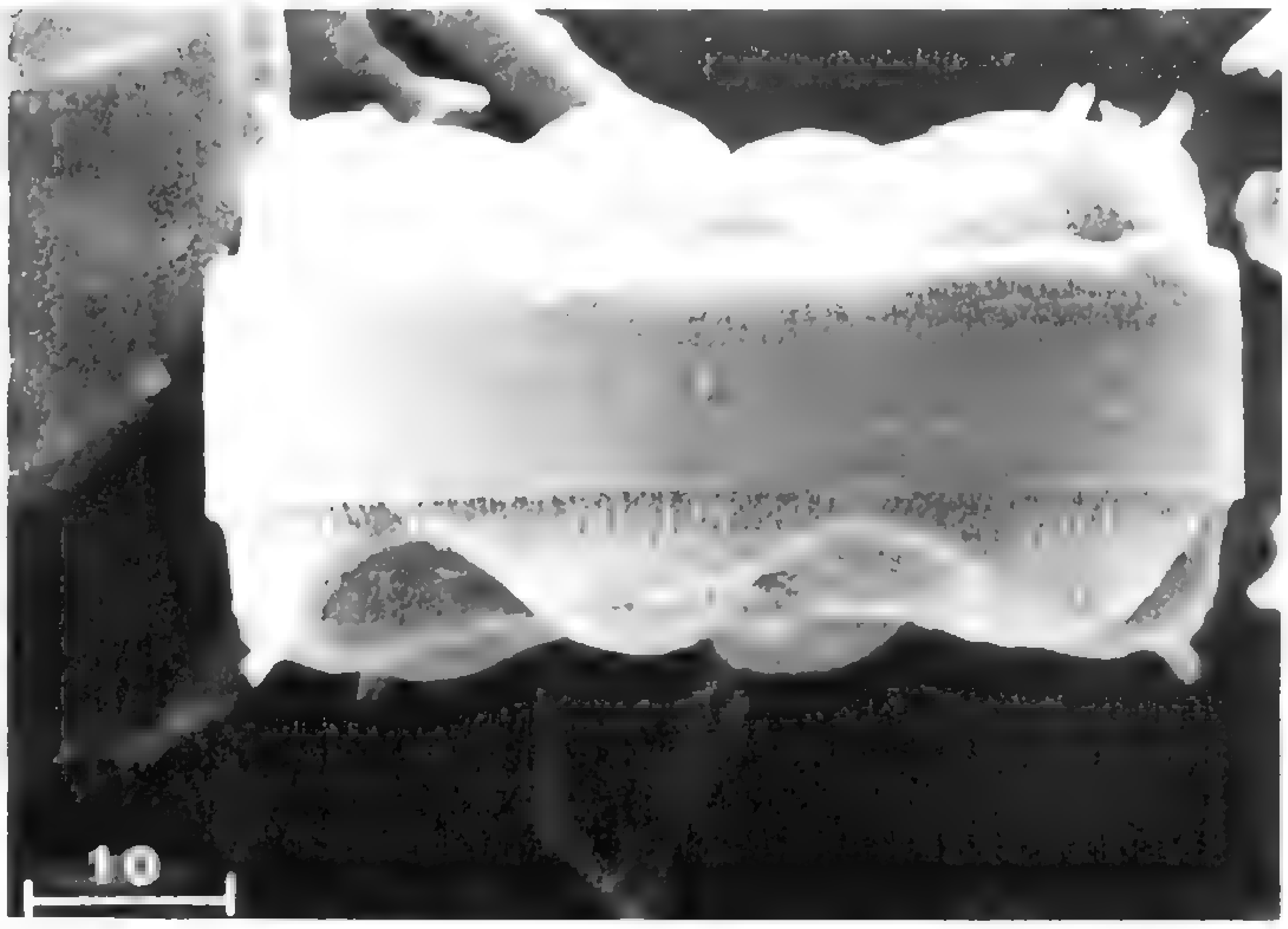


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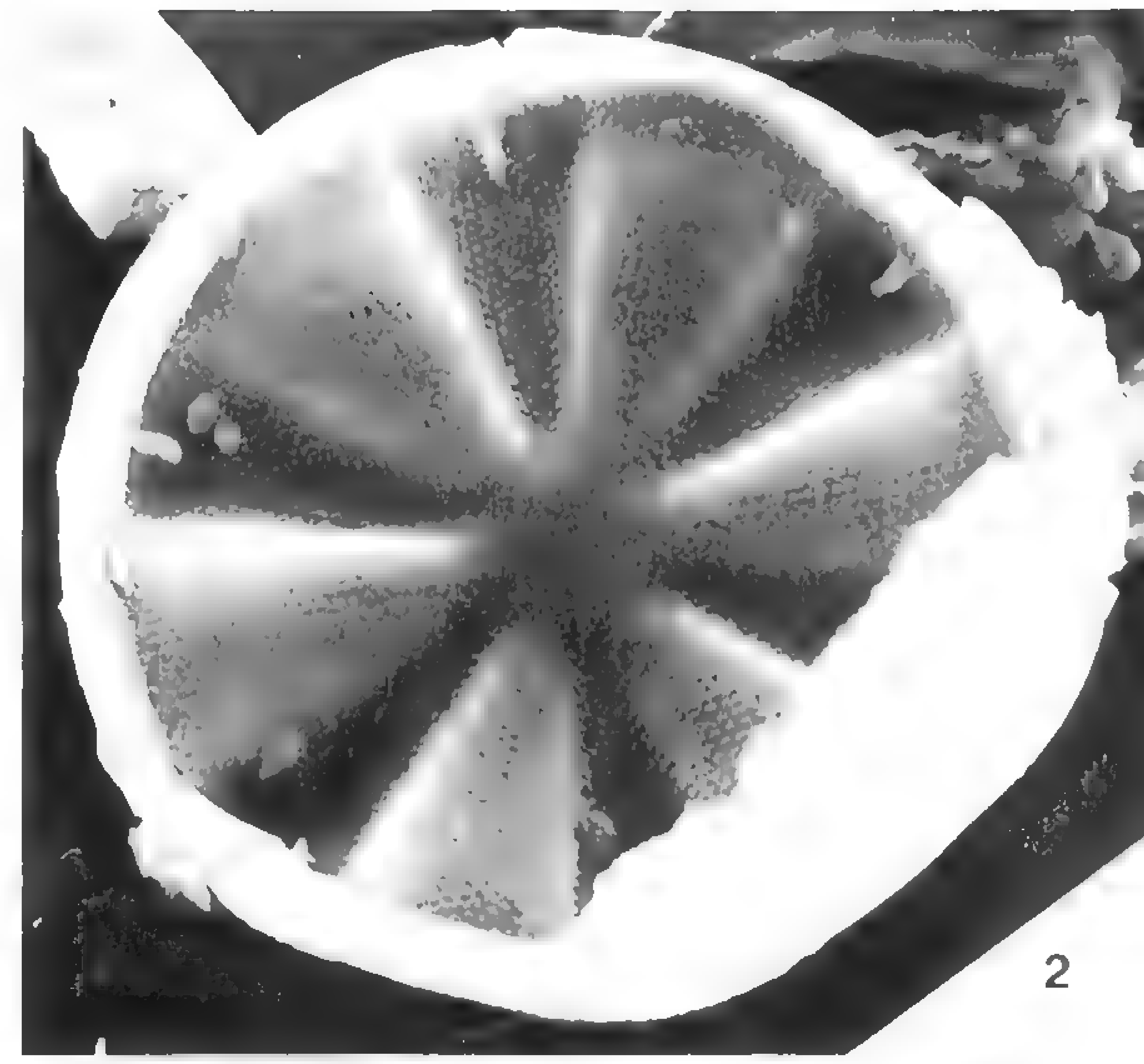

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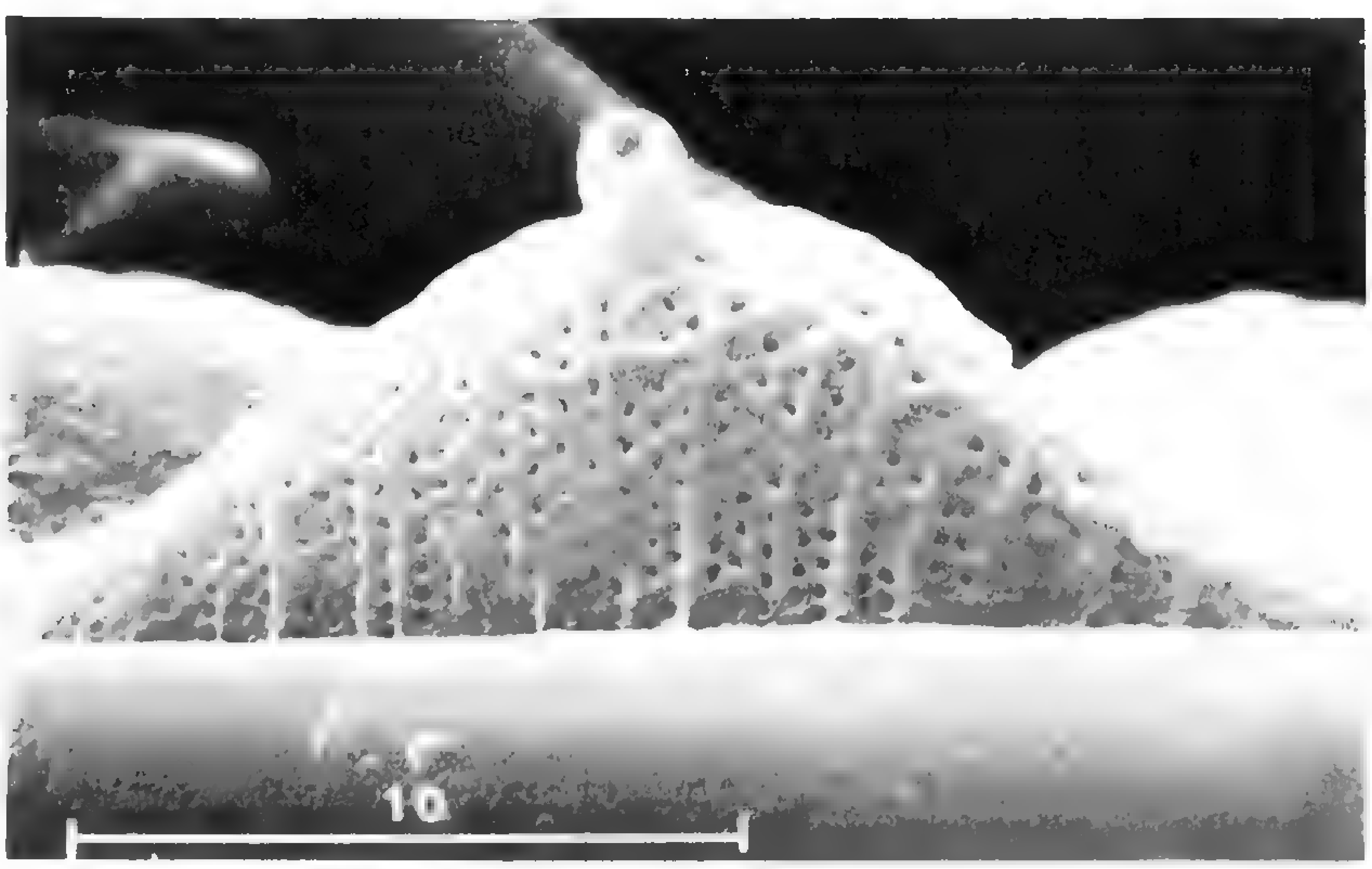


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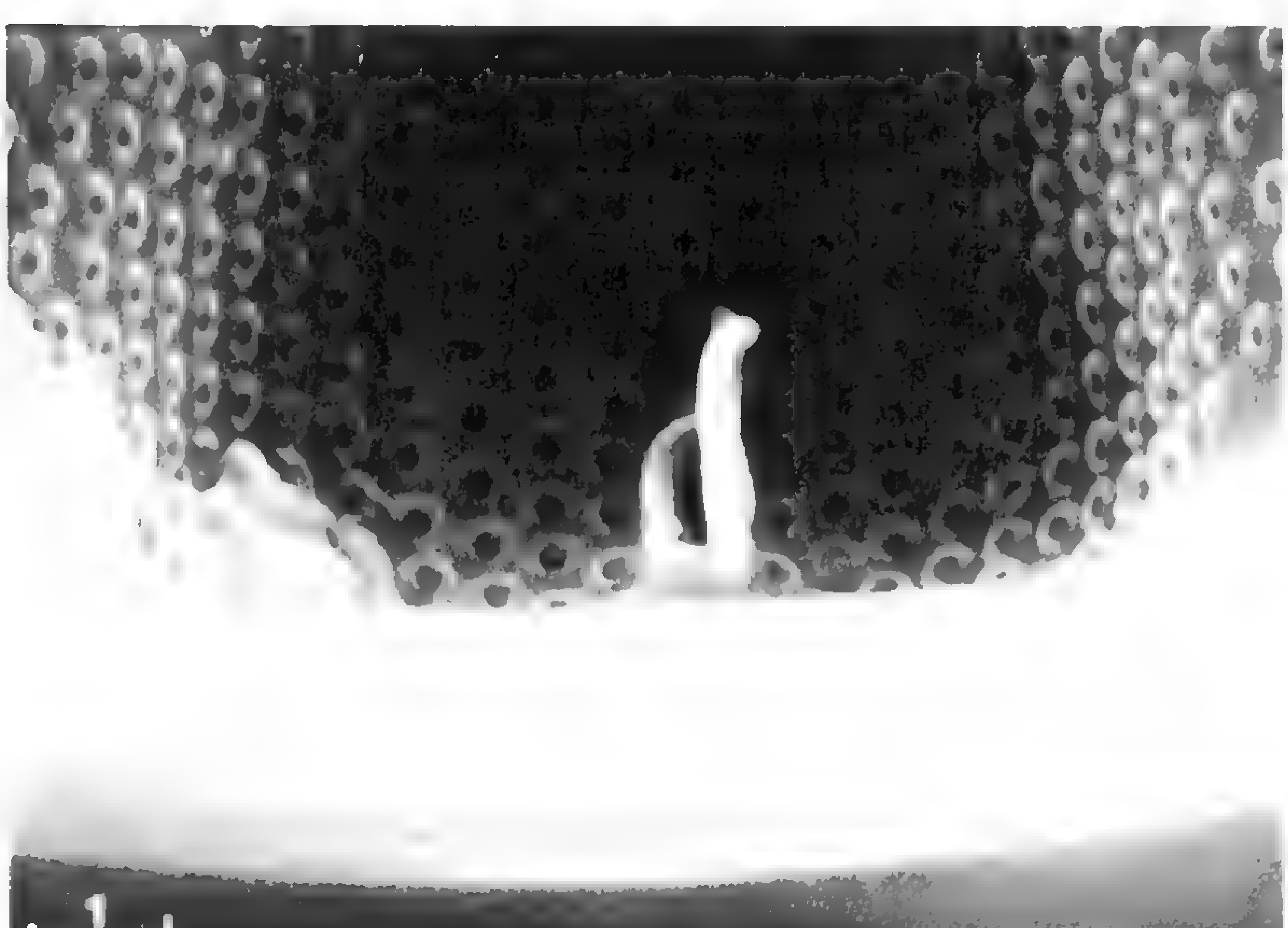


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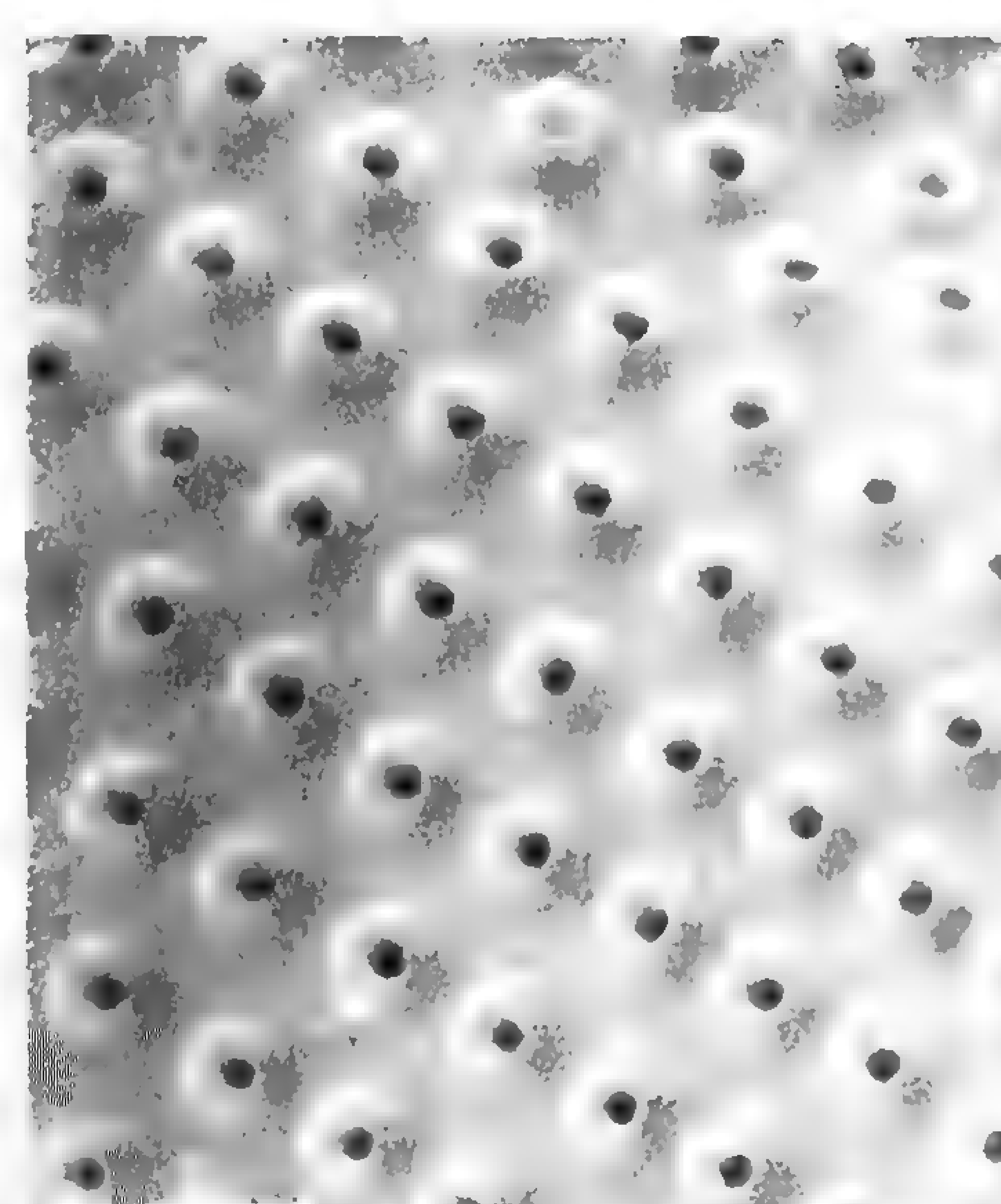

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## EXPLANATION OF PLATE 11

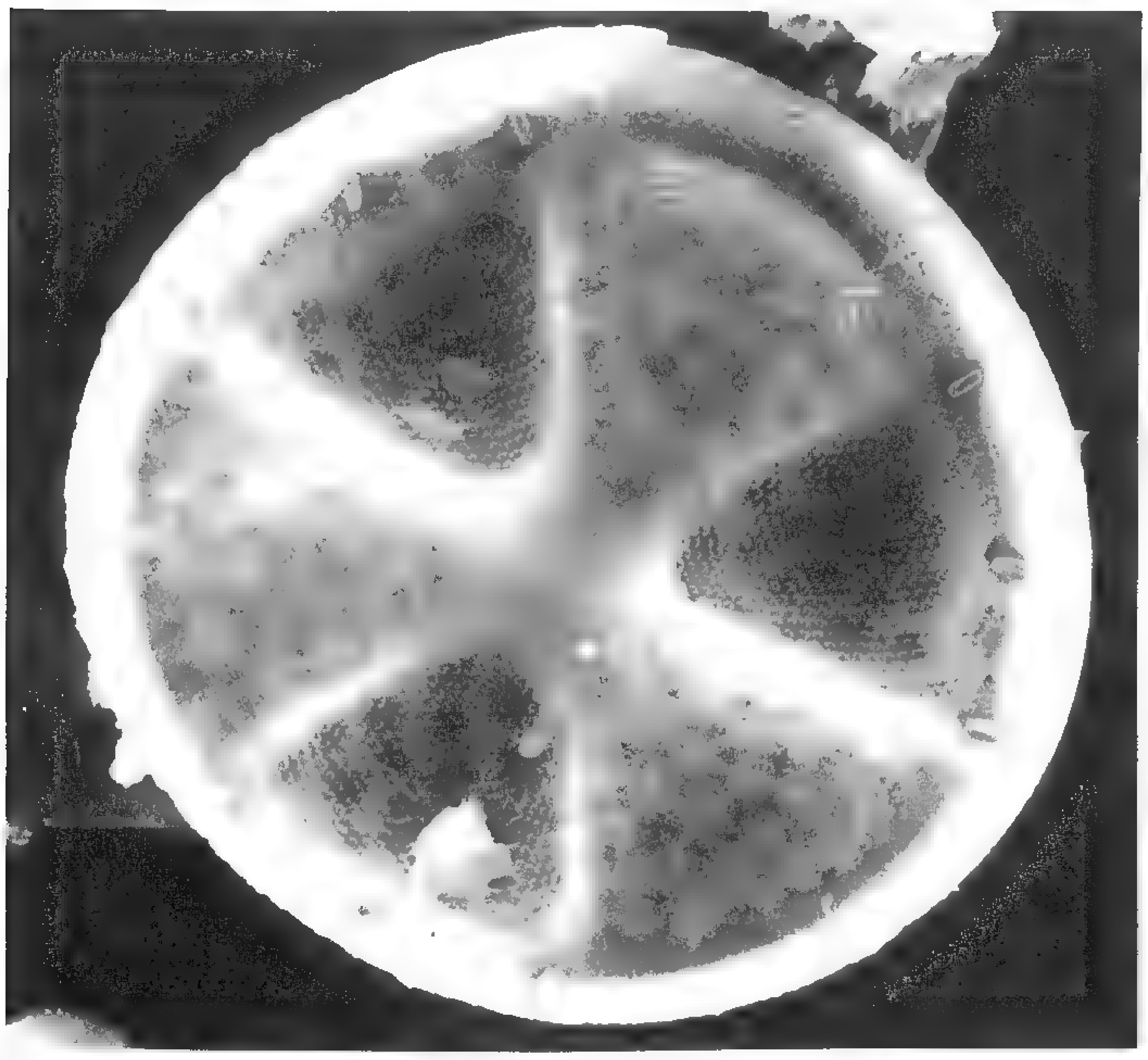
### Scanning electron micrographs

| Figure | | Page |
|---|---|---|
| 1–6. | ***Actinoptychus aequalis*** Andrews, new species | 69 |

1. Girdle view of frustule, 12-sectored specimen, USGS diatom locality 6469, ×1500, diameter 49 μm.
2. Interior of 12-sectored specimen, USGS diatom locality 6469, ×1700, diameter 41 μm.
3. Detail of edge of valve shown in figure 1, ×5250.
4. Detail of labiate process in specimen shown in figure 2, ×27,500.
5. Detail of inside of valve and aberrant labiate process, USGS diatom locality 6469, ×10,000.
6. Detail of pore structure on interior of valve, same specimen as figure 5, ×15,000.

## EXPLANATION OF PLATE 12

### Scanning electron micrographs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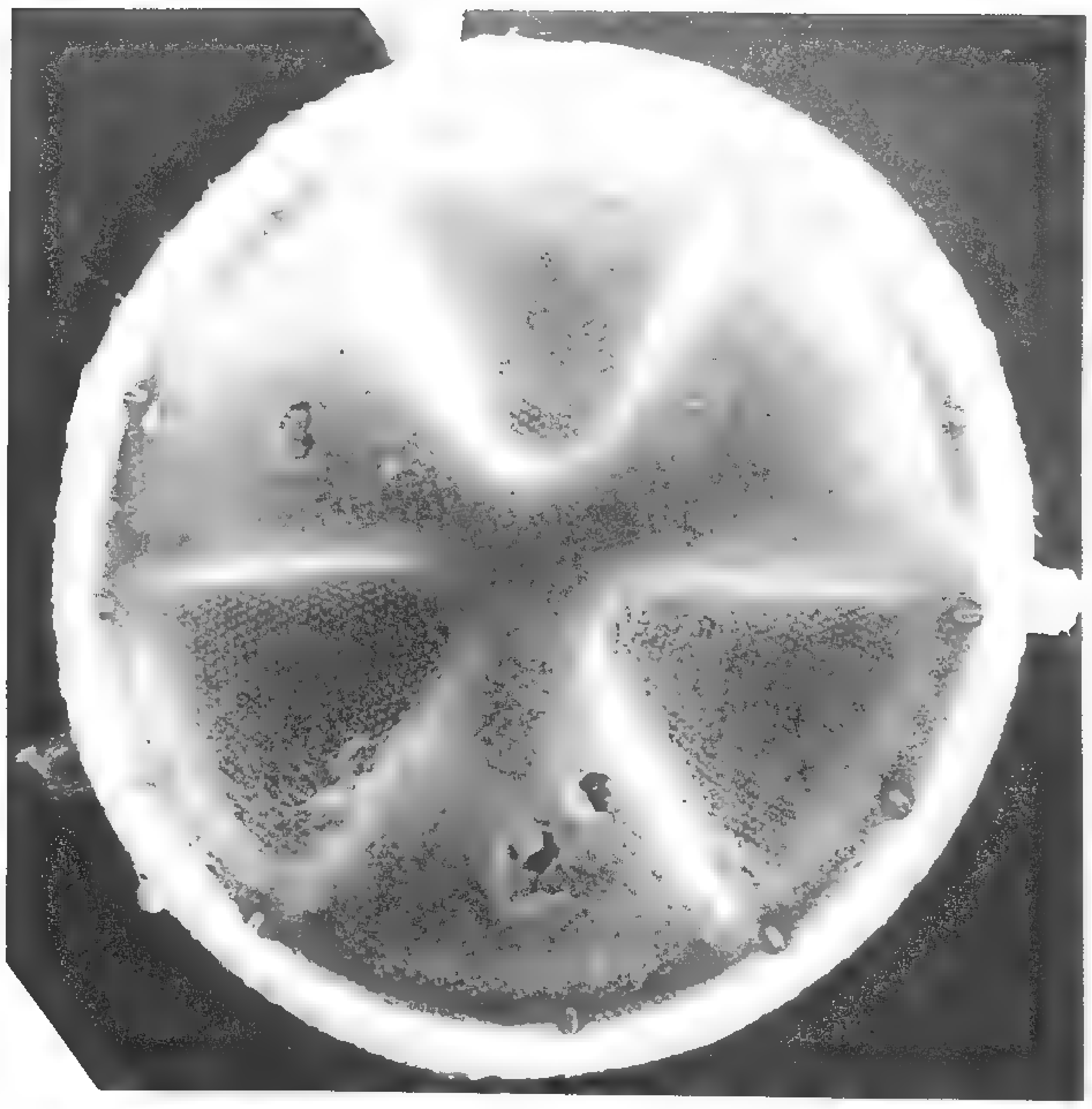
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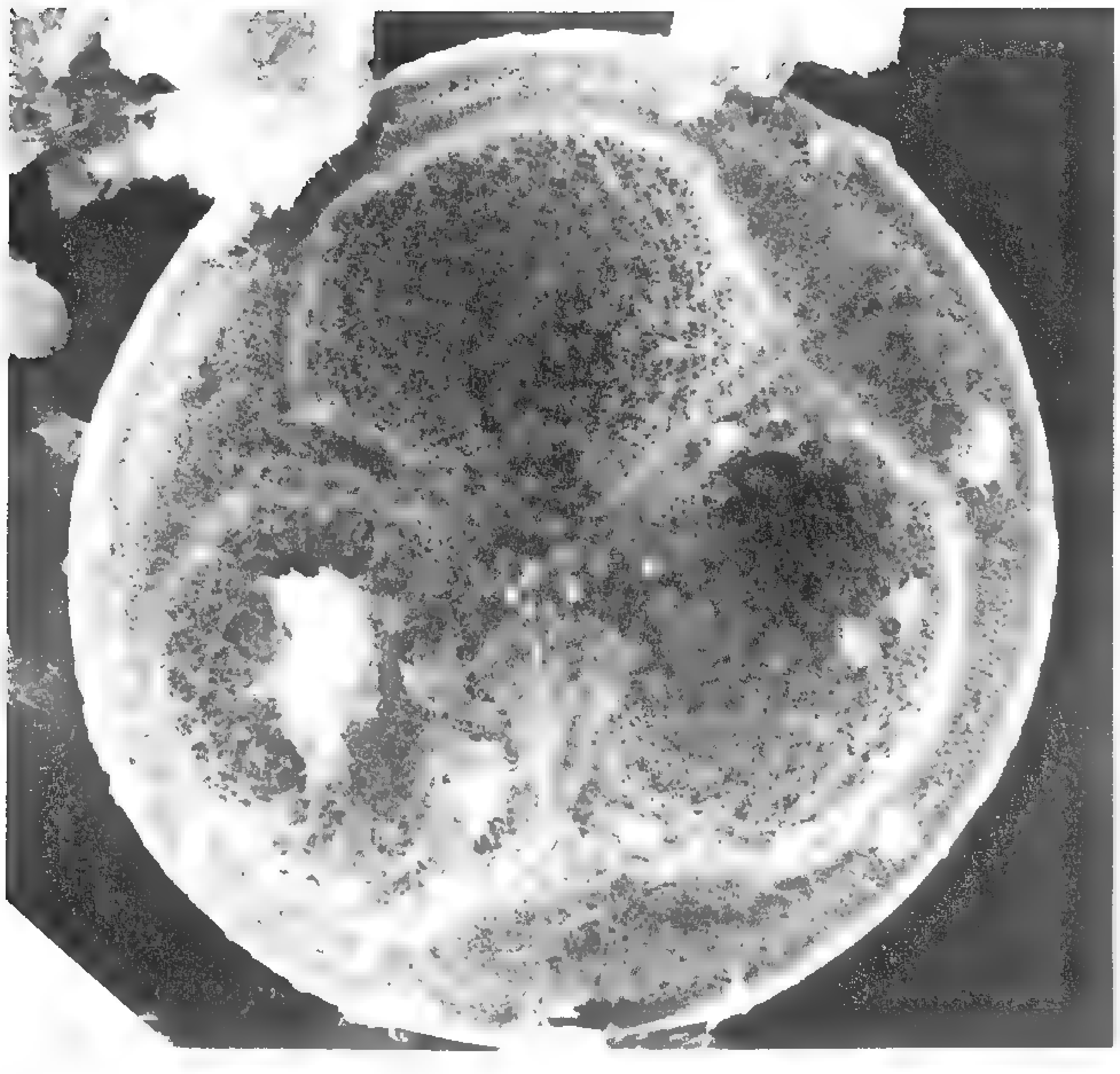
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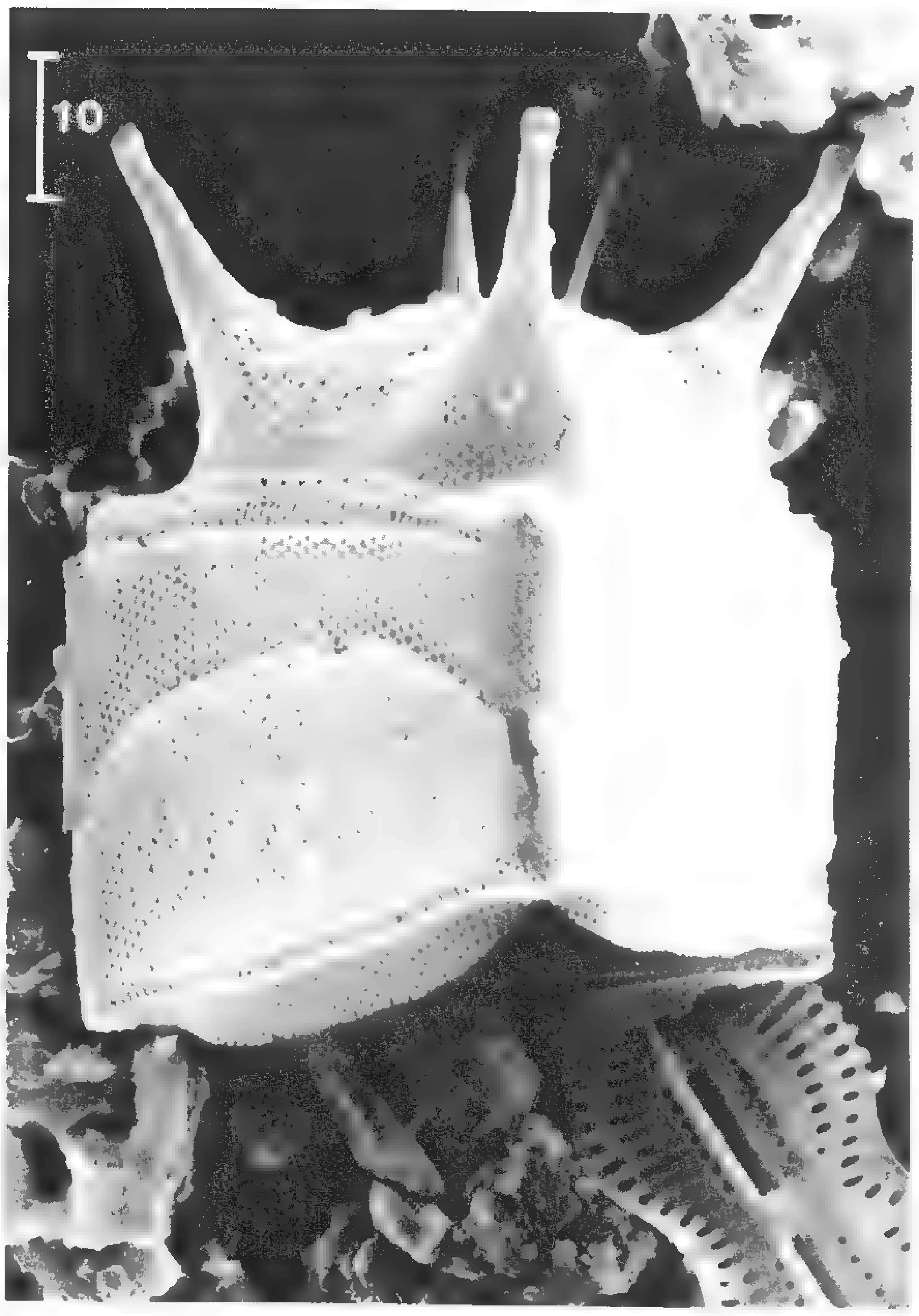

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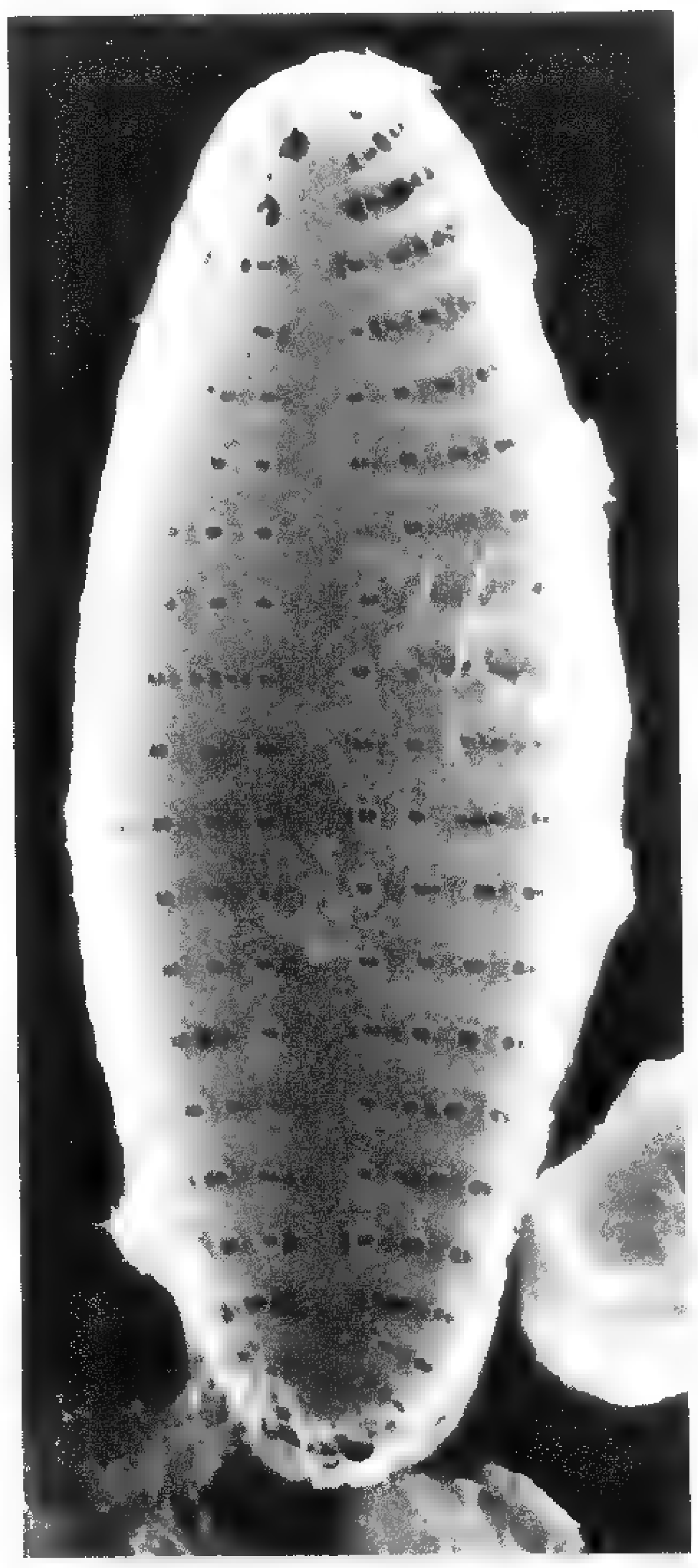
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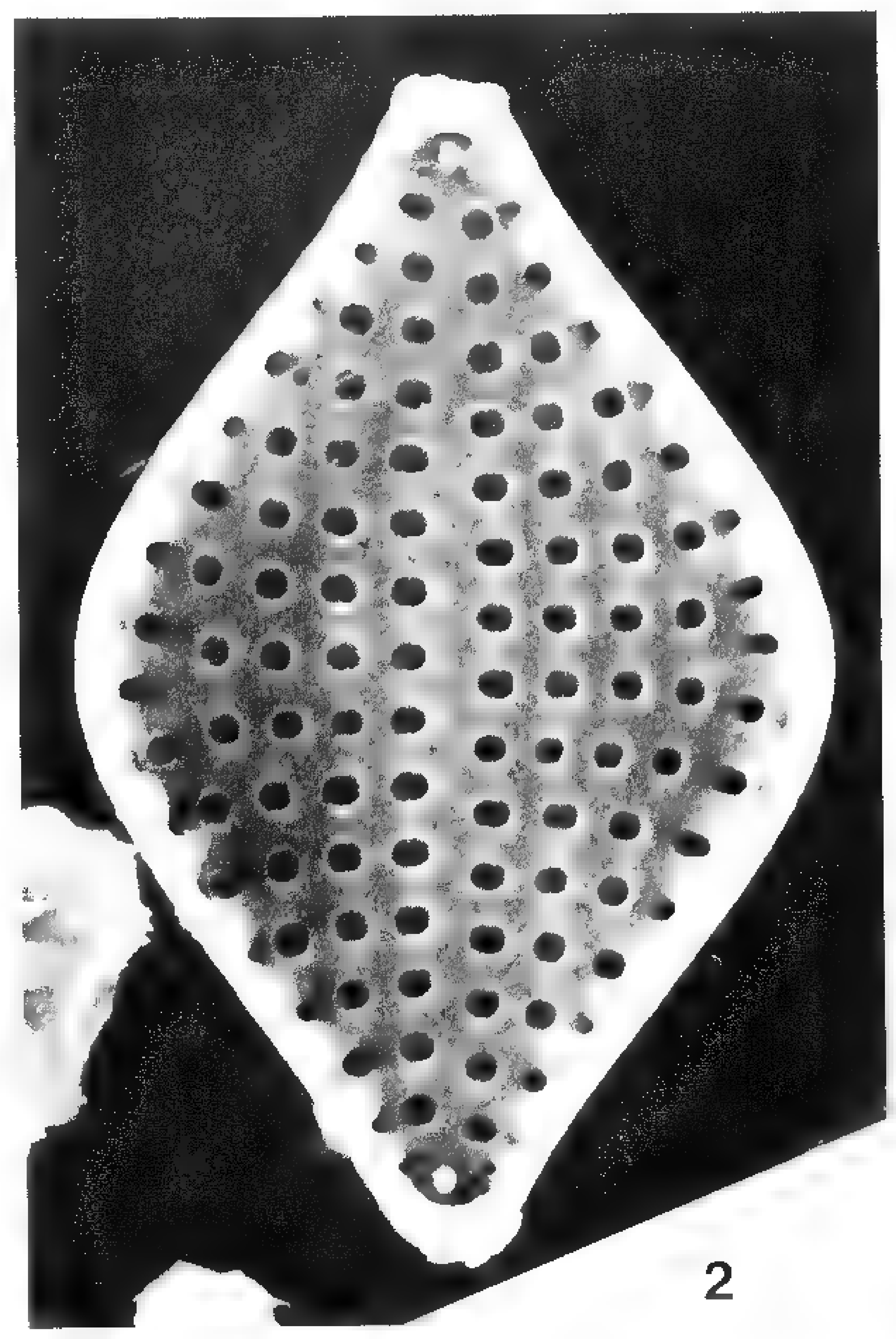
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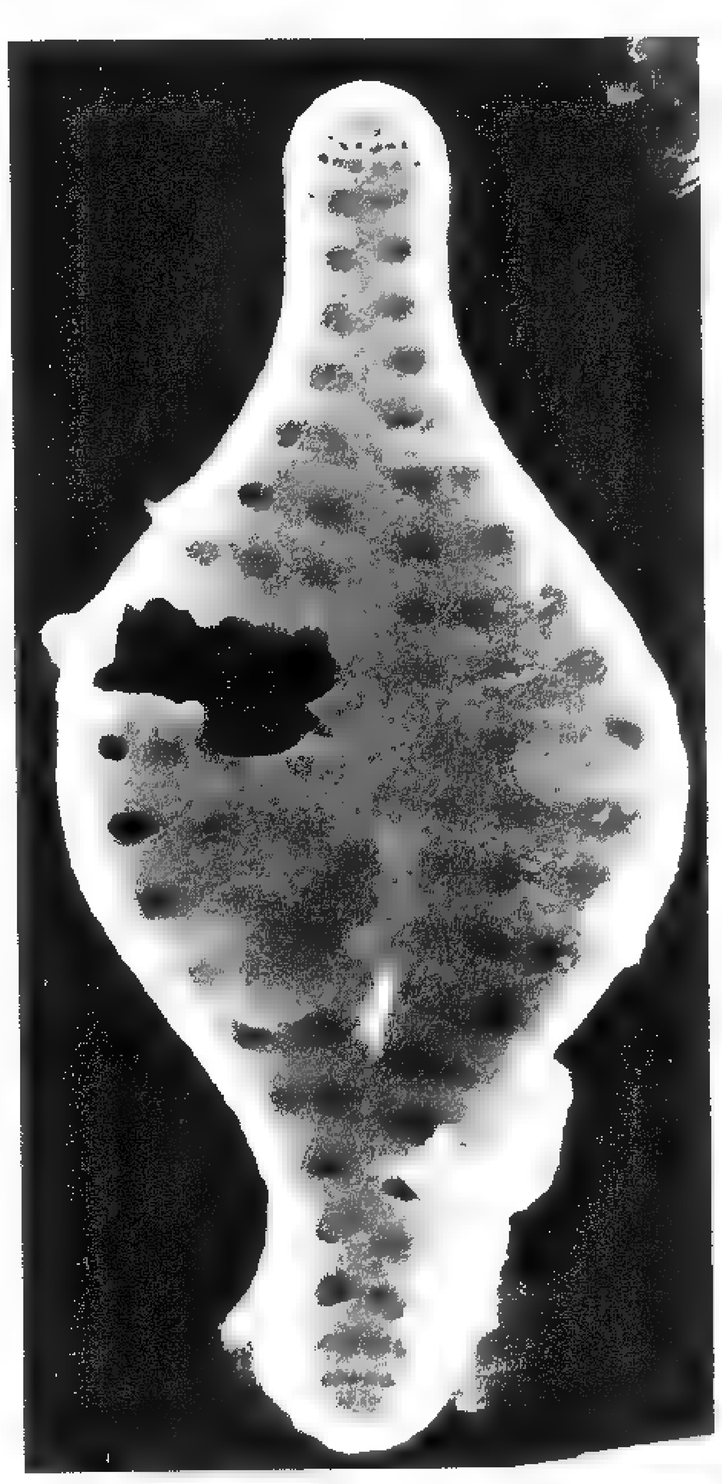
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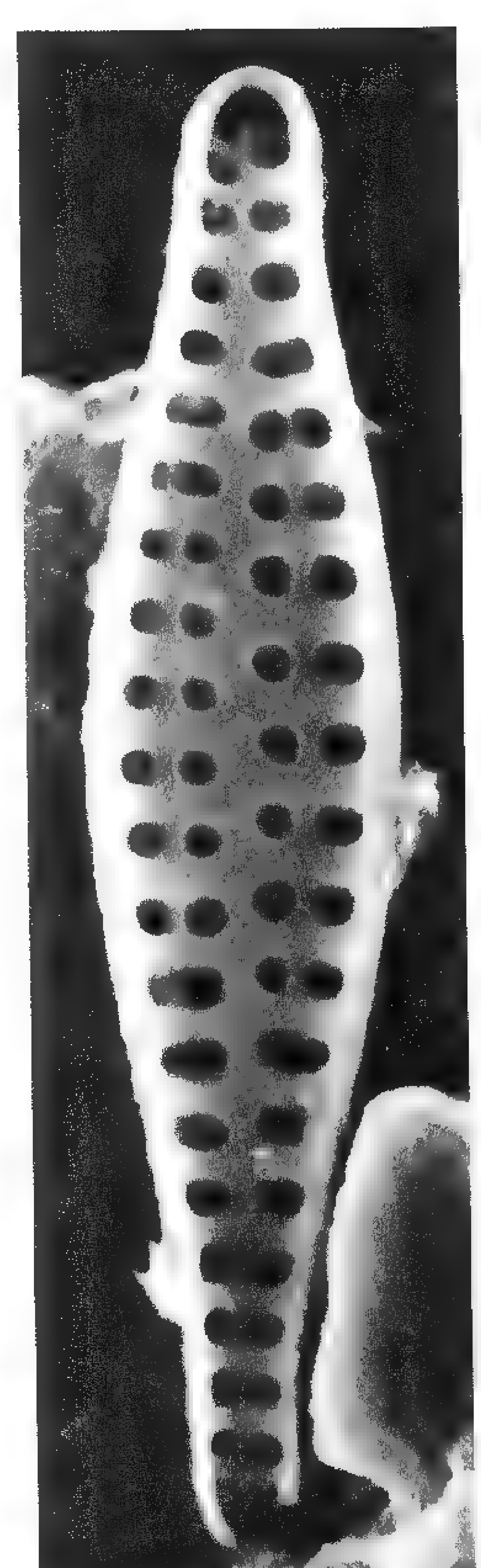
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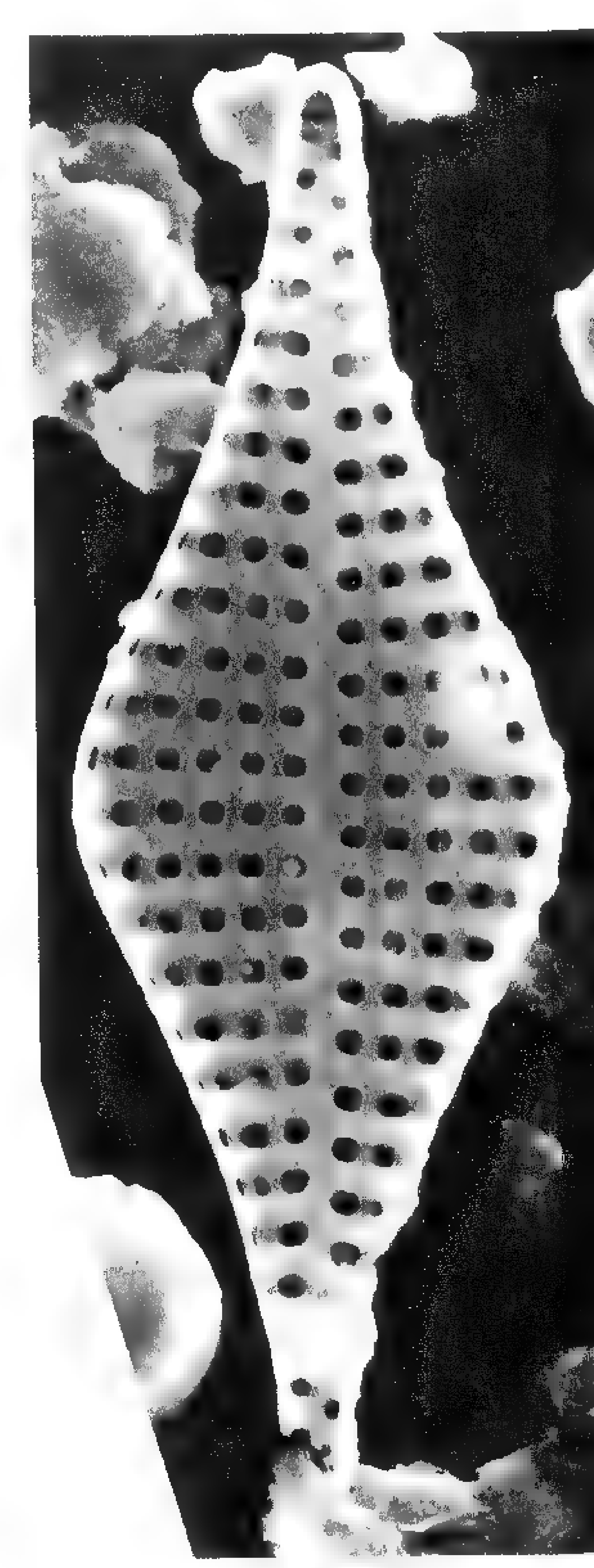
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## EXPLANATION OF PLATE 13

### Scanning electron micrographs

| Figure | | Page |
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| 1. | ***Delphineis penelliptica*** Andrews | 77 |
| | Exterior of valve, USGS diatom locality 5578, ×3500, length 24 $\mu$m. | |
| 2, 3. | ***Rhaphoneis adamantea*** Andrews | 82 |
| | 2. Interior of valve, USGS diatom locality 5578, ×1600, length 44 $\mu$m. | |
| | 3. Detail of interior of another specimen, same locality, showing labiate process and sieve plates, ×8900. | |
| 4. | ***Rhaphoneis elegans*** (Pantocsek and Grunow) Hanna | 83 |
| | Exterior of valve, USGS diatom locality 6468, ×2000, length 38 $\mu$m. | |
| 5. | ***Rhaphoneis fusiformis*** Andrews | 83 |
| | Interior of valve, USGS diatom locality 5578, ×2400, length 46 $\mu$m. | |
| 6. | ***Rhaphoneis parilis*** Hanna | 83 |
| | Interior of valve, USGS diatom locality 5578, ×1500, length about 70 $\mu$m. | |
| 7. | ***Rhaphoneis magnapunctata*** Andrews | 83 |
| | Interior of valve, USGS diatom locality 5578, ×1200, length about 78 $\mu$m. | |

# INDEX

Note: Page numbers are in light face, plate numbers are in **bold face** type; numbers in *italics* indicate principal discussions.

## MARINE ASSEMBLAGES

Table 1.—Relative frequency of occurrence of marine diatom taxa in the Coosawhatchie equivalent beds, Thomas County, Georgia. Estimated relative frequency under 18 mm cover glass viewed at ×250 is defined as follows: A = abundant (at least one specimen in all fields of view); C = common (one specimen in many, but not all, fields of view); F = frequent (several specimens observed on slide but seen only in a few fields of view); R = rare (about one or two specimens observed on a slide).

| SAMPLE NUMBER & STRATIGRAPHIC POSITION | Actinocyclus octonarius | Actinocyclus tenellus | Actinoptychus aequalis, n. sp. | Actinoptychus marylandicus | Actinoptychus senarius | Actinoptychus thumii | Amphiprora aff. A. alata | Aulacodiscus argus | Aulacosira italica | Auliscus sculptus | Biddulphia aurita | Biddulphia tuomeyi | Coscinodiscus curvatulus | Coscinodiscus lacustris | Coscinodiscus oculus-iridis | Coscinodiscus perforatus | Coscinodiscus perforatus var. cellulosus | Coscinodiscus rothii | Cymatogonia amblyoceros | Cymatosira belgica | Cymatosira immunis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FE110, 4.6 m (15 ft.) | | R | C | | R | R | | F | | | R | F | | | | R | | | R | R | |
| FE109, 6.1 m (18 ft.) | | | | | | | | | | | | | | | | | | | | | |
| 6469, 8.8 m (29 ft.) | R | | C | | R | | | | R | | | F | | | | | | F | | | |
| FE106, 10.4 m (34 ft.) | R | R | | | F | | | R | | | R | R | | | | | F | R | F | F | |
| 6468, 12.8 m (42 ft.) | R | F | F | | F | | | R | | | | R | R | | | F | F | R | R | F | R |
| 6467, 13.7 m (45 ft.) | | F | | | F | | | R | | | | R | | R | R | F | R | R | R | F | |
| 6466, 14.6 m (48 ft.) | R | F | | R | F | | | F | | R | | F | | | | | F | R | R | F | |
| 6465, 15.5 m (51 ft.) | | F | | | F | | | F | | | | R | | | | R | F | R | R | F | |
| 6464, 16.5 m (54 ft.) | R | F | R | | F | | | F | | | | | | | | | F | R | R | F | |
| 6463, 17.4 m (57 ft.) | R | F | R | | F | | | F | | | R | R | R | | | F | R | R | R | F | |
| 6462, FE100, 18.3 m (60 ft.) | R | F | R | | F | | R | F | | R | | F | R | | | R | R | R | R | F | R |
| 6461, 19.2 m (63 ft.) | | R | | | F | | | F | | | | F | | | | R | | R | | R | |

| SAMPLE NUMBER & STRATIGRAPHIC POSITION | Cymatosira lorenziana | Delphineis angustata | Delphineis novaecaesaraea | Delphineis penelliptica | Diploneis crabro | Diploneis aff. D. suborbicularis | Endictya oceanica | Grammatophora marina | Gyrosigma sp. | Hemiaulus bipons | Hyalodiscus scoticus | Liradiscus bipolaris | Lithodesmium ehrenbergii | Lithodesmium undulatum | Melosira westii | Navicula arenaria | Navicula maculata | Nitzschia sp. A | Paralia complexa | Paralia sulcata | Paralia sulcata var. coronata |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FE110, 4.6 m (15 ft.) | | | | | R | | R | | | | F | | | | | | R | | R | F | F |
| FE109, 6.1 m (18 ft.) | | | | | | | | | | | | | | | | | | | | | |
| 6469, 8.8 m (29 ft.) | | | | | | | | R | | | F | | | | R | | | | | F | F |
| FE106, 10.4 m (34 ft.) | | R | | R | F | | R | | | | | | | | R | | | | | F | F |
| 6468, 12.8 m (42 ft.) | | R | | F | F | F | R | | R | R | R | | | | R | R | | R | | C | C |
| 6467, 13.7 m (45 ft.) | | | | R | F | | R | R | | | R | | | | | | | | R | C | C |
| 6466, 14.6 m (48 ft.) | | | | R | F | | | R | | | R | | | | R | | | | | C | C |
| 6465, 15.5 m (51 ft.) | | R | | F | F | R | | | | | R | | | | | | | | | C | C |
| 6464, 16.5 m (54 ft.) | | | R | R | F | R | | R | | R | R | R | | | | | | R | | C | C |
| 6463, 17.4 m (57 ft.) | | | | R | F | | | | | R | R | | | | R | | | | | C | F |
| 6462, FE100, 18.3 m (60 ft.) | R | | | R | F | | R | R | | R | R | | R | R | F | | R | | R | C | C |
| 6461, 19.2 m (63 ft.) | | | | R | F | | | | | | R | | | | | | | | | F | F |

| SAMPLE NUMBER & STRATIGRAPHIC POSITION | Periptera petiolata | Pleurosigma aff. P. aestuarii | Pyrgupyxis johnsoniana | Rhaphoneis adamantea | Rhaphoneis elegans | Rhaphoneis fusiformis | Rhaphoneis magnapunctata | Rhaphoneis parilis | Rossiella paleacea | Stephanopyxis turris | Stictodiscus kittonianus | Thalassionema nitzschiodes | Thalassionema obtusum | Thalassiosira eccentrica | Thalassiosira leptopus | Thalassiosira sp. A | Thalassiothrix longissima | Triceratium condecorum | Triceratium spinosum | Gen. et sp. indet. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FE110, 4.6 m (15 ft.) | | | | | | | | | | | | | | | | | | | | |
| FE109, 6.1 m (18 ft.) | | | | | | | | | | | | | | | | | | | | |
| 6469, 8.8 m (29 ft.) | R | R | | R | | | R | R | | | | | | | | | | | R | |
| FE106, 10.4 m (34 ft.) | | | R | F | | R | F | F | | R | | | | | R | | | | R | |
| 6468, 12.8 m (42 ft.) | | R | | F | | F | F | F | R | R | | R | R | R | R | | | F | R | |
| 6467, 13.7 m (45 ft.) | | | | F | R | R | F | F | | | | R | | R | R | | | R | | R |
| 6466, 14.6 m (48 ft.) | | | | F | | R | F | F | R | R | | R | | R | R | | | R | | R |
| 6465, 15.5 m (51 ft.) | | R | | F | R | F | F | F | F | | | R | | R | R | | | R | R | R |
| 6464, 16.5 m (54 ft.) | | R | | F | | F | F | F | F | | | R | | R | R | R | | F | | R |
| 6463, 17.4 m (57 ft.) | | R | | F | | F | F | F | | R | R | R | | R | R | | | R | R | |
| 6462, FE100, 18.3 m (60 ft.) | R | R | | F | | F | F | F | | R | | R | | R | R | | R | F | R | R |
| 6461, 19.2 m (63 ft.) | | | | R | | | F | | | | | | | | | | | | R | |

# PREPARATION OF MANUSCRIPTS

*Bulletins of American Paleontology* usually comprises two or more separate monographs in two volumes each year. This series is a publication outlet for significant longer paleontological monographs for which high quality photographic illustrations and the large quarto format are a requisite.

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Authors must provide three (3) copies of the text and accompanying illustrative material. The text and line-drawings may be reproduced xerographically, but glossy prints at publication scale must be supplied for all half-tone illustrations and photographic plates. These prints should be identified clearly on the back.

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Authors are requested to enclose $10 with each manuscript submitted, to cover costs of postage during the review process.

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Collinson, J.
1962. *Size of lettering for text-figures.* Journal of Paleontology, vol. 36, p. 1402.

Gilbert Dennison Harris
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