Miocene Marine Diatoms From the Choptank Formation, Calvert County, Maryland

GEOLOGICAL SURVEY PROFESSIONAL PAPER 910

Miocene Marine Diatoms From the Choptank Formation, Calvert County, Maryland

By GEORGE W. ANDREWS

GEOLOGICAL SURVEY PROFESSIONAL PAPER 910

A description of a middle Miocene marine diatom assemblage for the Atlantic Coastal Plain region and its stratigraphic and paleoecologic significance

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1976

UNITED STATES DEPARTMENT OF THE INTERIOR

THOMAS S. KLEPPE, ***Secretary***

GEOLOGICAL SURVEY

V. E. McKelvey, ***Director***

Library of Congress Cataloging in Publication Data

Andrews, George William, 1929–
Miocene marine diatoms from the Choptank Formation, Calvert County, Maryland.

(Geological Survey professional paper ; 910)
Bibliography: p.
Includes index.
Supt. of Docs. no.: I 19.16:910

1. Diatoms, Fossil. 2. Paleontology—Miocene. 3. Paleontology—Maryland—Calvert Co. I Title II. Series: United States. Geological Survey. Professional paper ; 910.
QE955.A62 561'.93 74–34195

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402
Stock Number 024-001-02735-6

CONTENTS

ILLUSTRATIONS

[Plates follow index]

TABLE

MIOCENE MARINE DIATOMS FROM THE CHOPTANK FORMATION, CALVERT COUNTY, MARYLAND

By GEORGE W. ANDREWS

ABSTRACT

The Choptank Formation of Miocene age contains diatom-bearing strata in outcrops in the Calvert Cliffs on the west side of Chesapeake Bay. A good diatom assemblage is present in the upper part (stratigraphic zone 19 of Shattuck [1904]) in the section exposed immediately north of the Calvert Cliffs nuclear power plant, Calvert County, Md.

The Choptank Formation has long been correlated with the middle Miocene of the European section principally on the basis of its molluscan fauna. Recent studies of planktonic Foraminifera suggest that it correlates with either the upper Langhian, the Serravalian, or the Tortonian Stages (middle to upper Miocene), but a more precise determination has not yet been made. The macrofauna and microfauna of the formation are suggestive of deposition in a shallow, inner-shelf marine environment. The diatom assemblage in the upper part of the Choptank Formation reinforces these conclusions. There are fewer extinct taxa and more still-living taxa in the Choptank assemblage than in the older assemblages present in the underlying Calvert Formation. The Choptank assemblage consists of exclusively marine diatom species and is dominated by the more robust centric planktonic diatoms. The presence of these diatoms is indicative of a shallow, agitated depositional environment and the fact that only a low percentage of benthonic species is present suggests muddy bottom conditions and a shifting substratum.

Sixty taxa of marine diatoms have been identified in this Choptank assemblage; seven are previously unreported, 18 are extinct forms known only from Miocene rocks, six are extinct forms ranging outside Miocene rocks, and 29 are long-ranging forms still living in modern oceans. This study of the Choptank diatoms adds to our knowledge of the stratigraphic ranges of diatom species and thus increases their usefulness in stratigraphic correlation and geologic age determination of Tertiary strata.

INTRODUCTION

This report is the first part of a study of fossil marine diatoms in the Tertiary strata of the Atlantic Coastal Plain. The Calvert, Choptank, and St. Marys Formations, all part of the Chesapeake Group, crop out as a sequence of clastic deposits along the Atlantic Coastal Plain of Maryland and Virginia. The Calvert Formation is highly to moderately diatomaceous, the Choptank Formation is sparingly diatomaceous, and diatoms have not yet been found in the St. Marys Formation of Maryland. The upper shell bed of the Choptank Formation, exposed in the Calvert Cliffs southeast of Long Beach, Calvert County, Md., contains a diatom assemblage of 60 taxa; this assemblage is the specific subject of this report. The assemblage is distinctly more modern in aspect than those reported previously from the Calvert Formation, and it is considered to be a representative middle Miocene diatom assemblage developed in a shallow marine shelf environment. It occurs in a formation of fairly well determined stratigraphic position (specifically, the base of lithologic unit 18 of Gernant [1970, p. 74] from stratigraphic zone 19 of Shattuck [1904] of the Choptank Formation) and hence should be adequate to serve the purpose of this study—to provide data on the occurrence of fossil marine diatoms from a stratum of known geologic age and to make these data available for regional geologic correlation and dating.

ACKNOWLEDGMENTS

Access to the collection locality was made possible through the kind cooperation of Robert E. Gernant, University of Wisconsin-Milwaukee and Lincoln Dryden, Bryn Mawr College, who were in charge of the Calvert Cliffs Project sponsored by the Maryland Academy of Sciences. John L. Stone, Washington, D.C., prepared several slides for the writer with Naphrax,[1] a high-index mounting medium; in addition, he searched a number of slides for additional specimens and provided helpful discussion of the diatom identification and taxonomy. Kenneth E. Lohman, Division of Paleobotany, The Smithsonian Institution, Blake Blackwelder, Joseph E. Hazel, and Sergius H. Mamay, U.S. Geological Survey, have reviewed the manuscript and their many helpful comments are appreciated.

[1] Any use of trade names in this publication is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

MIOCENE STRATIGRAPHY

The Miocene strata of the Middle Atlantic States have been well known since early colonial times because of their excellent exposure along Chesapeake Bay in Maryland and along the Potomac River estuary in Virginia. Shattuck (1904, p. 41–64) gives an exhaustive bibliography of publications on the Miocene strata of Maryland for the years 1669–1903. Modern stratigraphic terminology began with Darton (1891, p. 433), who named the entire Miocene stratigraphic section of the region the Chesapeake Formation. This name was modified by Dall and Harris (1892, p. 123) to Chesapeake Group and was extended to include all Miocene strata of the Atlantic Coastal Plain. The Chesapeake Group in Maryland was first divided into the Calvert, Choptank, and St. Marys Formations by Shattuck (1902).

The Chesapeake Group in Maryland was described in detail by Shattuck (1904, p. 69–92), and the systematic paleontology of various fossil groups of the Miocene deposits of Maryland was also presented in that volume, including a chapter by C. S. Boyer (1904) on the diatoms. Shattuck (1904) divided the Calvert Formation into a lower Fairhaven Diatomaceous Earth Member and an upper Plum Point Marl Member. In addition, he divided the entire Miocene section into 24 numbered stratigraphic zones. Of these, zones 1–3 were referred to the Fairhaven of the Calvert Formation, zones 4–15 to the Plum Point of the Calvert Formation, zones 16–20 to the Choptank Formation, and zones 21–24 to the St. Marys Formation. Gernant (1970) assigned names of member rank to the numbered zones of Shattuck (1904) for the Choptank Formation.

The Chespeake Group of Maryland, in general, consists of a series of sands, silts, and clays containing abundant macrofossils and microfossils in certain beds. Practically all the strata consist of mixtures of sand, silt, and clay in varying amounts, so that the beds differ in degree, rather than in kind. The deposits are generally blue gray in fresh exposures, but rapidly weather to slate gray. Organic matter is common, and dissociation of the sediments for diatom study has indicated traces of hydrocarbons. Traces of iron are present throughout the section and probably account for the change of color upon weathering. Calcium carbonate appears to occur only as fossils or fossil fragments, and there seems to be little evidence of primary deposition. The few hard calcareous beds in the section are associated with the shell beds; the abundance of shell molds in these cemented strata indicates leaching of the shells and secondary carbonate deposition.

The Fairhaven Diatomaceous Earth Member of the Calvert Formation rests unconformably on underlying Eocene strata. It may be readily distinguished from the Eocene deposits, which contain abundant glauconite and quartz granules but lack diatoms. The Fairhaven consists mainly of an impure silty diatomite. The overlying Plum Point Marl Member of the Calvert Formation consists of a series of impure fine sands, silts, and clays and beds composed primarily of mollusk shells in a sand-silt-clay matrix. This part of the Calvert Formation is moderately diatomaceous.

The Choptank Formation is said by Shattuck (1904, p. 80) to rest unconformably upon the Calvert Formation. Although this may be apparent on a regional basis, the Choptank lithology is so similar to that of the upper part of the Calvert Formation that an exact determination of the contact is difficult in most outcrops. Two parts of the Choptank Formation, stratigraphic zones 17 and 19, are distinguished primarily by their high content of mollusk shells. The Choptank Formation is part barren of diatoms and sparingly diatomaceous in some beds of all its members.

The St. Marys Formation rests conformably on the Choptank Formation according to Shattuck (1904, p. 84–85). Gernant (1970, p. 8–10), however, cites evidence for a surface of either erosion or nondeposition on the top of the Choptank Formation and, therefore, postulates an unconformable contact with the St. Marys Formation. The St. Marys Formation consists of four recognized zones of clastic sediments in the Chesapeake Bay region. Up to the present I have found no diatoms in the St. Marys Formation in samples from zones 22 and 23 at the Calvert Cliffs locality or from the Chancellors Point or Windmill Point localities, St. Marys County, Md.

CALVERT CLIFFS LOCALITY

The exposure of the Choptank Formation from which the studied diatom assemblage was obtained is on the western shore of Chesapeake Bay in the Cove Point 7½-minute quadrangle, Calvert County, Md. The location of the Calvert Cliffs area in Maryland is shown on the index map (fig. 1). During an early stage of construction of the Calvert Cliffs nuclear power plant of the Baltimore Gas and Electric Co., an area of the cliffs about 200 yards (183 m) northwest of the plant site was cleared of surficial debris for the stratigraphic and paleontologic studies conducted by the Maryland Academy of Sciences.

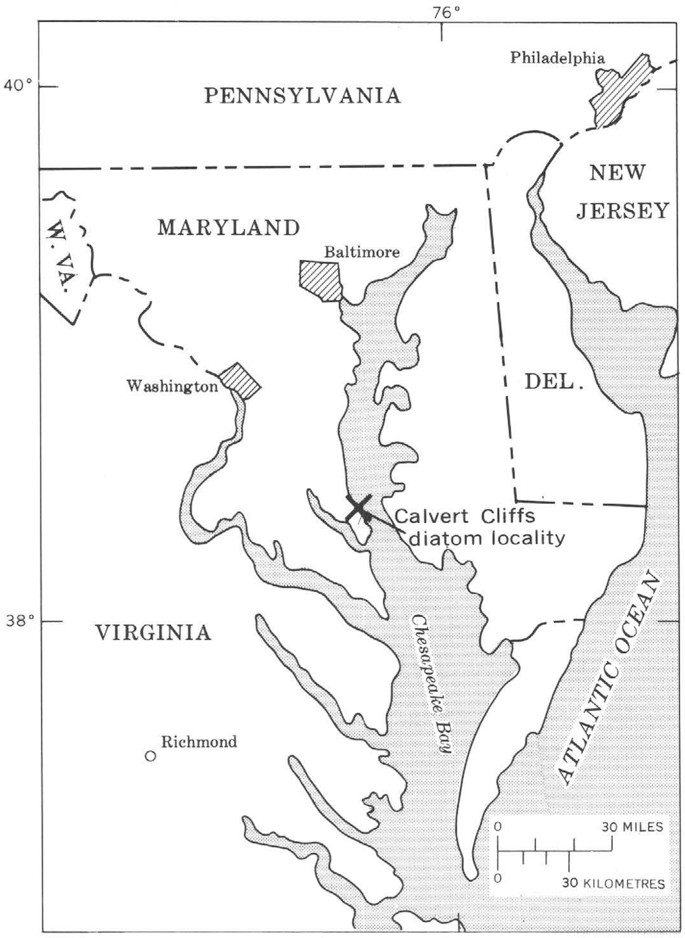


FIGURE 1.—Location of the Calvert Cliffs area in Maryland.

The site is at the end of a line of nearly continuous cliffs extending in a southeasterly direction from Flag Ponds, and it is approximately 2.0 miles (3.2 km) southeast of Long Beach, Md., at lat 38° 26′ 16″ N., and long 76° 26′ 40″ W. The collection locality is shown in detail in figure 2.

Stratigraphy.—The rocks exposed at the Calvert Cliffs power-plant locality range from the upper part of zone 17 of Shattuck [1904], into the St. Marys Formation (zone 23 of Shattuck [1904]). The Miocene section is overlain unconformably by Pleistocene sand. A detailed measured section of the Choptank Formation at this locality has been published by Gernant (1970, p. 73–76) as his locality 66–25 (Flag Pond II). Gernant measured the total thickness for the Choptank Formation here as 39 feet 1 inch, but recognized that zone 16 and part of zone 17 are below sea level and, hence, not exposed. The measured thicknesses of the members of the Choptank Formation are: zone 17, 1 foot exposed; zone 18, 15 feet 4 inches; zone 19, 13 feet 2 inches; zone 20, 9 feet 7 inches.

The Choptank Formation exposed at this section was further divided by Gernant (1970) into 21 lithologic units. Of these, units 11 through 19 make up stratigraphic zone 19. The diatom assemblage studied for this report was collected at the base of Gernant's unit 18, or approximately 16 inches below the top of stratigraphic zone 19. Gernant (1970, p. 74) describes the lithology of his unit 18 as follows: "Reddish-brown muddy, fine sand. Oxidation causing color mottling with various browns, reds, and oranges. Contacts slightly undulating and distinct." The sediments, therefore, appear to be somewhat oxidized, but the abundance of shells suggests only moderate carbonate leaching.

Diatoms occur sparingly throughout stratigraphic zone 16 in the nuclear-power-plant excavation adjacent to the natural exposure in the Calvert Cliffs. They were found in internal fillings of pelecypods about 1 foot below the top of stratigraphic zone 17. No diatoms were found in a sample taken 3 feet below the top of zone 18. No diatoms were found in samples taken 6 and 10 feet below the top of zone 19; however, the sample taken about 16 inches below the top of zone 19 contained a diatom assemblage suitable for study, which is herein reported. Diatoms of sparing occurrence were found in stratigraphic zone 20 in samples taken about 2 and 8 feet below the top of the zone, but no diatoms were found in a sample taken near the top of that zone. No diatoms were found in a sample taken 5 feet above the base of zone 21 nor in samples taken 1, 2, and 3 feet above the base of zone 23, all in the St. Marys Formation.

Geologic age relationships.—The Chesapeake Group of Maryland has been considered Miocene in age primarily on the basis of molluscan and vertebrate faunas. The consensus, as expressed by Cooke, Gardner, and Woodring (1943), has been that the Calvert Formation is of early middle Miocene age; the Choptank Formation, middle middle Miocene; and the St. Marys Formation, late middle Miocene. Gibson (1967, and in Gernant and others, 1971) indicates that stratigraphic zone 10 of the Plum Point Marl Member of the Calvert Formation falls in either planktonic foraminiferal zone N. 8 or N. 9 of Blow (1969), which Berggren (1972), and Berggren and Van Couvering (1973) place near the lower-middle Miocene boundary, or about 16 million years B. P. J. E. Hazel (oral commun., 1974) suggests that the St. Marys Formation (as the formation name is used in Virginia) probably falls in planktonic foraminiferal zone N. 17, which in the time-scale of Berggren (1972) and Berggren and Van Couvering (1973) is Tortonian or Messinian

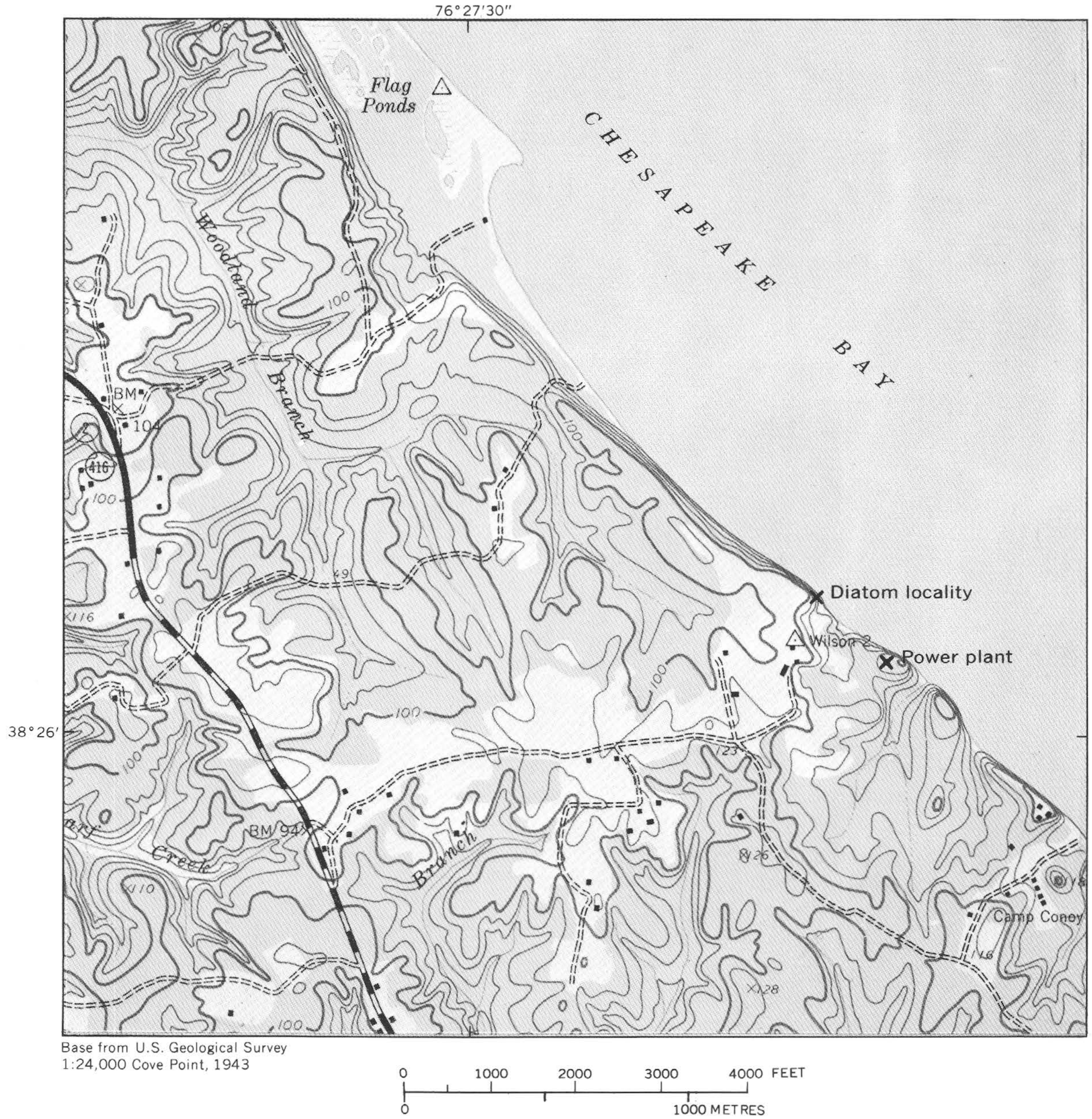


FIGURE 2.—Location of the Choptank fossil diatom locality, Calvert County, Md.

in age, that is, about 5 to 8 million years B. P. These correlations indicate that the Choptank Formation falls within the interval of zones N. 10 to N. 16, but a more precise correlation has not been made. The stratigraphic position of the formation suggests that it probably falls in the Serravalian Stage of middle Miocene age, but absolute certainty on this point is impossible at this time.

PREVIOUS WORK ON DIATOMS OF THE CHESAPEAKE GROUP

The discovery of diatoms in the rocks of the Chesapeake Group is credited to W. B. Rogers (1841), State Geologist of Virginia, who reported the occurrence of a "tertiary infusorial stratum" at Richmond. Rogers sent samples to J. W. Bailey, Professor of Chemistry, Mineralogy, and Geology at the U.S. Military Academy; Bailey was apparently the first American scientist to develop an interest in diatoms. Bailey (1842a) mentioned diatom localities at Richmond, Va., and on the Rappahannock River. Bailey (1842b, p. 329–331) further reported on diatoms, silicoflagellates, radiolaria and sponge spicules from the Chesapeake Group of Virginia. Bailey (1842b, p. 330) also stated that he sent specimens of the Richmond deposit to C. G. Ehrenberg in Berlin. A diatom-assemblage list and discussion of the correlation of the deposit was published by Ehrenberg (1843, p. 327–330) in his paper on the microscopical life of South and North America. Bailey (1843) presented a paper on microfossils from Petersburg, Va., before the Association of American Geologists and Naturalists. A fuller account of this assemblage and another at Piscataway, Md., was published by Bailey in 1844.

Bailey evidently sent specimens from Petersburg and Piscataway to Ehrenberg, who (1844, p. 68–72) published a chart comparing the Richmond, Petersburg, and Piscataway assemblages and commented on their geologic correlation. Bailey (1845a) reviewed and summarized this work of Ehrenberg. The next event in this active sequence of discovery and discussion is a paper by Bailey (1845b) comparing fossil diatom assemblages from Virginia, Maryland, and "Bermuda," with modern diatoms in United States coastal waters.

The locality reported on by Bailey (1845b) as "Bermuda" deserves further scrutiny at this time. Bailey (p. 323) states of this locality:

> Some months ago I received from M. Tuomey, Esq. of Petersburg, Va., a fine specimen of infusorial earth, labelled 'Tripoli from Bermuda'. * * * The only information with regard to the history of the specimen which I have yet been able to obtain is, that Mr. Tuomey received it with its present label from some mineralogical correspondent, and that he has no doubt that it came from Bermuda.

Thus the "Bermuda Islands" diatom assemblage, based on an inadequately labeled specimen of unknown provenance made by an anonymous collector, found its way into the literature. Bailey (1845b, p. 329) admits the peculiarity of the occurrence:

> It is also remarkable that a deposit so purely siliceous could be formed among the coralline isles of Bermuda. No mention of any such "Tripoli" is contained in any of the accounts of the geology of those islands which I have yet seen.

Subsequent investigation of the Bermuda Islands has shown deposits of coralline rock, but no trace whatever of Miocene diatomite. An alternative explanation must be sought.

There is, in Chesterfield County, about 16 miles southeast of Richmond, Va., and somewhat closer to Petersburg, an early colonial settlement on the bank of the James River called Bermuda Hundred, which has now dwindled to a few houses and a historical marker. I have not found an outcrop of the Calvert Formation here, but it is highly likely that one does (or did) exist somewhere along the banks or nearby bluffs of the meandering James River. The "Bermuda" diatom assemblage is essentially identical with the other Calvert diatom assemblages reported by Bailey (1845b). In view of the ambiguous origin of the sample and the close degree of correlation, it seems highly probable that the so-called Bermuda assemblage came from Bermuda Hundred, Va., rather than the Bermuda Islands.

Bailey (1845b, p. 323) states that he sent a sample of the "Bermuda" material to Ehrenberg, who (1845, p. 257–261) published a species list of microfossils. Unfortunately he published the source unequivocally as "Bermuda Islands," so that the locality error has been perpetuated in the European literature. Bailey (1849) published one further note on the Tertiary Infusoria localities in Maryland. With his death in 1857, scientific diatom work in the United States came to a near standstill for almost 40 years.

In his "Mikrogeologie" Ehrenberg (1854, pls. 18, 33) devoted an entire plate to the assemblage from Richmond and part of a plate to other Miocene assemblages from Virginia. Much later, Grunow in Van Heurck (1880–1885) described taxa from the Chesapeake Group of Maryland and Virginia. *Raphidodiscus marylandicus*, a Miocene index diatom of worldwide occurrence, was described by Christian (1887) from subsurface Calvert Formation of eastern Maryland. A systematic study of the diatoms of the Calvert Formation of Maryland was made by Boyer (1904). Although he published two plates of the more common and interesting diatoms, many species are not figured and only a few are described. The most recent published report on the diatoms of the Calvert Formation is that by Lohman (1948) on assemblages from the Hammond well in eastern Maryland. This is the most complete systematic study made to date, and it proved to be a helpful guide in the preparation of this report.

As far as I have been able to determine, all the previous diatom studies have probably been made on diatoms from the Calvert Formation with the possible exception of assemblages from Petersburg, Va. The Choptank Formation does crop out at the Stratford Cliffs, and assemblages from this place were reported by Bailey (1845b) and Ehrenberg (1854, pl. 33). However, the Calvert Formation is more easily accessible at this locality and was probably the deposit examined. Diatoms occur in far greater abundance in the Calvert Formation than in the Choptank Formation, and the Calvert is considerably more widespread and thicker. It is, therefore, understandable that the Choptank diatoms have been neglected. Diatoms are not common in the St. Marys Formation but may be discovered upon further investigation.

DIATOM ASSEMBLAGE

The samples from U.S. Geological Survey diatom locality 6098 were prepared for diatom study following standard procedures of the U.S. Geological Survey as outlined by Lohman (1972). An initial treatment with hydrochloric acid removed particulate calcareous material and finely divided iron minerals. Organic matter was removed by heating in a solution of potassium permanganate and sulfuric acid. Finally, the diatom-sized particles were concentrated by differential settling and decanting. Strewn mounts were made in Caedax and Aroclor, and additional mounts in the high-index medium Naphrax were supplied by Mr. John Stone. Specimens were located by systematic traversing with a mechanical stage, and their locations were recorded as coordinates of the mechanical stage. Eight strewn mounts, 18 mm in diameter, were examined. The relative abundance of each of the 60 diatom taxa is shown in the list below, in which the estimated relative frequency under an 18-mm cover glass viewed at × 250 magnification is defined as follows: abundant (A), at least one specimen in all fields of view; common (C), one specimen in many (but not all) fields of view; frequent (F), several specimens observed on slide, but seen only in a few fields of view; rare (R) one or two specimens on a slide. An asterisk (*), precedes the 19 taxa which are extinct forms known only from Miocene rocks; most of these forms have been previously reported from the Calvert Formation and some have been reported from other Miocene localities. A dagger (†) precedes the seven taxa which are previously unreported; in addition to these, numerous forms of *Xanthiopyxis* show great variation but occur in quantities too small for taxonomic treatment. A double dagger (‡) precedes the six taxa which are extinct forms having a known range not limited to the Miocene; all forms range from Miocene to Pliocene except *Liradiscus ovalis* and *Triceratium condecorum*, which range from Eocene to Miocene. Thus, of the 60 taxa represented in the Choptank assemblage and listed below, 31 (51.7 percent) are extinct forms and the remaining 29 (48.3 percent) are long-ranging forms still living in modern oceans.

Melosira westii W. Smith	C
**Paralia complexa* (Lohman) Andrews, n. comb	R
sulcata (Ehrenberg) Cleve	A
sulcata var. *coronata* (Ehrenberg) Grunow	A
**Pyxidicula cruciata* Ehrenberg	F
**Stephanopyxis corona* (Ehrenberg) Grunow	R
* *lineata* (Ehrenberg) Forti	F
turris (Greville and Arnott) Ralfs	R
Coscinodiscus apiculatus Ehrenberg	R
curvatulus Grunow	R
‡ *inclusus* Rattray	R
marginatus Ehrenberg	R
oculus-iridis Ehrenberg	R
perforatus Ehrenberg	R
perforatus var. *cellulosa* Grunow	R
perforatus var. *pavillardi* (Forti) Hustedt	R
radiatus Ehrenberg	R
rothii (Ehrenberg) Grunow	R
‡ *vetustissimus* Pantocsek	R
**Craspedodiscus coscinodiscus* Ehrenberg	R
**Actinocyclus ellipticus* Grunow	R
ingens Rattray	R
octonarius Ehrenberg	R
tenellus (Brébisson) Andrews, n. comb	R
Hyalodiscus laevis Ehrenberg	R
†*Actinoptychus marylandicus* Andrews, n. sp	R
senarius (Ehrenberg) Ehrenberg	F
* *virginicus* (Grunow) Andrews, n. comb	R
**Rattrayella inconspicua* (Rattray) Hanna	R
†*Liradiscus asperulus* Andrews, n sp	R
‡ *ovalis* Greville	R
Biddulphia aurita var. *obtusa* (Kützing) Hustedt	R
* *semicircularis* (Brightwell) Boyer	F
tuomeyi (Bailey) Roper	R
‡*Goniothecium rogersii* Ehrenberg	F
**Eucampia virginica* Grunow	R
Terpsinoë americana (Bailey) Ralfs	R
‡*Triceratium condecorum* Ehrenberg	F
**Hemiaulus polymorphus* var. *virginica* Grunow	R
†*Xanthiopyxis microspinosa* Andrews, n. sp	R
spp	R
†*Dossetia hyalina* Andrews, n. sp	R
‡*Periptera tetracladia* Ehrenberg	R
**Stephanogonia actinoptychus* (Ehrenberg) Grunow	R
**Pseudopyxilla americana* (Ehrenberg) Forti	R
Rhaphoneis amphiceros Ehrenberg	R
* *angustata* Pantocsek	R
† *diamantella* Andrews, n. sp	F
* *immunis* Lohman	R
* *lancettula* Grunow	F
**Thalassionema obtusa* (Grunow) Andrews, n. comb	R
Thalassiothrix longissima Cleve and Grunow	R
Grammatophora angulosa Ehrenberg	F
marina (Lyngbye) Kützing	R
†*Cocconeis* sp	R
Navicula hennedyi W. Smith	R
lyra Ehrenberg	R
pennata Schmidt	F
Diploneis crabro (Ehrenberg) Ehrenberg	R
**Pleurosigma affine* var. *marylandica* Grunow	R
†*Amphora* sp	R

Stratigraphic significance.—Because the diatom assemblage from the Calvert Formation reported by Lohman (1948) and the Choptank assemblage of this paper were studied by similar techniques and analyzed in a similar manner, a comparison of these two assemblages has some validity (table 1). The Choptank diatom assemblage contains substantially fewer taxa (60) than the Calvert assemblage (89). The difference may be due to the fact that the Calvert study was made on several stratigraphic horizons, whereas the Choptank study was made on a single horizon. However, from what I have observed of Calvert diatoms, the Calvert Formation appears to have a substantially more varied diatom assemblage. It contains, in good abundance, a considerable number of extinct species that do not occur in the Choptank Formation; many of these are known only from the Calvert Formation and its time-stratigraphic equivalents. The smaller percentage of extinct Miocene species in the Choptank Formation is balanced by the increased percentage of still-living taxa; this gives the Choptank assemblage a more modern character. (The figures in table 1 are reasonable considering the greater age of the Calvert Formation.) Nearly all these long-ranging forms also occur in the Calvert Formation, and a few range from Cretaceous or early Tertiary to modern seas. The increase in the Choptank in the number and percentage of extinct taxa ranging outside the Miocene probably reflects the improved knowledge of diatom ranges since 1948 more than anything else.

TABLE 1.—*Comparison of diatom taxa from the Chesapeake Group*

Taxa	Choptank Formation, this report		Calvert Formation, Lohman (1948)	
	Number of taxa	Percent	Number of taxa	Percent
New	7	11.7	11	12.5
Extinct, known only from Miocene rocks	18	30.0	37	41.5
Extinct, ranging outside Miocene rocks	6	10.0	5	5.5
Long ranging, still living in modern assemblages	29	48.3	36	40.5
Total	60	100.0	89	100.0

This Choptank diatom assemblage is significant in that it occurs in a formation dated, according to other fossil groups present, as middle Miocene. Because the age of the formation is relatively well known, this assemblage can be used with confidence in stratigraphic correlation. It is hoped that future investigation of older and younger Tertiary diatom assemblages in the Atlantic and Gulf Coastal Plains will so sharpen the precision of our knowledge of the stratigraphic ranges of diatom taxa that their usefulness for stratigraphic correlation will be greatly increased.

Paleoecologic interpretation.—The paleoecology of the macrofaunas and microfossil faunas of the Choptank Formation has been discussed by Gernant (1970). The evidence from the diatom assemblage of stratigraphic zone 19 suggests a shallow neritic open-shelf marine depositional environment. Nearly all the still-living species in this fossil assemblage are reportedly common in coastal waters of modern temperate regions. Most of the diatoms in this assemblage are robust centric forms, which suggests that they were mainly planktonic but lived in shallow, agitated waters. The relative scarcity of benthonic forms indicates a muddy, shifting substratum, which is amply confirmed by the nature of the sediments. The diatom assemblage indicates nothing but normal marine salinity; not a single specimen of a nonmarine diatom was observed, not even salt-tolerant nonmarine forms. This confirms that the environment of growth and deposition was normal marine, far enough away from fresh-water sources to prevent the influx of nonmarine species.

The relatively shallow-water environment is evident by contrasting this assemblage with those reported by Schrader (1973) and Koizumi (1973) from the deep-sea environments in the Pacific Ocean basin. Those assemblages are almost exclusively planktonic and contain many genera and species not found in the Choptank assemblage. The generally poor quality of the diatom assemblages in the Choptank Formation and the lack of diatoms in some strata are difficult to explain. The formation is generally considered to be entirely of shallow marine deposition, perhaps characterized by some fluctuation in depth of water but not by a drastic change in environment. At times clastic deposition might have increased to the point where diatoms were obscured by the influx of muddy sediments. It is also possible that diatoms were winnowed from the sediments by currents or waves and carried away in suspension to be deposited elsewhere. Perhaps at the time of deposition of the studied assemblage the waters were slightly deeper and a more open inner-shelf environment allowed a greater bloom of diatoms, which resulted in a more extensive and varied marine diatom assemblage. Preservation of diatoms in this type of fine sand-silt-clay lithology is often less than the best. The diatoms were initially deposited in soft muddy bottom sediments, but as a result of later compaction, many were crushed by pressure from adjacent sand grains in the matrix. This deformation may well account for the abundance of broken specimens, particularly of the larger forms, which is common in diatom assemblages from both the Calvert and the Choptank Formations.

SYSTEMATIC DESCRIPTIONS

The classification of diatoms used in this report is based on a proposed classification by K. E. Lohman (unpub. data), and it is similar in many respects to the earlier classifications by Schütt (1896), Karsten (1928), and Hendey (1937). The treatment of the nomenclature in the generic and lower ranks is conservative, and the few changes made are in the direction of a less complex binomial system. It seems advisable to give a brief description of each taxon in the assemblage, for many of these species and varieties have been inadequately described, or the descriptive literature has long been out of print. The descriptions refer only to the specimens observed in this assemblage and do not necessarily indicate the total variation of the form; such information should be found in the general references cited in the synonymies.

The first citation in each synonymy is to the original description of the taxon. The second citation includes references to the taxon in the literature in chronologic order using the nomenclature adopted throughout this report. Subsequent citations include synonyms, misidentifications, misspellings, and incorrect attributions of authorship. The synonymies are intended to be informative but not exhaustive, and further details should be sought in the general references. References not examined by the author are marked with an asterisk. Information on geologic ranges is taken mainly from Lohman (1948), but other sources are indicated. Comments on ecology of the living diatom species are mainly from Hustedt (1927–30, 1931–59, 1961–66).

Kingdom PROTISTA
Subkingdom PROTOCTISTA
Division CHRYSOPHYTA
Class DIATOMOPHYCEAE
Order CENTRALES
Suborder DISCINEAE
Family COSCINODISCACEAE
Subfamily MELOSIROIDEAE

Genus MELOSIRA Agardh, 1824

Melosira westii Wm. Smith

Plate 1, figures 1, 2

Melosira westii Wm. Smith, 1856, Synopsis of the British Diatomaceae, v. 2, p. 59, pl. 52, fig. 333.
Hustedt, 1927, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 268–269, fig. 113.
Hendey, 1964, An introductory account of the smaller algae of British coastal waters, part V, Bacillariophyceae (Diatoms), p. 73, pl. 1, fig. 4; pl. 22, fig. 8.

Description.—Valves disciform having heavy mantle which is rarely seen because of almost exclusive orientation in valve view. Diameter, about 25μ–30μ. Immediately inside mantle rim is a row of very short, fine striae. The center of the valve is dominated by moderately large, irregularly distributed blobs of silica giving a patchy appearance which is often not sharply resolved by the light microscope.

Remarks.—*Melosira westii* is common in this assemblage.

Known geologic range.—From the Calvert Formation of Miocene age to coastal waters of modern oceans.

Genus PARALIA Heiberg, 1863

Paralia complexa (Lohman) Andrews, n. comb.

Plate 1, figures 3, 4

Melosira complexa Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 156, pl. 5, fig. 1–7.

Description.—Valves, circular, convex, diameter about 53μ. Outer zone dominated by highly irregular but generally radiate striae, followed concentrically inward by a ring of concentric areolae, then by an inner concentric band, 3μ–5μ wide, of fine puncta, about 12 in 10μ, arranged in a quincuncial pattern. Center of valve highly convex with many irregularly distributed large puncta.

Remarks.—Because of the affinity of this species for *Paralia sulcata,* it has been placed in the genus *Paralia* following Boyer (1904) and Hendey (1964).

Paralia complexa is rare in this assemblage.

Known geologic range.—The Calvert and Choptank Formation of Miocene age.

Paralia sulcata (Ehrenberg) Cleve

Plate 1, figures 5, 6

Gaillonella sulcata Ehrenberg, 1838, Die Infusionsthierchen als volkommene Organismen, p. 170, pl. 21, fig. 5.*
Paralia sulcata (Ehrenberg) Cleve, 1873, Kgl. svenska akad. Handl., Bihang, v. 1, no. 13, p. 7.
Boyer, 1904, Maryland Geol. Survey, Miocene, p. 491, pl. 135, fig. 9.
Hendey, 1964, An introductory account of the smaller algae of British coastal waters, Part V, Bacillariophyceae (Diatoms), p. 73, pl. 23, fig. 5.
Melosira sulcata (Ehrenberg) Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 55, pl. 2, fig. 7.
Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 276–279, fig. 119.
Lohman, 1941, U.S. Geol. Survey Prof. Paper 196, pt. 3, p. 64, pl. 12, fig. 1.
Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 156–157.

Description.—Valve round, nearly flat, about 30μ–40μ in diameter. Outer rim complexly loculate with an orderly arrangement of about 5 chambers in 10μ. This is succeeded inwardly by a narrow band of fine puncta, about 14 in 10μ, arranged in a quincuncial pattern, then a narrow hyaline band less than 1μ in width, afterwards a band of prominent radial striae, about 10 in 10μ, which taper toward a hyaline center.

Remarks.—*Paralia sulcata* is abundant and well-preserved in this assemblage.

Known geologic range.—Lohman (1948) states that the geologic range of this species covers all the Tertiary and that a variety has been reported from the Cretaceous. It is common in modern marine coastal waters.

Paralia sulcata var. coronata (Ehrenberg) Andrews, n. comb.

Plate 1, figures 7, 8

Gaillonella coronata Ehrenberg, 1845, Kgl. preuss. Akad. Wiss. Berlin Ber., p. 154.*
Ehrenberg, 1854, Mikrogeologie, pl. 38, XXII, fig. 5.
Melosira (*Paralia*) *sulcata* var. *coronata* (Ehrenberg) Grunow *in* Van Heurck, 1882, Synopsis des Diatomées de Belgique, pl. 91, fig. 17.
Melosira sulcata forma *coronata* Grunow. Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 278, fig. 119d.

Description.—Valve round, nearly flat, about 23μ–33μ in diameter. Outer rim complexly loculate similar to the type variety, succeeded inwardly by a hyaline band about 2μ in width, then by a band of somewhat knobby and irregular siliceous processes, 3–4 in 10μ, directed outwards from a broad, flat hyaline center.

Remarks.—*Paralia sulcata* var. *coronata* is distinguished from the type variety by the lack of the quincuncial band of puncta and by the replacement of the radial striae by the knobby processes.

This variety is abundant in the assemblage.

Known geologic range.—The variety has been reported from the Calvert Formation of Miocene age, and Hustedt (1928) states that it occurs with the type variety in European coastal waters.

Genus PYXIDICULA Ehrenberg, 1833

Pyxidicula cruciata Ehrenberg

Plate 1, figures 9, 10

Pyxidicula cruciata Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, pl. 3, VII, fig. 6.
Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 301–302.
Dictyopyxis cruciata Ehrenberg, 1845, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844, p. 267.
Ehrenberg, 1854, Mikrogeologie, pl. 33, XIII, fig. 7; XV, fig. 12; XVII, fig. 7.
Stephanopyxis turris var. *arctica* f. *inermis* Grunow, 1884, Kaisl.-Kgl. Akad. Wiss. Wien, Math.-Naturwiss. Kl., Denkschr. v. 48, p. 89, pl. 5, fig. 18, 21.
Cleve-Euler, 1951, Kgl. svenska vetensk. akad. Handl. 4th ser, v. 2, no. 1, p. 38, fig. 40 m, pl. 1, fig. 0.

Description.—Valve round, markedly domed, probably in the shape of a flattened hemisphere although it was not observed in valve view. Diameter 30μ–44μ, margin loculate, arching over as an areolate net arranged in an orderly hexagonal pattern. Large, round areolae, about 4 in 10μ. Top and margin of valve free of spines or spine bases.

Remarks.—Although often confused with *Stephanopyxis*, the genus *Pyxidicula* is distinguished by its lack of prominent spines.

The species is frequent in this assemblage.

Known geologic range.—In addition to its occurrence in the Choptank Formation, the species has been previously reported from the Calvert Formation. It is apparently restricted to fossil deposits that are probably all of Miocene age.

Genus STEPHANOPYXIS Ehrenberg, 1844

Stephanopyxis corona (Ehrenberg) Grunow

Plate 1, figures 11, 12

Systephania corona Ehrenberg, 1845, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844, p. 272.
Ehrenberg, 1854, Mikrogeologie, pl. 33, XV, fig. 22.
Stephanopyxis corona (Ehrenberg) Grunow *in* Van Heurck, 1882, Synopsis des Diatomées de Belgique, pl. 83 ter, fig. 10, 11.
Boyer, 1904, Maryland Geol. Survey, Miocene, p. 490–491, pl. 135, fig. 13.
Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 157.

Description.—Valve round, convex, probably in the shape of a hemisphere markedly flattened in the center. Diameter 53μ–74μ. Margin loculate, arching over as an areolate net arranged in an orderly hexagonal pattern. Areolae, 3–4 in 10μ, large, hexagonal. A ring of prominent thornlike siliceous spines radiate from a zone near the margin, but they do not extend beyond the margin. A second ring of prominent siliceous spines occurs at about half the distance from center to margin.

Remarks.—The species is rare in this assemblage.

Known geologic range.—This species is reported only from the Calvert and Choptank Formations of Miocene age.

Stephanopyxis lineata (Ehrenberg) Forti

Plate 1, figures 13, 14

Stephanodiscus? lineatus (=*Peristephania lineata*) Ehrenberg, 1854, Mikrogeologie, pl. 33, XIII, fig. 22.
Stephanopyxis lineata (Ehrenberg) Forti, 1912, La Nuova Notarisia, p. 83.*
Forti, 1913, R. ist. veneto sci., Atti, v. 72, pt. 2, p. 1547, pl. 11, fig. 21, 23; pl. 12, fig. 3.*
Hanna, 1932, California Acad. Sci. Proc., 4th ser., v. 20, p. 219, pl. 16, fig. 9–11.
Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 158, pl. 6, fig. 5,

Description.—Valve round, nearly flat, 40μ–72μ in diameter. Entire surface of valve shows a generally regular, hexagonal, areolate net. Areolae, about 4½ in 10μ, large, hexagonal. A ring of thornlike siliceous spines, somewhat irregularly spaced, occurs 2μ–3μ from the outer margin.

Remarks.—This species resembles *Coscinodiscus lineatus*, but the large thornlike spines near the periphery are sufficient to distinguish it from that species.

Stephanopyxis lineata is frequent in this assemblage.

Known geologic range.—Koizumi (1973, fig. 10) states that *S. lineata* ranges from foraminiferal zones N. 9 to N. 15 of Blow (1969), that is, throughout the middle Miocene.

Stephanopyxis turris (Greville and Arnott) Ralfs

Plate 2, figures 1, 2

Creswellia turris Greville and Arnott, 1857, Royal Soc. Edinburgh Trans., v. 21, pt. 4, p. 64, pl. 6, fig. 109.*

Stephanopyxis turris (Greville and Arnott) Ralfs *in* Pritchard, 1861, History of the Infusoria, 4th ed., p. 826, pl. 5, fig. 74.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 304–307, fig. 140.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 158.

Description.—Valve round, highly domed, so that the height is greater than the diameter; the usual orientation is the girdle view. Valve with flat or slightly concave base, expanded to a slight flange at base, then tapering to nearly parallel sides, arching over on top as a rounded or flattened dome. Diameter, 25μ–30μ. Surface of valve covered with a somewhat irregular hexagonal areolate net, with 4–6 hexagonal areolae in 10μ. Bases of large siliceous spines on the domed end are sometimes observed.

Remarks.—The species is rare in this assemblage.

Known geologic range.—This is a long-ranging species, extending from Cretaceous to modern oceans (Lohman, 1948). According to Hustedt (1928) it is a pelagic form frequently occurring in modern marine deposits.

Subfamily COSCINODISCOIDEAE

Genus COSCINODISCUS Ehrenberg, 1838

Coscinodiscus apiculatus Ehrenberg

Plate 2, figure 3

Coscinodiscus apiculatus Ehrenberg, 1844, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844. p. 77.

Ehrenberg, 1854, Mikrogeologie, pl. 18, fig. 43.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 449–452, fig. 248.

Hanna, 1932, California Acad. Sci. Proc., 4th ser., v. 20, p. 178–179, pl. 6, fig. 1.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 158.

Description.—Valve round, flat, diameter of observed specimen, 117μ. Surface covered with large round areolae, about $3\frac{1}{2}$ in 10μ, uniform in size, arranged primarily in radial lines and secondarily in a curved decussating pattern. Areolae somewhat less closely packed near center, and there is a small central hyaline area.

Remarks.—Although this species may be confused with *Coscinodiscus perforatus*, it lacks the fine terminal pores of the striae of that species. *Coscinodiscus apiculatus* is rare in this assemblage.

Known geologic range.—Miocene (Calvert Formation and equivalent) to modern oceans.

Coscinodiscus curvatulus Grunow

Plate 2, figure 4

Coscinodiscus curvatulus Grunow *in* Schmidt, 1878, Atlas der Diatomaceenkunde, pl. 57, fig. 33.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 406–410, fig. 214.

Lohman, 1941, U.S. Geol. Survey Prof. Paper 196, part 3, p. 74, pl. 15, fig. 8.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 160.

Description.—Valve round, flat, diameter of observed specimen, 48μ. Valve divided into curved sectors, more or less 11 in number, each defined by a curved row of areolae extending from the margin to the center, with the remainder of the sector filled by curved parallel rows of areolae, these rows decreasing in length toward the margin of the adjacent sector. About 7 round areolae in 10μ, arranged complexly in a curved radial as well as decussating pattern. This ordered pattern extends to the center of the valve.

Remarks.—*Coscinodiscus curvatulus* is rare in this assemblage.

Known geologic range.—This species is found throughout the Tertiary and is a pelagic form frequently occurring in modern oceans.

Coscinodiscus inclusus Rattray

Plate 2, figure 5

Coscinodiscus inclusus Rattray, 1889, Royal Soc. Edinburgh Proc., v. 16, p. 482.

Lohman, 1938, U.S. Geol. Survey Prof. Paper 189–C, p. 86, pl. 20, fig. 3.

Description.—Valve round, somewhat convex with narrow, indistinctly striated margin. Diameter of observed specimen, 38μ. Valve divided into straight sectors, more or less seven in number, each defined by a straight row of areolae extending from the margin to the center, with the remainder of the sector filled by parallel rows of areolae, these rows decreasing in length toward the margin of the adjacent sector. About 7–8 rounded areolae in 10μ, arranged primarily in straight radial lines but also secondarily in a curved decussating pattern. Center of valve more or less closely packed with areolae.

Remarks.—The species is rare in this assemblage.

Known geologic range.—The species has only been reported previously from the Calvert Formation of Miocene age at Richmond, Va., and the Etchegoin Formation of Pliocene age of California (Lohman, 1938).

Coscinodiscus marginatus Ehrenberg

Plate 2, figures 6, 7

Coscinodiscus marginatus Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh. 1841, p. 329, 371.

Ehrenberg, 1854, Mikrogeologie, pl. 18, fig. 44; pl. 33, XII, fig. 13; pl. 38, XXII, fig. 8.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 416–418, fig. 223.

Lohman, 1941, U.S. Geol. Survey Prof. Paper 196, part 3, p. 71–72, pl. 14, fig. 1, 6.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 162, pl. 7, fig. 4.

Description.—Valve round, slightly convex, diameter 44μ–91μ. Marginal rim zone 6μ–8μ wide, composed of radial striae, about 6 in 10μ. Inside of rim zone is an areolate net composed of hexagonal areolae, about $3\frac{1}{2}$ in 10μ, with a secondary orientation in curved decussating rows. Areolae fill the valve surface by intercalation of progressively shorter radial rows toward the margin. The areolate net is somewhat less than perfectly regular, and the center of the valve is closely packed with areolae.

Remarks.—A variant of this species that has round areolae rather than a tightly packed areolate net has been reported from the Calvert Formation. This form, although not observed in this assemblage, may also occur in the Choptank Formation.

Coscinodiscus marginatus is rare in this assemblage.

Known geologic range.—Reported from the Moreno Shale of Cretaceous and Paleocene age of California by Long, Fuge, and Smith (1946). It is still living in modern seas.

Coscinodiscus oculus-iridis Ehrenberg

Plate 2, figure 8

Coscinodiscus oculus-iridis Ehrenberg, 1841, Kgl. preuss. Akad. Wiss. Berlin, Abh., 1839, p. 147.

Ehrenberg, 1854, Mikrogeologie, pl. 18, fig. 42; pl. 19, fig. 2.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 454–456, fig. 252.

Hanna, 1932, California Acad. Sci. Proc., 4th ser., v. 20, p. 183, pl. 9, fig. 4.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 163.

Description.—Valve round, flat, large, diameter of observed specimen, 196μ. Marginal rim zone about 8μ wide composed of short striae, about 4–5 in 10μ. Inside of rim zone is an areolate net with a primary radial orientation superimposed on a secondary orientation of curved decussating rows. Areolae fill the valve surface by intercalation of progressively shorter radial rows toward the valve margin. Areolae, 2–3 in 10μ, somewhat coarser near the center than near the margin. The center of the valve has a rosette of elongate radiating areolae.

Remarks.—This species rarely occurs in fragments large enough for identification. There is a considerable amount of fragmentary debris in the assemblage, much of it from large disks such as *C. oculus-iridis*.

Known geologic range.—Entire Tertiary to modern oceans (Lohman, 1948).

Coscinodiscus perforatus Ehrenberg

Plate 2, figure 9

Coscinodiscus perforatus Ehrenberg, 1844, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844, p. 78.

Ehrenberg, 1854, Mikrogeologie, pl. 18, fig. 46.

Boyer, 1904, Maryland Geol. Survey, Miocene, p. 506, pl. 135, fig. 2.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 445–449, fig. 245.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 163.

Description.—Valve round, flat, diameter of observed specimen, 102μ. Valve surface covered with an areolate net having a primary radial orientation superimposed on a secondary orientation in curved decussating rows. Areolae fill the valve surface by intercalation of progressively shorter radial rows toward the valve margin. The definitive characteristic of the species is that each short row ends in a single small punctum. Hexagonal areolae, about $4\frac{1}{2}$ in 10μ, somewhat finer near the margin, net less than perfectly organized. Center of valve may be completely filled with areolae or show a small hyaline area.

Remarks.—The species is rare in this assemblage.

Known geologic range.—From the Calvert Formation of Miocene age to modern seas.

Coscinodiscus perforatus var. cellulosa Grunow

Plate 2, figure 10

Coscinodiscus perforatus var. *cellulosa* Grunow, 1884, Kaisl.-Kgl. Akad. Wiss. Wien, Math.—Naturwiss. Kl., Denkschr., v. 48, p. 75.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 447, fig. 246.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources, Bull. 2, p. 163–164, pl. 8, fig. 3.

Description.—Valve round, flat, diameter of observed specimen, 81μ. The variety *cellulosa* is similar to the type variety, except that the areolae are round rather than closely packed into a hexagonal shape. Areolae, about 6 in 10μ, finer near the margin.

Remarks.—This variety is rare in the assemblage.

Known geologic range.—From the Calvert Formation of Miocene age to modern seas. A reported occurrence of this variety by Rattray in the upper Eocene of Oamaru, New Zealand, appears to be erroneous.

Coscinodiscus perforatus var. pavillardi (Forti) Hustedt

Plate 2, figures 11, 12

Coscinodiscus pavillardi Forti, 1922, R. Comit. Thalassograf. Ital. Mem., 97, p. 124, pl. 8, fig. 143.*

Coscinodiscus perforatus var. *pavillardi* (Forti) Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 447–448, fig. 247.

Description.—Valve round, flat, diameter 59μ–140μ. Similar to the type variety except that some marginal areolae are round but areolae near the center are more closely packed into hexagons. The short striae terminate in a single punctum near the margins, but the striae of intermediate length terminate without the punctum. Areolae, about 3 in 10μ, finer near the margin.

Remarks.—This variety is somewhat more frequent than the type variety or var. *cellulosa*, but it is still rare in the assemblage.

Known geologic range.—This assemblage to modern seas.

Coscinodiscus radiatus Ehrenberg

Plate 2, figure 13

Coscinodiscus radiatus Ehrenberg, 1841, Kgl. preuss. Akad. Wiss. Berlin, Abh., 1839, p. 148, pl. 3, fig. 1A–C.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz pt. 1, p. 420–421, fig. 225.

Lohman, 1941, U.S. Geol. Survey Prof. Paper 196, part 3, p. 73, pl. 14, fig. 7, 8.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 164.

Description.—Valve round, flat, diameter of observed specimen, 100μ. Valve surface covered with an areolate net having a primary radial orientation and a secondary orientation in curved decussating rows. Areolae fill the valve surface by intercalation of progressively shorter rows toward the margin. Areolae round, 3–4 in 10μ, somewhat finer near the margin. There is often a small hyaline area in the center of the valve.

Remarks.—This species is similar in appearance to *C. perforatus* but lacks the terminal puncta on the shorter rows. In the figured specimen the widely spaced marginal dots are artifacts and not marginal apiculi.

Coscinodiscus radiatus is rare in this assemblage.

Known geologic range.—Miocene to modern oceans.

Coscinodiscus rothii (Ehrenberg) Grunow

Plate 3, figures 1, 2

Heterostephania rothii Ehrenberg, 1854, Mikrogeologie, pl. 35A, XIII B, fig. 4, 5.

Coscinodiscus rothii (Ehrenberg) Grunow *in* Schneider, 1878, Naturw. Beitr. zu Kenntn. der Kaukasuslander, p. 125*.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 400–406, fig. 211.

Coscinodiscus subtilis Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 412.

Ehrenberg, 1844, Kgl. preuss. Akad. Wiss, Berlin, Ber., 1844, p. 78.

Ehrenberg, 1854, Mikrogeologie, pl. 18, fig. 35; pl. 33, XIV, fig. 7.

Boyer, 1904, Maryland Geol. Survey, Miocene, p. 506.

Description.—Valve round, tapering upward from margin to a raised annular ring, but depressed in center. Diameter 58μ–92μ. Surface of valve divided into many sectors, each of which is defined by a relatively straight row of areolae from margin to center, then by progressively shorter rows to edge of adjacent sector, Areolae distinct and round, about 7 in 10μ, with primary radial and secondary curved decussating orientations. Areolate net not rigidly organized. The center may contain a small hyaline ring enclosing a few areolae.

Remarks.—Hustedt (1928, p. 404–406) gives a lengthy discussion of the reasons for abandoning the ill-defined *Coscinodiscus subtilis* in favor of *C. rothii,* and his conclusions are followed here. Reference to the occurrence of *C. subtilis* in the Chesapeake Group are included in the above synonymy.

Coscinodiscus rothii is rare in this assemblage.

Known geologic range.—Calvert Formation of Miocene age to modern seas, where it is common. Some of the varieties range into brackish and even fresh-water environments.

Coscinodiscus vetustissimus Pantocsek

Plate 3, figure 3

Coscinodiscus vetustissimus Pantocsek, 1886, Beiträge zur Kenntniss der fossilen Bacillarien Ungarns, pt. 1, p. 71, pl. 20, fig. 186.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 412–414, fig. 220.

Lohman, 1938, U.S. Geol. Survey Prof. Paper 189–C, p. 86, pl. 20, fig. 7.

Description.—Valve round, flat, diameters of observed specimens, 58μ and 67μ. Surface of valve divided 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. Areolae hexagonal, closely packed, about 5 in 10μ, having a primary radial orientation and a much less well-defined secondary curved decussating orientation. The center contains a small cluster of areolae surrounded by a hyaline ring.

Remarks.—This species is rare in the assemblage.

Known geologic range.—Originally described by Pantocsek (1886) from the Miocene of Hungary; reported by Lohman (1938) from the Pliocene of California. Koizumi (1973, fig. 10) states that this species ranges from foraminiferal zones N. 9 to N.

17 of Blow (1969), that is, throughout middle Miocene into late Miocene.

Genus CRASPEDODISCUS Ehrenberg, 1845

Craspedodiscus coscinodiscus Ehrenberg

Plate 3, figure 4

Craspedodiscus coscinodiscus Ehrenberg, 1845, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844, p. 266.

Ehrenberg, 1854, Mikrogeologie, pl. 18, fig. 108; pl. 33, XV, fig. 8; pl. 33, XVI, fig. 8.

Boyer, 1904, Maryland Geol. Survey, Miocene, p. 500–501, pl. 135, fig. 3.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 166, pl. 8, fig. 6.

Craspedodiscus microdiscus Ehrenberg, 1854, Mikrogeologie, pl. 33, XVII, fig. 4.

Description.—Valve round, having nearly flat outer flange and sharply convex center, diameter 74μ–100μ. Narrow zone of marginal striations, about 6 in 10μ, followed by a broad flange about half the diameter of valve in some specimens. Surface of flange is covered with a net of radiating round areolae, about 3 in 10μ. Center of valve contains a dome with markings distinct from those of the outer flange, the rows of puncta, about 5 in 10μ, having a primary radial orientation and a secondary orientation in curved decussating rows. There is a small hyaline area at the center of the valve.

Remarks.—The species is rare in this assemblage.

Known geologic range.—Previously reported only from the Calvert Formation of Miocene age of the eastern United States.

Genus ACTINOCYCLUS Ehrenberg, 1838

Actinocyclus ellipticus Grunow

Plate 3, figures 5, 6

Actinocyclus ellipticus Grunow *in* Van Heurck, 1883, Synopsis des Diatomées de Belgique, pl. 124, fig. 10.

Boyer, 1904, Maryland Geol. Survey, Miocene, p. 502, pl. 134, fig. 1.

Hustedt, 1929, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 533–534, fig. 303.

Description.—Valve broadly elliptical, but slightly tapered toward bluntly rounded ends. Length 27μ–79μ. Margin of valve irregularly striated, about 9 striae in 10μ. Marginal border band of fine puncta, about 13 rows in 10μ, arranged both in radial rows and in scalloped decussating curved rows. Irregular radial rows of coarser puncta, about 7 in 10μ along the row, extend toward the center of the valve, where similar coarse puncta are more or less randomly arranged. Pseudonodulus located near inner edge of the zone of fine puncta, on the side of the valve, but off center.

Remarks.—The species is rare in this deposit.

Known geologic range.—Although Peragallo and Peragallo (1902, p. 418, pl. 104, fig. 8) state that this species occurs today in the Mediterranean, I think that this is an error. Koizumi (1973, fig. 10) states that *A. ellipticus* ranges from foraminiferal zones N. 9 to N. 15 of Blow (1969), that is, throughout the middle Miocene.

Actinocyclus ingens Rattray

Plate 3, figure 10

Actinocyclus ingens Rattray, 1890, Jour. Queckett Microscop. Club, 2d. ser., v. 4, p. 149–150, pl. 11, fig. 7.

Kanaya, 1959, Tohoku Univ. Sci. Repts., 2d ser. (Geology), v. 30, p. 97–99, pl. 7, fig. 6–9; pl. 8, fig. 1–4.

Description.—Valve round, having sharp marginal convexity but otherwise nearly flat. Narrow marginal rim with fine striae, about 18 in 10μ. This rim is succeeded inwardly by a ring of fine puncta, about 18 in 10μ, arranged in a quincuncial pattern. Main part of valve covered with radial rows of areolae, about 5–6 areolae in 10μ, more closely spaced near the margin than the center. Areolae near margin show slight tendency toward a secondary arrangement in curved decussating rows, are arranged radially in midpart of valve and more or less randomly near the center. They are basically round, but sometimes show slight angularity because of lateral compression. Center of valve is an irregular hyaline area. Pseudonodulus obscure in observed specimen.

Remarks.—This is a most difficult species to identify because of the long confusion in the literature as to its affinities for *Actinocyclus* or *Coscinodiscus*. Kanaya (1959) has ably discussed this problem after examination of many specimens from California and Japan. The single specimen which I have observed in the Choptank Formation has much greater affinity for *Actinocyclus* and hence I have placed it in *Actinocyclus ingens* rather than in *Coscinodiscus elegans*. I have not been able to identify a pseudonodulus in the Choptank specimen. Apparently a pseudonodulus multiplex—a cluster of minute foramina—occurs in this species, but this is difficult to resolve under the light microscope.

The relationship of *Actinocyclus ingens* to *A. oculatus* Jousé and *A. ochotensis* Jousé seems problematical at this time. In fact, a careful analysis and comparison of *Actinocyclus ingens*, *A. ochotensis*, *A. tsugaruensis* Kanaya, and *Coscinodiscus elegans* would be helpful in understanding the relationships between these taxa. The Choptank specimen of *Actinocyclus ingens* seems to be very similar to forms published as *A. ochotensis* Jousé. The species does not seem to have been previously reported from the Atlantic Ocean basin, but is known from California, Japan, and central Europe (Kanaya, 1959, p. 98).

Actinocyclus ingens is rare in this assemblage.

Known geologic range.—Perhaps restricted to the Miocene. If the species is eventually proved indistinguishable from *A. ochotensis* Jousé, however, the range must be extended to the Holocene.

Actinocyclus octonarius Ehrenberg

Plate 3, figure 7

Actinocyclus octonarius Ehrenberg, 1838, Die Infusionsthierchen als vollkommene Organismen, p. 172, pl. 21, fig. 7.*
Hendey, 1937, Discovery Reports, v. 16, p. 262.
Lohman, 1941, U.S. Geol. Survey Prof. Paper 196, part 3, p. 77, pl. 16, fig. 4.
Lohman, 1948, Maryland Dept. Geology, Mines, and Mineral Resources Bull. 2, p. 167, pl. 8, fig. 8.
Actinocyclus ehrenbergii Ralfs *in* Pritchard, 1861, History of Infusoria, 4th ed., p. 834.
Boyer, 1904, Maryland Geol. Survey, Miocene, p. 502.
Hustedt, 1929, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 525–533, fig. 298.

Description.—Valve round, large, nearly flat, thin and fragile, usually found only as fragments. Diameter 46μ–114μ. Marginal zone of fine puncta, 16–20 in 10μ, arranged in a quincuncial pattern. Most of the surface of the valve is divided into sectors by single radial rows of puncta extending from the center to the marginal zone. Each sector is filled with parallel striae composed of discrete puncta, arranged normal to the margin of sector, but not parallel to the dividing striae. Each sector is filled by progressively shorter striae on both sides of the sector. About 10 striae in 10μ; about 7 puncta in 10μ along the striae. Pseudonodulus on inner edge of the quincuncial zone.

Remarks.—The justification for using *Actinocyclus octonarius* in place of *A. ehrenbergii* has been well presented by Hendey (1937) and Lohman (1942) and need not be repeated here.

The species is rare in this deposit.

Known geologic range.—Miocene to modern seas in which its occurrence is widespread.

Actinocyclus tenellus (Brébisson) Andrews, n. comb.

Plate 3, figures 8, 9

Eupodiscus tenellus Brébisson, 1854, Mem. Soc. Imp. Sci. Nat. Cherbourg, v. 2, p. 257, pl. 1, fig. 9.*
Actinocyclus moniliformis Ralfs *in* Pritchard, 1861, History of Infusoria, 4th ed., p. 834.
Grunow *in* Van Heurck, 1883, Synopsis des Diatomées de Belgique, p. 124, fig. 9.
Boyer, 1904, Maryland Geol. Survey, Miocene, p. 502–503, pl. 134, fig. 2.
Actinocyclus ehrenbergii var. *tenella* (Brébisson). Hustedt, 1929, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 530, fig. 302.

Description.—Valve round, nearly flat. Diameter 56μ–70μ. Margin with fine striations, about 18 in 10μ, followed inwardly by a narrow quincuncial zone of fine puncta, about 16 in 10μ. The greater part of valve is divided into sectors by radial punctate striae, and the sectors are filled with punctate striae in an arrangement identical to that of *Actinocyclus octonarius*. 10 striae in 10μ; 6 puncta in 10μ along the striae. Pseudonodulus at inner margin of quincuncial zone. There is often an irregular hyaline area at the center of the valve.

Remarks.—This species shows obvious affinities for *Actinocyclus octonarius*, and Hustedt (1929) makes it a variety of that species. In this assemblage, however, the specimens are distinctive from that species in the more robust markings of the valve and the generally smaller size.

Known geologic range.—Miocene to modern oceans.

Genus HYALODISCUS Ehrenberg, 1845

Hyalodiscus laevis Ehrenberg

Plate 4, figures 1, 2

Hyalodiscus laevis Ehrenberg, 1845, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1845, p. 78.*
Ehrenberg, 1854, Mikrogeologie, pl. 33, XV, fig. 17.
Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 294–295, fig. 135.

Description.—Valve round, markedly convex, 35μ–53μ in diameter. Valve slopes upward from margin to raised umbilical ring at about half the radius; center of valve depressed. Extreme margin of valve has very narrow zone of striations, about 10 in 10μ. Remainder of valve irregularly mottled, and fine structure, if any, not observed. Top of umbilical ring irregularly scattered with sharp, well-defined puncta in some specimens.

Remarks.—*Hyalodiscus laevis* is rare in this assemblage.

Known geologic range.—Miocene to modern coastal marine and brackish waters.

Family ACTINODISCACEAE
Subfamily ACTINOPTYCHOIDEAE
Genus ACTINOPTYCHUS Ehrenberg, 1843
Actinoptychus marylandicus Andrews, n. sp.

Plate 4, figures 3–6

Diagnosis.—Valve round, flat, fragile. Diameter 54μ–95μ. Valve margin often missing or poorly preserved, main part of valve divided into sectors, 14–18 in the specimens observed. Sectors are alternately elevated and depressed, the elevated group having different markings from the depressed group. (1) Coarsely punctate sectors (pl. 4, figs. 3, 5): single row of puncta at margin, succeeded inwardly by a narrow but distinct hyaline band; main part of sector covered with parallel rows of puncta, about 10 in 10μ, arranged in a quincuncial pattern, but showing a bladelike hyaline area extending one-third to one-half the length of the sector from the hyaline central area; bladelike hyaline area caused by absence of 1–3 rows of puncta in center of sector. (2) Finely punctate sectors (pl. 4, figs. 4, 6): each sector shows a single spinelike process, centrally located near the margin; main part of sector covered with fine puncta, about 16 in 10μ, and arranged in a hexagonal pattern. There is no bladelike hyaline area analogous to that of the alternate sectors. Central area hyaline, vaguely marked, about one-fifth of the diameter of the valve, warped near margin to join alternate sectors on different planes.

Remarks.—This species is very similar to *Actinoptychus virginicus*, except that the hyaline areas in the coarsely punctate sectors are bladelike rather than irregular. It is perhaps similar to *A. vulgaris* var. *australis* Grunow, but the lack of an adequate description of that form makes comparison difficult.

Actinoptychus marylandicus is rare in this assemblage.

Known geologic range.—Middle Miocene, not previously reported. This may be a short-ranging species and hence useful as a marker fossil.

Holotype: USGS diatom catalog No. 3904–12 (pl. 4, figs. 3, 4), diameter 54μ. Paratype: USGS diatom catalog No. 3901–28 (pl. 4, figs. 5, 6), diameter 59μ.

Actinoptychus senarius (Ehrenberg) Ehrenberg

Plate 4, figures 7, 8

Actinocyclus senarius Ehrenberg, 1838, Die Infusionsthierchen als vollkommene Organismen, p. 172, pl. 21, fig. 6.*

Actinoptychus senarius (Ehrenberg) Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 400, pl. 1, fig. 27.

Hendey, 1937, Discovery Reports, v. 16, p. 271–272.

Lohman, 1941, U.S. Geol. Survey Prof. Paper 196, part 3, p. 80–81, pl. 16, fig. 9.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 170.

Actinoptychus undulatus Kützing. Boyer, 1904, Maryland Geol. Survey, Miocene, p. 499–500, pl. 134, fig. 4.

Actinoptychus undulatus (Bailey) Ralfs. Hustedt, 1929, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 475–478, fig. 264.

Description.—Valve round, flat; diameter 41μ–66μ. Valve divided into six sectors, alternately elevated and depressed, one group having different markings from the other group. (1) Coarsely punctate sectors (pl. 4, fig. 7): surface completely and regularly covered with parallel rows of puncta, about 14 in 10μ, arranged in a quincuncial pattern. This layer appears to be underlain by a vague net of larger rectilinear areolae, about 4 in 10μ. (2) Finely punctate sectors (pl. 4, fig. 8). Each sector shows a single outwardly directed tubular process near the center of the margin, some extending slightly beyond the edge of the valve; surface completely and regularly covered with fine puncta, about 17 in 10μ, arranged in a hexagonal areolate net. This appears to be underlain by a vague net of larger hexagonal areolae, about 4 in 10μ. Central area hyaline, vaguely marked, about one-fifth the width of the valve, warped near margins to join alternate sectors on different planes.

Remarks.—The nomenclature of this species is ably discussed by Hendey (1937) and Lohman (1942) and need not be repeated here.

The species occurs frequently in this assemblage.

Known geologic range.—*Actinoptychus senarius* is reported from the Cretaceous of California to cool coastal waters of modern seas, where it is common.

Actinoptychus virginicus (Grunow) Andrews, n. comb.

Plate 4, figures 9–12

Actinoptychus vulgaris var. *virginica* Grunow *in* Van Heurck, 1883, Synopsis des Diatomées de Belgique, pl. 121, fig. 7.

Actinoptychus vulgaris var. *virginiae* Grunow. Boyer, 1904, Maryland Geol. Survey, Miocene, p. 500.

Description.—Valve round, flat, fragile, diameter 35μ–72μ. Valve margin often missing or poorly preserved, main part of valve divided into sectors, 10–18 in the specimens observed. Sectors are alternately elevated and depressed, one group having different markings from the other group. (1) Coarsely punctate sectors (pl. 4, figs. 9, 11), single row of puncta at margin, succeeded inwardly by a narrow but distinct hyaline band; main part of sector covered with parallel rows of puncta, about 10 in 10μ, arranged in a quincuncial pattern, but showing an irregular hyaline area in the center of each sector, seemingly an extension of the hyaline central area of the valve. (2) Finely punctate sectors (pl. 4, figs. 11, 12), some specimens show a single spinelike process, centrally located near the margin; main part of sector covered with fine puncta, about 16 in 10μ, arranged in a hexagonal pattern and completely filling the sector. Central area hyaline, vaguely marked, about one-fifth of the diameter of the valve, warped near margin to join the alternate sectors on different planes.

Remarks.—This species is very similar to *Actinoptychus marylandicus*, differing only in the irregular hyaline spaces on the coarsely punctate sectors. In view of the doubtful validity of *A. vulgaris*, as expressed by Hustedt (1929, p. 482), I have raised Grunow's variety to specific rank.

Actinoptychus virginicus is rare in this assemblage.

Known geologic range.—Calvert and Choptank Formations of middle Miocene age.

Suborder EUPODISCINEAE
Family EUPODISCACEAE
Subfamily EUPODISCOIDEAE
Genus RATTRAYELLA Hanna, 1932

Rattrayella inconspicua (Rattray) Hanna

Plate 5, figures 1, 2

Eupodiscus inconspicuus Rattray, 1888, Jour. Roy. Microscopical Soc., v. 9, p. 911.*
Boyer, 1904, Maryland Geol. Survey, Miocene, p. 498, pl. 135, fig. 6, 7.
Rattrayella inconspicua (Rattray) Hanna, 1932, California Acad. Sci. Proc., 4th ser., v. 20, p. 210–211, pl. 14, fig. 5; pl. 15, fig. 1, 2.

Description.—Valve round, convex, diameter 72μ–88μ. Six short tubular processes extend above valve surface at regular intervals along the margin. Surface of valve covered with a net of hexagonal areolae, about 3 in 10μ and variable in size. The net is not rigidly organized in rows of areolae.

Remarks.—The number of marginal tubular processes may vary, and they are not always easy to discern. The specimens figured by Hanna (1932) show a more obvious pattern of curved decussating rows in the areolate net than my specimens show.

The species is rare in this deposit.

Known geologic range.—Miocene from both eastern and western United States.

Suborder AULISCINEAE
Family LIRADISCACEAE
Subfamily LIRADISCOIDEAE
Genus LIRADISCUS Greville, 1865

Liradiscus asperulus Andrews, n. sp.

Plate 5, figures 3–5

Diagnosis.—Valve ovate, convex, observed length 23μ–43μ, width 13μ–15μ. Single row of prominent thornlike spines along margin of valve, extending normal to the plane of the valve. Entire valve surface covered with an irregular network of anastomosing low ridges, a few of these near the center developed into irregular rugose processes.

Remarks.—This species is distinguished by the marginal spines and the rugose processes irregularly distributed on the center of the valve.

Liradiscus asperulus is rare in this assemblage.

Known geologic range.—Middle Miocene. Not previously reported.

Holotype: USGS diatom catalog No. 3903–7 (pl. 5, fig. 3), length 40μ. Paratype: USGS diatom catalog No. 3904–6 (pl. 5, fig. 4), length 43μ. Paratype: USGS diatom catalog No. 3902–14 (pl. 5, fig. 5), length 23μ.

Liradiscus ovalis Greville

Plate 5, figures 6, 7

Liradiscus ovalis Greville, 1865, Trans. Microscop. Soc. London, v. 13, n. s., p. 5, pl. 1, fig. 15, 16.*
Rattray, 1889, Roy. Soc. Edinburgh Proc., v. 16, p. 670–671.

Description.—Valve convex, ovate with bluntly pointed apices. Surface of valve covered randomly with short spines. A network of low ridges connects adjacent spines. Length of observed specimens 22μ–30μ.

Remarks.—*Liradiscus ovalis* is rare in this assemblage.

Known geologic range.—Upper Eocene (Oamaru) to middle Miocene (this assemblage). Rattray described the species from Barbados.

Order BIDDULPHIALES
Suborder BIDDULPHIINEAE
Family BIDDULPHIACEAE
Subfamily BIDDULPHIOIDEAE
Genus BIDDULPHIA Gray, 1831

Biddulphia aurita var. obtusa (Kützing) Hustedt

Plate 5, figure 8

Odontella obtusa Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 137, pl. 18, fig. VIII, 1–3, 6–8.
Biddulphia aurita var. *obtusa* (Kützing) Hustedt, 1930, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 848–849, fig. 502.
Biddulphia roperiana Greville, 1859, Quart. Jour. Microscop. Sci., v. 7, p. 163, pl. 8, fig. 11–13.*
Grunow *in* Van Heurck, 1882, Synopsis des Diatomées de Belgique, pl. 99, fig. 4–6.

Description.—Valve convex, subrhomboidal, with bluntly pointed apices. Length of observed specimen, 47μ. Surface of valve covered with radiating rows of puncta, about 7 in 10μ, showing a secondary pattern of curved decussating rows. Two short tubular processes, about 4μ in diameter, extend vertically from the plane of the valves at the apices.

Remarks.—This variety is rare in this assemblage.

Known geologic range.—Middle Miocene to coastal waters of modern seas.

Biddulphia semicircularis (Brightwell) Boyer

Plate 5, figures 9, 10

Triceratium semicirculare Brightwell, 1853, Quart. Jour. Royal Microscop. Soc., v. 1, p. 252, pl. 4, fig. 21.*
Biddulphia semicircularis (Brightwell) Boyer, 1901, Acad. Nat. Sci. Philadelphia Proc., v. 52, p. 726.
Boyer, 1904, Maryland Geol. Survey, Miocene, p. 494, pl. 134, fig. 10.
Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 173–174.
Triceratium obtusum Ehrenberg, 1854 (in part), Mikrogeologie, pl. 18, fig. 49.
Euodia brightwelli Ralfs *in* Pritchard, 1861, History of Infusoria, 4th ed., p. 852.
Grunow *in* Van Heurck, 1883, Synopsis des diatomées de Belgique, pl. 126, fig. 20.

Description.—Valve lunate, convex near margins, but nearly flat on top. Convex side is highly arched, concave side slightly arched to nearly straight. The two apices are more or less protracted in some specimens. Surface of valve covered with roughly circular rows of large discrete puncta, 4–7 in 10μ, concentric around a hyaline central area. Length of observed specimens, 45μ–70μ.

Remarks.—*Biddulphia semicircularis* has a robust valve, which is generally well preserved. It is frequent in this assemblage.

Known geologic range.—Middle Miocene, occurring in the Calvert and Choptank Formations.

Biddulphia tuomeyi (Bailey) Roper

Plate 5, figure 11

Zygoceros Tuomeyi Bailey, 1844, Am. Jour. Sci., v. 46, p. 138, pl. 3, fig. 3–9.

Biddulphia Tuomeyi (Bailey) Roper, 1859, Royal Microscopical Soc. Trans., v. 7, p. 8, pl. 1, fig. 1, 2.*

Grunow *in* Van Heurck, 1882, Synopsis des Diatomées de Belgique, pl. 98, fig. 2–3.

Hustedt, 1930, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 834–836, fig. 491.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources, Bull. 2, p. 174.

Biddulphia tridens Ehrenberg, 1840, Kgl. Akad. Wiss. Berlin, Ber., p. 205.*

Boyer, 1901, Acad. Nat. Sci. Philadelphia Proc., v. 52, p. 695.

Description.—Valve usually oriented in girdle view, length of observed specimens, 48μ–57μ. Base slightly extended beyond main part of valve, which consists of a large domed central process and two somewhat deflected tubular apical processes. Tips of apical processes are usually missing. Main part of valve covered with large discrete puncta, arranged radially on the central dome but apparently of random distribution elsewhere.

Remarks.—The illustrations of Hustedt (1930) and Van Heurck (1882) show two pronounced lateral swellings or domes between the central dome and the apical processes. There are only faint suggestions of these in specimens observed in this assemblage.

This species is rare in this assemblage.

Known geologic range.—Cretaceous to Holocene according to Lohman (1948).

Genus GONIOTHECIUM Ehrenberg 1843

Goniothecium rogersii Ehrenberg

Plate 5, figures 12, 13

Goniothecium rogersii Ehrenberg, 1843, Kgl. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 401, 416.

Ehrenberg, 1854, Mikrogeologie, pl. 18, fig. 92, 93.

Hanna, 1932, California Acad. Sci. Proc., 4th ser., v. 20, p. 192, pl. 11, fig. 4–6.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources, Bull. 2, p. 179.

Description.—Valve irregularly elliptical, convex, 48μ–80μ in length. Valve has a tiered "wedding-cake" structure with three levels of surface elevation. These levels are defined by circular "escarpments," which are truncated by the lateral margins of the valves. Valve surface covered by large scattered puncta having no discernible orientation.

Remarks.—*Goniothecium rogersii* is a distinctive species, usually well preserved, and it is frequent in this assemblage.

Known geologic range.—Middle Miocene of eastern and western United States to San Joaquin Formation of Pliocene age of California.

Family EUCAMPIACEAE
Genus EUCAMPIA Ehrenberg, 1839

Eucampia virginica Grunow

Plate 5, figures 14, 15

Eucampia virginica Grunow *in* Van Heurck, 1882, Synopsis des Diatomées de Belgique, pl. 95 bis, fig. 6.

Eucampia zoodiacus Ehrenberg (in part). Boyer, 1927, Acad. Nat. Sci. Philadelphia, Proc., v. 78, suppl., p. 116.

Hustedt, 1930, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 772.

Description.—Valve elongate-elliptical with bluntly rounded apices, length of observed specimens, 62μ–76μ. Surface of valve with irregular rows of puncta, about 8 in 10μ, radiating from center. Central area small with a single process of undetermined nature. Ends of valve hyaline, with no trace of projecting processes.

Remarks.—There seems to be little justification for lumping this species with *E. zoodiacus* in view of the former's coarser punctation and lack of projecting apical processes.

Eucampia virginica is rare in this assemblage.

Known geologic range.—Middle Miocene (Calvert and Choptank Formations).

Family TERPSINOACEAE
Genus TERPSINOË Ehrenberg, 1843
Terpsinoë americana (Bailey) Ralfs

Plate 5, figures 16, 17

Tetragramma americana Bailey, 1854, Smithsonian Contributions to Knowledge, v. 7, art. 2, p. 7–8, fig. 1.

Terpsinoë americana (Bailey) Ralfs *in* Pritchard, Infusoria, p. 859.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, suppl., p. 145.

Hustedt, 1930, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 900–901, fig. 541.

Description.—Valve elongate, markedly undulating, divided by two transverse septa into three expanded segments; ends rounded, distinct from adjacent segments, but not separated from them by septa. Length 61μ–90μ. Surface of valve covered with large but vague puncta in a randomly oriented pattern. In many specimens, central part of valve shows one or more slitlike processes of undetermined nature. Ringlike hyaline areas at apices appear to be bases for some sort of attachment process, but do not project far above the surface.

Remarks.—The species is rare in this assemblage.

Known geologic range.—Miocene to modern coastal marine and brackish waters.

Suborder TRICERATIINEAE
Family TRICERATACEAE
Genus TRICERATIUM Ehrenberg, 1841

Triceratium condecorum Ehrenberg

Plate 5, figures 18, 19

Triceratium condecorum Ehrenberg, 1845, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844, p. 272.
Grunow in Schmidt, 1882, Atlas der Diatomaceenkunde, pl. 76, fig. 28.
Hanna, 1932, California Acad. Sci. Proc., 4th ser., v. 20, p. 221, pl. 17, fig. 1, 3.
Hustedt, 1959, Schmidt's Atlas der Diatomaceenkunde, pl. 478, fig. 14–21
Biddulphia condecora (Ehrenberg) Boyer, 1901, Acad. Nat. Sci. Philadelphia Proc., v. 52, p. 720.
Boyer, 1904, Maryland Geol. Survey, Miocene, p. 492–493, pl. 134, fig. 7.
Triceratium interpunctatum Grunow *in* Schmidt, 1882, Atlas der Diatomaceenkunde, pl. 76, fig. 7.
Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 175, pl. 10, fig. 2.
Biddulphia interpunctatum (Grunow) Boyer, 1900, Acad. Nat. Sci. Philadelphia Proc., v. 52, p. 720.
Boyer, 1904, Maryland Geol. Survey, Miocene, p. 494, pl. 134, fig. 9.

Description.—Valve triangular, has a raised rim and depressed triangular center. Sides vary from slightly concave to straight to slightly convex. Apices vary from obtusely rounded to a rounded point. Length of side, 44μ–60μ. Surface of valve covered with a net of areolae, arranged primarily in a radial pattern and secondarily in a roughly concentric pattern around the center. About 5 areolae in 10μ near center, somewhat more closely spaced at the margin. Radial striae terminate in a single small punctum, in a manner analogous to that of the short striae of *Coscinodiscus perforatus*. A small area of finer areolae occurs on each of the apices.

Remarks.—I have seen no convincing evidence in any of the literature cited in the synonymy on how *Triceratium interpunctatum* differs from *T. condecorum*. As they occur in the same deposits and appear to be indistinguishable, *T. interpunctatum* has been placed in synonymy and *T. condecorum* preserved on the basis of priority.

Triceratium condecorum is frequent in this assemblage.

Known geologic range.—Hustedt reports this species from the upper Eocene of Oamaru, New Zealand. It is well known from the Calvert and Choptank Formations of middle Miocene age. Koizumi (1973, fig. 10) states that *T. condecorum* ranges from foraminiferal zones N. 9 to N. 17 of Blow (1969), that is, from middle to late Miocene.

Suborder HEMIAULIINEAE
Family HEMIAULACEAE
Genus HEMIAULUS Ehrenberg, 1845

Hemiaulus polymorphus var. virginica Grunow

Hemiaulus polymorphus var. *virginica* Grunow, 1884, Kaisl.-Kgl. Akad. Wiss. Wien, Math.-Naturwiss. Kl., Denkschr., v. 48, p. 66, pl. B, fig. 46.

Description.—Valve usually oriented in girdle view, length of observed specimen about 33μ. Main part of valve divided into three bulbous parts, of which the center is largest and best defined. Ends of valve have tubular processes, about 30μ in length, slightly deflected outward; a small terminal spine on inside margin of tubular processes deflected inward. Entire valve covered with well defined puncta having a random distribution.

Remarks.—The form observed in this assemblage is identical to that figured by Grunow (1884) as var. *virginica* in that it is also characterized by the three bulbous processes, is the same size, and has the same length-height ratio. Whether or not these features are consistent enough to maintain the validity of this taxon remains to be determined.

Known geologic range.—The variety has been previously reported only by Grunow (1884) from the Calvert Formation of Miocene age at Richmond, Va. Lohman (1948) states that the species ranges from Cretaceous to Holocene. Koizumi (1973) states that the species ranges from foraminiferal zones N. 9 to N. 15 of Blow (1969), that is, throughout the middle Miocene.

Order HETERALES
Suborder HETERINEAE
Family XANTHIOPYXACEAE

Genus XANTHIOPYXIS Ehrenberg, 1845

Xanthiopyxis microspinosa Andrews, n. sp.

Plate 6, figures 1–3

Diagnosis.—Valve ovate, convex, with blunt, obtusely pointed apices. Length 32μ–52μ; width 21μ–32μ. Margin of valve narrow, striated, about 12 striae in 10μ. Entire valve surface covered with short fine spines having a random distribution.

Remarks.—The species is distinguished by its external shape and by the randomly and unevenly distributed short spines over the entire surface.

Xanthiopyxis microspinosa is rare in this assemblage.

Known geologic range.—Middle Miocene. Not previously reported.

Holotype: USGS diatom catalog No. 3901–43 (pl. 6, fig. 1), length, 52μ. Paratype: USGS diatom catalog No. 3772–37 (pl. 6, fig. 2), length, 32μ. Paratype: USGS diatom catalog No. 3900–46, (pl. 6, fig. 3) length, 32μ.

Xanthiopyxis spp.

A large number of varied forms of *Xanthiopyxis* were observed among the diatoms from locality 6098. In general, these specimens were small (less than 50μ in maximum dimension). They varied in outline from round through ovate to elliptical to elongate. The ornamentation varied from hyaline to punctate to spinose, with both puncta and spines differing in size and distribution. In general, only one specimen of each type was observed, and there was no real evidence to determine if each represented a valid species or simply unique individuals. Because of the rarity of each form in the sample and hence their dubious value in stratigraphic age determination, it seems sufficient to mention their occurrence but to forgo a taxonomic analysis.

Genus DOSSETIA Azpeitia, 1911

Dossetia hyalina Andrews, n. sp.

Plate 6, figures 4–7

Diagnosis.—Valve ovate, highly convex, surrounded at the margin with a vaguely laminate flange parallel to the plane of the valves, strongly dentate on its outer margin. Observed length, 37μ–50μ, but probably somewhat greater because the tips of the larger marginal spines are usually broken off. The convex main part of the valve is hyaline and shows no discernible structure with the light microscope under an oil-immersion objective.

Remarks.—This species is similar to *Dossetia temperei* Azpeitia except that the valve is hyaline rather than granular.

Dossetia hyalina is rare in this assemblage.

Known geologic range.—Middle Miocene. Not previously reported.

Holotype: USGS diatom catalog No. 3901–38 (pl. 6, fig. 4), length, 45μ. Paratype: USGS diatom catalog No. 3901–19 (pl. 6, fig. 5), length, 37μ. Paratype: USGS diatom catalog No. 3901–29 (pl. 6, fig. 6), length, 40μ. Paratype: USGS diatom catalog No. 3904–3 (pl. 6, fig. 7), length, 42μ.

Genus PERIPTERA Ehrenberg, 1845

Periptera tetracladia Ehrenberg

Plate 5, figures 20, 21

Periptera tetracladia Ehrenberg, 1845, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844, p. 270.
Ehrenberg, 1854, Mikrogeologie, pl. 33, XVIII, fig. 9.
Grunow *in* Van Heurck, 1882, Synopsis des Diatomées de Belgique, pl. 83 ter, fig. 7–9.
Hanna, 1932, California Acad. Sci. Proc., 4th ser., v. 20, p. 205, pl. 13, fig 8.
Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 178–179.

Description.—Valve roughly quadrangular in girdle view, slightly swollen at center. Length of observed specimens, 28μ–32μ. Prominent large thornlike spines, many of which are partially broken, extend from the valve margin normal to the plane of the valves. One or two rows of fine puncta, about 12 in 10μ but irregular in distribution, occur around the girdle.

Remarks.—*Periptera tetracladia* is rare in this assemblage.

Known geologic range.—Middle Miocene to Pliocene according to Lohman (1948).

Genus STEPHANOGONIA Ehrenberg, 1845

Stephanogonia actinoptychus (Ehrenberg) Grunow

Plate 6, figure 8

Mastogonia actinoptychus Ehrenberg, 1845, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844, p. 269.
Ehrenberg, 1854, Mikrogeologie, pl. 18, fig. 109; pl. 33, XIII, fig. 16.
Stephanogonia actinoptychus (Ehrenberg) Grunow *in* Van Heurck, 1882, Synopsis des Diatomées de Belgique, pl. 83 ter, fig. 2–4.
Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 178.
Stephanogonia polyacantha Forti, 1913, R. ist. veneto sci., Atti, v. 72, pt. 2, p. 1560, pl. 12, fig. 11.*
Hanna, 1932, California Acad. Sci. Proc, 4th ser., v. 20, p. 218, pl. 16, fig. 8.

Description.—Valve broadly ovate, convex, length of observed specimen, 62μ; width, 48μ. Narrow marginal rim, main part of valve divided into more or less equal sectors by irregular septa which fuse near the center into an irregular ring. Valve surface covered with randomly scattered puncta, fine but distinct.

Remarks.—The species is rare in this assemblage.

Known geologic range.—Reported only from Miocene assemblages in eastern and western United States.

Family PYXILLACEAE
Genus PSEUDOPYXILLA Forti 1909

Pseudopyxilla americana (Ehrenberg) Forti

Plate 6, figures 9–12

Rhizosolenia americana Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin Abh. 1841, p. 422.
Ehrenberg, 1854, Mikrogeologie, pl. 18, fig. 98; pl. 33, fig. 13/20, 17/14.
Pseudopyxilla americana (Ehrenberg) Forti, 1909, La Nuova Notarisia, ser. 20, pl. 1, fig. 6, 7.*
Pyxilla americana (Ehrenberg) Grunow in Van Heurck, 1882, Synopsis des Diatomées de Belgique, pl. 83 bis, fig. 1–3.

Description.—Only tips of valves preserved, two general shapes: (1) round, tapering gently to a truncated point; (2) round, curved, tapering rather abruptly to an end bearing one or two sharply deflected spines. Ends of valves hyaline, with a sharp boundary between punctate main part of valve. Puncta fine, about 12 in 10μ, in a closely spaced random distribution. A single transverse septum is seen in some valve tips.

Remarks.—Although the gently and abruptly tapered tips are somewhat different in appearance, both have been customarily included in this species. *P. americana* is rare in this assemblage.

Known geologic range.—This species has been reported only from the middle Miocene of eastern and western United States.

Order PENNALES
Suborder ARAPHIDINEAE
Family FRAGILARIACEAE
Subfamily FRAGILARIOIDEAE

Genus RHAPHONEIS Ehrenberg, 1845

Rhaphoneis amphiceros Ehrenberg

Plate 6, figures 13, 14

Rhaphoneis amphiceros Ehrenberg, 1844, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844, p. 87.

Ehrenberg, 1854, Mikrogeologie, pl. 33, XIV, fig. 22.

Van Heurck, 1885, Synopsis des Diatomées de Belgique, p. 147; 1881, pl. 36, fig. 22, 23.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 174–176, fig. 680.

Hanna, 1932, California Acad. Sci. Proc., 4th ser., v. 20, p. 211–212, pl. 15, fig. 3–5.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 180.

Description.—Valve elliptical-lanceolate, nearly flat, with produced, sharply rounded apices. Length of observed specimens, 45μ–71μ, width about 22μ. Surface of valve covered with curved radial rows of distinct puncta, 7–8 rows in 10μ and 7–8 puncta in 10μ along the row. In addition to a primary arrangement as curved transverse striae, the puncta show a secondary arrangement in nearly straight longitudinal rows. Pseudoraphe very narrow near apices, but slightly expanded near center. Transverse striae may or may not show continuity across the pseudoraphe.

Remarks.—The species is rare in this assemblage.

Known geologic range.—Miocene to modern coastal marine and brackish waters.

Rhaphoneis angustata Pantocsek

Plate 7, figures 1, 2

Rhaphoneis angustata Pantocsek, 1886, Beiträge zur Kenntnis der fossilen Bacillarien Ungarns, pt. 1, p. 33, pl. 11, fig. 97; pl. 30, fig. 313.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources, Bull. 2, p. 180–181, pl. 11, fig. 11.

Description.—Valve elongate, tapering slightly to bluntly rounded apices. Length of observed specimens, 28μ–58μ, width about 7μ. Striae short, 8–9 rows in 10μ, composed of only 2 or 3 longitudinal rows of puncta. The striae are parallel in the center, becoming slightly radial near the apices, and finer striae curve completely around the ends of the valves. Pseudoraphe comparatively wide for the narrow valve, about one-quarter to one-fifth of the width. Pairs of transverse striae may or may not be alined across the pseudoraphe.

Remarks.—The species is rare in this assemblage.

Known geologic range.—*Rhaphoneis angustata* has been previously reported only from the Miocene of Hungary and from the Calvert Formation of Miocene age.

Rhaphoneis diamantella Andrews, n. sp.

Plate 6, figures 15–18

Diagnosis.—Valve lozenge-shaped, obtuse to rounded at the center of the lateral margins, tapering by straight or slightly concave sides to bluntly pointed apices. Length, 33μ–70μ width, 15μ–22μ. Transverse striae composed of large pearllike puncta, about 5 in 10μ in both transverse and longitudinal directions. In addition to a primary orientation in slightly radiating transverse rows, the puncta are secondarily oriented in slightly curved longitudinal rows. Pseudoraphe very narrow near the apices but slightly expanded in the central region. Individual transverse striae are consistently staggered at, and do not show continuity across, the pseudoraphe.

Remarks.—This species resembles *R. gemmifera* in coarseness of the pearllike puncta and in their general arrangement. It differs significantly in outline, however, showing a much more nearly perfect lozenge shape, sharper medial angulation on the lateral margins, and less protracted apices. Comparison of *R. diamantella* with specimens of *R. gemmifera* under the scanning electron microscope confirms this differentiation. *R. diamantella* shows clean, round openings which form the puncta and only vestigial fine pore fields in the apical regions, whereas *R. gemmifera* shows openings with paired, inward-projecting apiculi, and well-defined fine pore fields near the apices. The presence of inward-directed apiculi in the large pores has been cited as a generic characteristic of *Rhaphoneis*. However, these structures do not seem to occur in either *R. diamantella* or *R. lancettula* as viewed under the scanning electron microscope, and hence must be characteristic of only some species of *Rhaphoneis*.

Known geologic range.—Middle Miocene. Known only from this assemblage. This distinctive species may be an excellent index fossil if it proves to be of wide distribution.

Holotype: USGS diatom catalog No. 3772–29 (pl. 6, fig. 17), length, 62μ. Paratype: USGS diatom catalog No. 3771–9 (pl. 6, fig. 15), length, 40μ. Paratype: USGS diatom catalog No. 3772–52 (pl. 6, fig. 16), length, 50μ. Paratype: USGS diatom catalog No. 3900–14 (pl. 6, fig. 18), length, 70μ.

Rhaphoneis immunis Lohman

Plate 7, figure 3

Rhaphoneis immunis Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 182, pl. 11, fig. 6.

Description.—Valve lanceolate, tapering to narrow rounded apices. Length about 45μ, width about 6μ. Single row of marginal puncta, 6–7 puncta in 10μ. Inner row of larger puncta, 5½ puncta in 10μ, parallel to the marginal row, but with distribution bearing no obvious relationship to the marginal puncta. Pseudoraphe hyaline in center, tapering rapidly toward the apices and becoming obscured by the converging rows of inner, coarser puncta.

Remarks.—Although the species as here observed is somewhat smaller and the marginal puncta are a bit more closely spaced than those described by Lohman (1948, p. 182), it agrees with Lohman's species completely in the unusual dual punctation of the valves.

Rhaphoneis immunis is rare in this assemblage.

Known geologic range.—The Calvert and Choptank Formations of Miocene age.

Rhaphoneis lancettula Grunow

Plate 7, figures 4, 5

Rhaphoneis lancettula Grunow *in* Pantocsek, 1886, Beiträge zur Kenntnis der fossilen Bacillarien Ungarns, p. 35, pl. 27, fig. 271.

Fragilaria amphiceros Ehrenberg, 1854, Mikrogeologie, pl. 18, fig. 77.

Description.—Valve narrow, elongate, lateral margins tapering gently toward the apices, then becoming nearly parallel to attenuate the valve in the apical direction. Apices rounded, slightly capitate in some specimens. Length, 55μ–76μ; width, 7–8½μ. Puncta, 6 in 10μ, large, evenly spaced, and arranged in regular rows both transversely and longitudinally. Pseudoraphe narrow, identified only as the central hyaline space between longitudinal rows of puncta, and not noticeably wider than the spaces between other rows of puncta.

Remarks.—This species is recognized by the narrow valve with the attenuate apices and by the rectilinear arrangement of the puncta. The regular arrangement of the puncta as well as the very narrow pseudoraphe relegate the pseudoraphe in this species to more of a concept than a reality.

The species occurs frequently in this assemblage.

Known geologic range.—Choptank Formation at this locality; described by Grunow from the Miocene deposit at Richmond, Va., probably from the Calvert Formation.

Genus THALASSIONEMA Grunow, 1881

Thalassionema obtusa (Grunow) Andrews, n. comb.

Plate 7, figures 6–8

Thalassiothrix? nitzschioides var. *obtusa* Grunow *in* an Heurck, 1881, Synopsis des Diatomées de Belgique, pl. 43, fig. 6.

Description.—Valve small, lanceolate, with rounded apices. Length, 32μ–37μ; width, about 5μ–6μ. Along the lateral margins of the valve is a row of single puncta or very short transverse striae, about 9½ in 10μ. Pseudoraphe relatively wide, lanceolate, hyaline.

Remarks.—This form seems to be sufficiently distinct from *Thalassionema nitzschioides* to be recognized as a separate species.

Thalassionema obtusa is rare in this assemblage.

Known geologic range.—Previously reported only from the Rappahannock deposit of middle Miocene age by Grunow in Van Heurck, (1881).

Genus THALASSIOTHRIX Cleve and Grunow, 1880

Thalassiothrix longissima Cleve and Grunow

Plate 7, figures 9, 10

Synedra thalassiothrix Cleve, 1873, Kgl. svenska vetensk. akad. Handl., Bihang, Bd. 1, No. 13, p. 22, pl. 4, fig. 24.

Thalassiothrix longissima Cleve and Grunow, 1880, Kgl. svenska vetensk, akad. Handl., v. 17, No. 2, p. 108.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 247, fig. 726.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 185.

Description.—Valve extremely elongate, narrow, with bluntly rounded apices. Length unknown in this assemblage as only fragments were observed; width, 3μ–4μ. Transverse striae short, marginal, about 12 in 10μ. Pseudoraphe about one-third the width of the valve, narrowing near the apices.

Remarks.—Although this species should properly be named *Thalassiothrix thalassiothrix* (Cleve) Cleve and Grunow, a change seems pointless after over 90 years' consistent use of *T. longissima.*

Thalassiothrix longissima is rare in this assemblage.

Known geologic range.—Middle Miocene to modern seas, where it is especially abundant in cold waters.

Subfamily TABELLARIOIDEAE
Genus GRAMMATOPHORA Ehrenberg, 1839

Grammatophora angulosa Ehrenberg

Plate 7, figures 11–13

Grammatophora angulosa Ehrenberg, 1841, Kgl. preuss. Akad. Wiss. Berlin, Abh., 1839, p. 153.

Ehrenberg, 1854, Mikrogeologie, pl. 18, fig. 88.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 39–40, fig. 564.

Description.—Valve elongate-elliptical with bluntly rounded apices, length 27μ–62μ. Only the more robust girdle part was preserved in observed specimens, so the fine structure is not known from this assemblage. Girdle view shows prominent S-shaped internal septa of the valve (see pl. 7, fig. 13).

Remarks.—The species is frequent in this assemblage.

Known geologic range.—Middle Miocene to coastal waters of modern seas, where it is common.

Grammatophora marina (Lyngbye) Kützing

Plate 7, figures 14, 15

Diatoma marinum Lyngbye, 1819, Hydrophyt. dan., pl. 62A.*
Grammatophora marina (Lyngbye) Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 128, pl. 17, fig. XXIV, 1–6, pl. 18, fig. I, 1–5.
Van Heurck, 1881, Synposis des Diatomées del Belgique, pl. 53, fig. 10–13.
Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pl. 2, p. 43–44, fig. 569.

Description.—Valve elongate-elliptical with bluntly rounded apices, length of observed specimens, 38μ–44μ. Fine structure not preserved, and only the more robust internal septa are known from this assemblage. Septa nearly flat, not sharply bent as in *Grammatophora angulosa*. Single elliptical central opening is the most striking feature of the valve.

Remarks.—The species is rare in this assemblage.

Known geologic range.—Middle Miocene to modern marine coastal waters, where it is common.

Suborder MONORAPHIDINEAE
Family ACHNANTHACEAE
Subfamily COCCONEOIDEAE
Genus COCCONEIS Ehrenberg, 1838
Cocconeis sp.

Plate 7, figure 16

Description.—Valve broadly elliptical with bluntly rounded apices, the one measurable 41μ in length and 28μ in width. Marginal puncta, about 14 in 10μ, about 9–10 rows in 10μ of large, somewhat irregularly spaced puncta in the lateral areas. Pseudoraphe narrow, bounded on either side by rows of large puncta.

Remarks.—This form is seen rarely in the assemblage, but only as fragments of the pseudoraphe valve. The figured specimen is the most nearly complete valve observed. This appears to be a distinctive species which may have stratigraphic value, but formal diagnosis must await the discovery of the raphe valve as well as better specimens of the pseudoraphe valve.

Known geologic range.—This assemblage.

Suborder BIRAPHIDINEAE
Family NAVICULACEAE
Subfamily NAVICULOIDEAE
Genus NAVICULA Bory, 1822
Navicula hennedyi W. Smith

Plate 7, figures 17, 18

Navicula hennedyi W. Smith, 1856, Synopsis of the British Diatomaceae, v. 2, p. 93.
Hendey, 1964, An introductory account of smaller algae of British coastal waters, part 5, Bacillariophyceae (Diatoms), p. 212–213, pl. 33, fig. 14.
Hustedt, 1964, Die Kieselalgen Deutschlands, Ősterreichs, und der Schweiz, pt. 3, p. 453–455, fig. 1516.

Description.—Valve broadly elliptical with obtusely rounded apices. Length of observed specimens, 48μ–58μ; width 23μ–28μ. Axial area narrow. Transverse striae divided into two bands: (1) the axial striae forming a narrow band, 1–4 puncta wide on either side of the raphe and having a parallel orientation; (2) the marginal striae forming a broader band which narrows toward the apices and has a radiate orientation. Transverse striae, about 11 in 10μ, distinctly punctate. Between the axial and marginal striae are broad half-lanceolate hyaline lateral areas.

Remarks.—*Navicula hennedyi* is rare in this assemblage and occurs mostly as broken fragments of valves.

Known geologic range.—Miocene to modern marine coastal waters, where it is common.

Navicula lyra Ehrenberg

Plate 7, figure 19

Navicula lyra Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 419, pl. 1, I, fig. 9a.
Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 185–186.
Hendey, 1964, An introductory account of smaller algae of British coastal waters, Part V, Bacillariophyceae (Diatoms), p. 209, pl. 33, fig. 2.
Hustedt, 1964, Die Kieselalgen Deutschlands, Ősterreichs, und der Schweiz, pt. 3, p. 500–502, fig. 1548a.

Description.—Valve elliptical-lanceolate with slightly produced, subrostrate, narrowly rounded apices. Length of observed specimen, 67μ; width, 25μ. Valve surface covered with punctate transverse striae about 13 in 10μ. Axial and marginal striae are separated by four lyre-shaped hyaline horns extending from the hyaline central area. Axial area enclosing raphe is very narrow.

Remarks.—*Navicula lyra* occurs rarely in the assemblage, mostly as broken fragments of valves.

Known geologic range.—Miocene to modern marine coastal waters, where it is common.

Navicula pennata Schmidt

Plate 7, figures 20, 21

Navicula pennata Schmidt, 1876, Atlas der Diatomaceenkunde, pl. 48, fig. 41–43.
Lohman, 1938, U.S. Geol. Survey Prof. Paper 189–C, p. 84, pl. 22, fig. 16.
Lohman, 1941, U.S. Geol. Survey Prof. Paper 196, part 3, p. 83–84, pl. 17, fig. 14.
Hendey, 1964, An introductory account of smaller algae

of British coastal waters, Part V, Bacillariophyceae (Diatoms), p. 203, pl. 30, fig. 21.

Description.—Valve linear-lanceolate, convex, with acutely rounded apices. Length 66μ–78μ; width about 14μ. Transverse striae coarse, widely spaced, about 5 in 10μ. A quadrate hyaline central area is formed by the shortening of about two of the transverse striae at the center. Axial area narrow, terminating in small apical nodules.

Remarks.—*Navicula pennata* is frequent in this assemblage.

Known geologic range.—Miocene to modern seas, where it is a benthonic form.

Genus DIPLONEIS Ehrenberg, 1845

Diploneis crabro (Ehrenberg) Ehrenberg

Plate 7, figures 22, 23

Pinnularia (*Diploneis*) *crabro* Ehrenberg, 1844, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844, p. 85.

Diploneis crabro (Ehrenberg) Ehrenberg, 1854, Mikrogeologie, pl. 19, fig. 29.

Diploneis crabro Ehrenberg. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 100–102.

Hustedt, 1937, Die Kieselalgen Deutschlands, Ősterreichs, und der Schweiz, pt. 2, p. 616–626, fig. 1028.

Hendey, 1964, An introductory account of smaller algae of British coastal waters, Part V, Bacillariophyceae (Diatoms), p. 225, pl. 32, fig. 1, 3.

Description.—Valve panduriform with obtusely rounded apices. Length 31μ–45μ; width as great as 15μ. Central nodule longitudinally quadrate, extended to form siliceous horns on either side of the raphe. A single row of large puncta borders very narrow furrows. Transverse striae, 8 in 10μ, radiate, consisting of double rows of fine puncta alternating with costae.

Remarks.—This is a variable and complex species with a large number of named varieties. A related species, *Diploneis prisca*, has been previously reported from the Calvert Formation, but differs in having more tapered and less rounded lateral margins near the apices than does the *D. crabro* which occurs in this assemblage.

Known geologic range.—A variety of *Diploneis crabro* has been previously reported from the Calvert Formation of Miocene age. The species occurs in modern marine environments of high salinity.

Subfamily PLEUROSIGMOIDEAE

Genus PLEUROSIGMA Wm. Smith, 1852

Pleurosigma affine var. marylandica Grunow

Plate 7, figure 24

Pleurosigma affine var. *marylandica* Grunow *in* Cleve and Grunow, 1880, Kgl. svenska vetensk. akad. Handl., v. 17, no. 2, p. 51.

Lohman, 1948, Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 187.

Pleurosigma normanii var. *marylandica* (Grunow) Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 40.

Boyer, 1904, Maryland Geol. Survey, Miocene, p. 488.

Description.—Only the more robust central part of valves preserved in this assemblage. Width about 30μ. Axial area very narrow, central area small, rounded. Lateral parts of valve both convex between the raphe and the margins, covered with a grid of puncta, about 14 in 10μ, arranged in both oblique and transverse striae, the oblique striae intersecting at an angle of about 60°. This pattern grades into a narrow band of exclusively transverse striae near the margin.

Remarks.—The variety is rare in this assemblage.

Known geologic range.—Previously reported only from the Calvert Formation of Miocene age.

Family CYMBELLACEAE

Amphora sp.

Plate 7, figure 25

Description.—Valve lunate with gently curved dorsal side and slightly concave ventral side having a faint suggestion of a central swelling, tapering in width to rounded apices. Length of observed specimen, 56μ; width, 9μ. Raphe paralleling the ventral side, flexed slightly toward that side near the center. Single rows of puncta paralleling the raphe on both sides. Puncta on dorsal side separated from dorsal striae by a thin hyaline band, extending nearly the length of the valve, but becoming obscure near the apices. Striae along dorsal side distinctly punctate, about 10 in 10μ, curving around the dorsal edge of the valve as a mantle.

Remarks.—The figured specimen is the only complete valve observed in this assemblage. This appears to be a distinctive species of *Amphora,* which may have stratigraphic value, and it has not been previously described. Formal diagnosis, however, should await the study of additional, specimens.

Known geologic range.—This assemblage.

SELECTED REFERENCES

Bailey, J. W., 1842a, A sketch of the Infusoria of the family Bacillaria, pt. 2: Am. Jour. Sci., v. 42, p. 88–105, pl. 2.

——— 1842b, Sketch of the Infusoria of the family Bacillaria, pt. 3: Am. Jour. Sci., v. 43, p. 321–332, pl. 3.

——— 1843, Infusorial stratum and adjacent Miocene deposits at Petersburg, Virginia [abs.]: Am. Jour. Sci., v. 45, p. 313.

——— 1844, Account of some new infusorial forms discovered in the fossil Infusoria from Petersburg, Virginia, and Piscataway, Maryland: Am. Jour. Sci., v. 46, p. 137–141, pl. 1.

——— 1845a, Ehrenberg's observations on the fossil Infusoria of Virginia and Maryland and comparison of the same with those found in the chalk formations of Europe and Africa: Am. Jour. Sci., v. 48, p. 201–204.

——— 1845b, Notice of some new localities of Infusoria, fossil and recent: Am. Jour. Sci., v. 48, p. 321–343.

——— 1849, New localities of Infusoria in the Tertiary of Maryland: Am. Jour. Sci., 2d ser., v. 7, p. 437.

Berggren, W. A., 1972, A Cenozoic time-scale—some implications for regional geology and paleobiogeography: Lethaia, v. 5, p. 95–215.

Berggren, W. A., and Van Couvering, John, 1973, Late Neogene chronostratigraphy, biostratigraphy, biochronology, and paleoclimatology: Woods Hole Oceanographic Institution ref. no. 73–40, 348 p., 14 figs.

Blow, W. H., 1969, Late middle Eocene to Recent planktonic foraminiferal biostratigraphy: Internat. Conf. on Planktonic Microfossils, 1st, Geneva, Switzerland, 1967, Proc., v. 1, Leiden, Netherlands, E. J. Brill, p. 199–421.

Boyer, C. S., 1904, Thallophyta-Diatomacea *in* Systematic paleontology of the Miocene deposits of Maryland: Maryland Geol. Survey, Miocene, p. 487–507, pls. 134–135.

Christian, Thomas, 1887, New diatomaceous deposits: The Microscope, v. 7, p. 65–68.

Cooke, C. W., Gardner, J. A., and Woodring, W. P., 1943, Correlation of the Cenozoic formations of the Atlantic and Gulf Coastal Plain and the Caribbean region: Geol. Soc. America Bull., v. 54, p. 1713–1723.

Dall, W. H., and Harris, G. D., 1892, Correlation papers; Neocene: U.S. Geol. Survey Bull. 84, 349 p.

Darton, N. H., 1891, Mesozoic and Cenozoic formations of eastern Virginia and Maryland: Geol. Soc. America Bull., v. 2, p. 431–450.

Ehrenberg, C. G., 1843, Verbreitung und Einfluss des mikroskopischen Lebens in Süd- und Nord-Amerika: Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 291–445, 4 pls.

——— 1844, Über 2 neue Lager von Gebirgsmassen aus Infusorien als Meeres-Absatz in Nord-Amerika und eine Vergleichung derselben mit den organischen Kreide-Gebilden in Europa und Afrika: Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844, p. 57–97.

——— 1845, Untersuchungen über die kleinsten Lebensformen in Quellenlande des Euphrats und Araxes, so wie über eine an neuen Formen sehr reiche marine Tripelbildung von den Bermuda-Inseln vor: Kgl. preuss. Akad. Wiss. Berlin, Ber., 1844, p. 253–275.

——— 1854, Mikrogeologie: Leipzig, L. Voss, 374 p., 41 pl.

Gernant, R. E., 1970, Paleoecology of the Choptank Formation (Miocene) of Maryland and Virginia: Maryland Geol. Survey Rept. Inv. 12, 90 p.

Gernant, R. E., Gibson, T. G., and Whitmore, F. G., 1971, Environmental history of Maryland Miocene: Maryland Geol. Survey, Guidebook 3, p. 1–58.

Gibson, T. G., 1967, Stratigraphy and paleoenvironment of the phosphatic Miocene strata of North Carolina: Geol. Soc. America Bull., v. 78, p. 631–650, 2 pls.

Grunow, Albert, 1884, Die Diatomeen von Franz Josefs-Land: Kaisl.-Kgl. Akad. Wiss. Wien, Math.-Naturwiss. Kl., Denkschr., v. 48, p. 53–112, 5 pls.

Hanna, G. D., 1932, The diatoms of Sharktooth Hill, Kern County, California: California Acad. Sci. Proc., 4th ser., v. 20, no. 6, p. 161–262, 18 pls.

Hendey, N. I., 1937, The plankton diatoms of the southern seas: Discovery Repts., v. 16, p. 151–364, pls. 6–13.

——— 1964, An introductory account of the smaller algae of British coastal waters, Part V, Bacillariophyceae (Diatoms): London, Ministry of Agriculture, Fisheries and Food, Fishery Inv. Ser. 4, 317 p., 45 pls.

Hustedt, Friedrich, 1927–30, 1931–59, 1961–66, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, Band 7 *of* Rabenhorst, G. L., Kryptogamenflora * * *: Leipzig, Akademische Verlagsgesellschaft, pt. 1, 920 p., 542 figs., 1927–30; pt. 2, 845 p., 637 figs., 1931–59; pt. 3, lieferungen 1–4, p. 1–816, figs. 1180–1788, 1962–66.

Kanaya, Taro, 1959, Miocene diatom assemblages from the Onnagawa Formation and their distribution in the correlative formations in northeast Japan: Tohoku Univ. Sci. Repts., 2d ser. (Geology), v. 30, p. 1–130, pls. 1–11.

Karsten, George, 1928, Bacillariophyta (Diatomeae), *in* Engler, Adolf, Die natürlichen (Pflanzenfamilien; Band 2, Peridineae (Dinoflagellatae), Diatomeae (Bacillariophyta), Myxomycetes: Leipzig, Wilhelm Engelmann, p. 105–303, 329 figs.

Koizumi, Itaru, 1973, The Late Cenozoic diatoms of sites 183–193, leg 19 Deep Sea Drilling Project, *in* Initial Reports of the Deep Sea Drilling Project, v. 19, Washington, D.C., U.S. Government Printing Office: p. 805–855, pls. 1–8.

Lohman, K. E., 1938, Pliocene diatoms from the Kettleman Hills, California: U.S. Geol. Survey Prof. Paper 189–C, p. 81–94, pls. 20–23.

——— 1942, Geology and biology of North Atlantic deep-sea cores between Newfoundland and Ireland, Part 3, Diatomaceae: U.S. Geol. Survey Prof. Paper 196, part 3, p. 55–86, pls. 12–17.

——— 1948, Middle Miocene diatoms from the Hammond Well—Cretaceous and Tertiary subsurface geology: Maryland Dept. Geology, Mines, and Water Resources Bull. 2, p. 151–187, 331–333, pls. 5–11.

——— 1972, A procedure for the microscopical study of diatomaceous sediments: Nova Hedwigia, issue no. 39, p. 267–283.

Long, J. A., Fuge, D. P., and Smith, James, 1946, Diatoms of the Moreno Shale: Jour. Paleontology, v. 20, no. 2, p. 89–118, pls. 13–18.

Pantocsek, Josef, 1886, Beiträge zur Kenntnis der fossilen Bacillarien Ungarns, pt. 1: Berlin, W. Junk, p. 1–76, pls. 1–30.

Peragallo, H. and Peragallo, M., 1897–1908, Diatomées marines de France: Grez-sur-Loing, M. J. Tempére, 491 p., pls. 1–137.

Rogers, W. B., 1841, Report of the progress of the geological survey of the State of Virginia for the year 1840: Richmond, Virginia, 132 p.

Schrader, H. J., 1973, Cenozoic diatoms from the northeast Pacific, leg 18, *in* Initial Reports of the Deep Sea Drilling Project, v. 18: Washington, D.C., U.S. Government Printing Office, p. 673–797, pls. 1–26.

Schütt Franz, 1896, Bacillariales (Diatomeae), *in* Engler, Adolf, and Prantl, K. A. E., Die natürlichen Pflanzenfamilien: Leipzig, pt. 1, Abt. 1b, p. 31–153, 282 figs.

Shattuck, G. B., 1902, The Miocene problem of Maryland [abs.]: Science, n. ser., v. 15, p. 906–907.

——— 1904, The Miocene deposits of Maryland; geological and paleontological relations, with a review of earlier investigations: Maryland Geol. Survey, Miocene, p. 33–137.

Van Heurck, Henri, 1880–85, Synopsis des Diatomées de Belgique: Anvers, 235 p., pls. 1–132, A–C.

INDEX

[Italic page numbers indicate descriptions and major references]

☆U.S. GOVERNMENT PRINTING OFFICE: 1976 O—211-317/38

PLATES 1-7

Contact photographs of the plates in this report are available, at cost, from U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225

PLATE 1

FIGURE 1, 2. *Melosira westii* W. Smith, × 960, (p. 8).

1. USGS diatom cat. No. 3902–11. Diameter, 30μ.
2. USGS diatom cat. No. 3901–21. Diameter, 27μ.

3, 4. *Paralia complexa* (Lohman) Andrews, × 960, (p. 8).

3. USGS diatom cat. No. 3903–9. Diameter, 52μ.
4. USGS diatom cat. No. 3903–8. Diameter, 53μ.

5, 6. *Paralia sulcata* (Ehrenberg) Cleve, × 960, (p. 8).

5. USGS diatom cat. No. 3900–1. Diameter, 38μ.
6. USGS diatom cat. No. 3771–1. Diameter, 36μ.

7, 8. *Paralia sulcata* var. *coronata* (Ehrenberg) Andrews, × 960, (p. 9).

7. USGS diatom cat. No. 3900–2. Diameter, 33μ.
8. USGS diatom cat. No. 3901–2. Diameter, 27μ.

9, 10. *Pyxidicula cruciata* Ehrenberg, × 960, (p. 9).

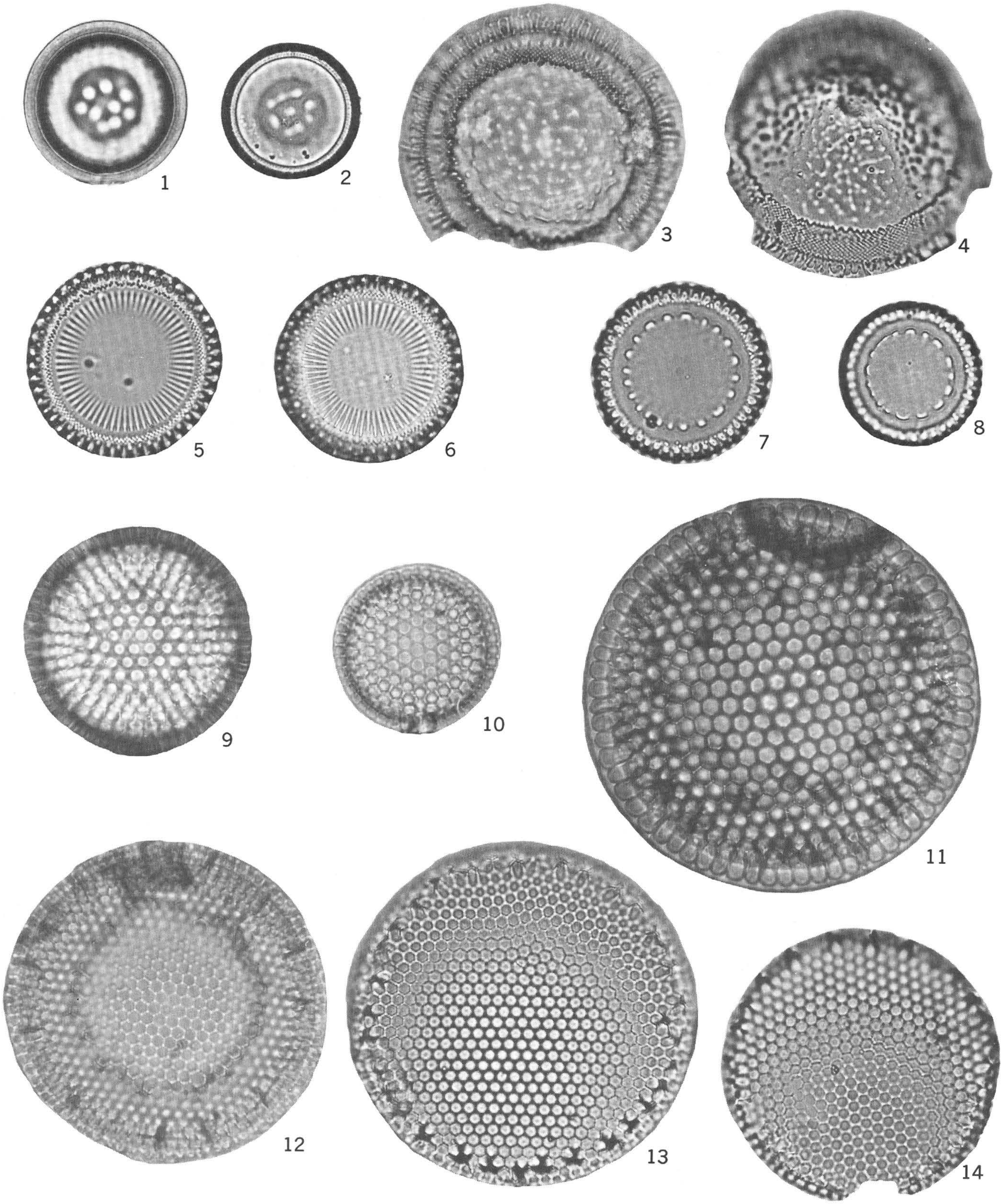
9. USGS diatom cat. No. 3772–47. Diameter, 44μ.
10. USGS diatom cat. No. 3772–11. Diameter, 31μ.

11, 12. *Stephanopyxis corona* (Ehrenberg) Grunow, × 960, (p. 9).

11. USGS diatom cat. No. 3901–16. Diameter, 74μ.
12. USGS diatom cat. No. 3901–26. Diameter, 60μ.

13, 14. *Stephanopyxis lineata* (Ehrenberg) Forti, × 960, (p. 9).

13. USGS diatom cat. No. 3900–28. Diameter, 64μ.
14. USGS diatom cat. No. 3772–46. Diameter, 52μ.



MELOSIRA, *PARALIA*, *PYXIDICULA*, AND *STEPHANOPYXIS*

PLATE 2

FIGURE 1, 2. *Stephanopyxis turris* (Greville and Arnott) Ralfs, × 960, (p. 10).
1. USGS diatom cat. No. 3903–12. Diameter, 30μ.
2. USGS diatom cat. No. 3771–12. Diameter, 25μ.

3. *Coscinodiscus apiculatus* Ehrenberg, × 475, (p. 10).
USGS diatom cat. No. 3900–20. Diameter, 117μ.

4. *Coscinodiscus curvatulus* Grunow, × 960, (p. 10).
USGS diatom cat. No. 3904–2. Diameter 48μ.

5. *Coscinodiscus inclusus* Rattray, × 960, (p. 10).
USGS diatom cat. No. 3771–13. Diameter, 38μ.

6, 7. *Coscinodiscus marginatus* Ehrenberg, × 475, (p. 11).
6. USGS diatom cat. No. 3772–56. Diameter, 90μ.
7. USGS diatom cat. No. 3771–29. Diameter, 91μ.

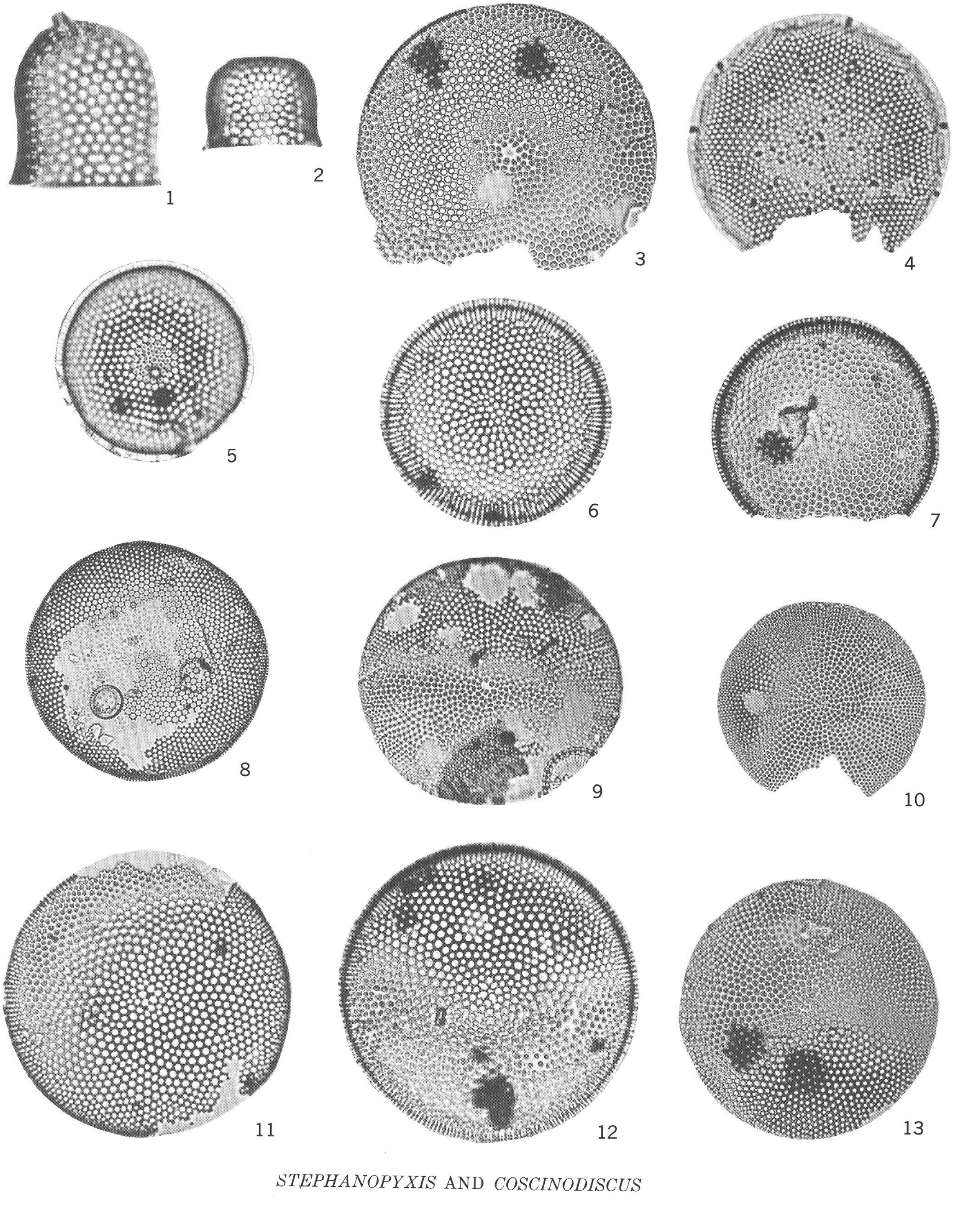
8. *Coscinodiscus oculus-iridis* Ehrenberg, × 228, (p. 11).
USGS diatom cat. No. 3772–39. Diameter, 196μ.

9. *Coscinodiscus perforatus* Ehrenberg, × 475, (p. 11).
USGS diatom cat. No. 3900–26. Diameter, 102μ.

10. *Coscinodiscus perforatus* var. *cellulosa* Grunow, × 475, (p. 11).
USGS diatom cat. No. 3903–3. Diameter, 81μ.

11, 12. *Coscinodiscus perforatus* var. *pavillardi* (Forti) Hustedt, × 475, (p. 12).
11. USGS diatom cat. No. 3772–27. Diameter, 111μ.
12. USGS diatom cat. No. 3772–23. Diameter, 118μ.

13. *Coscinodiscus radiatus* Ehrenberg, × 475, (p. 12).
USGS diatom cat. No. 3901–17. Diameter, 100μ.



STEPHANOPYXIS AND *COSCINODISCUS*

PLATE 3

FIGURE 1, 2. *Coscinodiscus rothii* (Ehrenberg) Grunow, × 475, (p. 12).
1. USGS diatom cat. No. 3771–33. Diameter, 58μ.
2. USGS diatom cat. No. 3772–28. Diameter, 67μ.

3. *Coscinodiscus vetustissimus* Pantocsek, × 960, (p. 12).
USGS diatom cat. No. 3901–44. Diameter, 58μ.

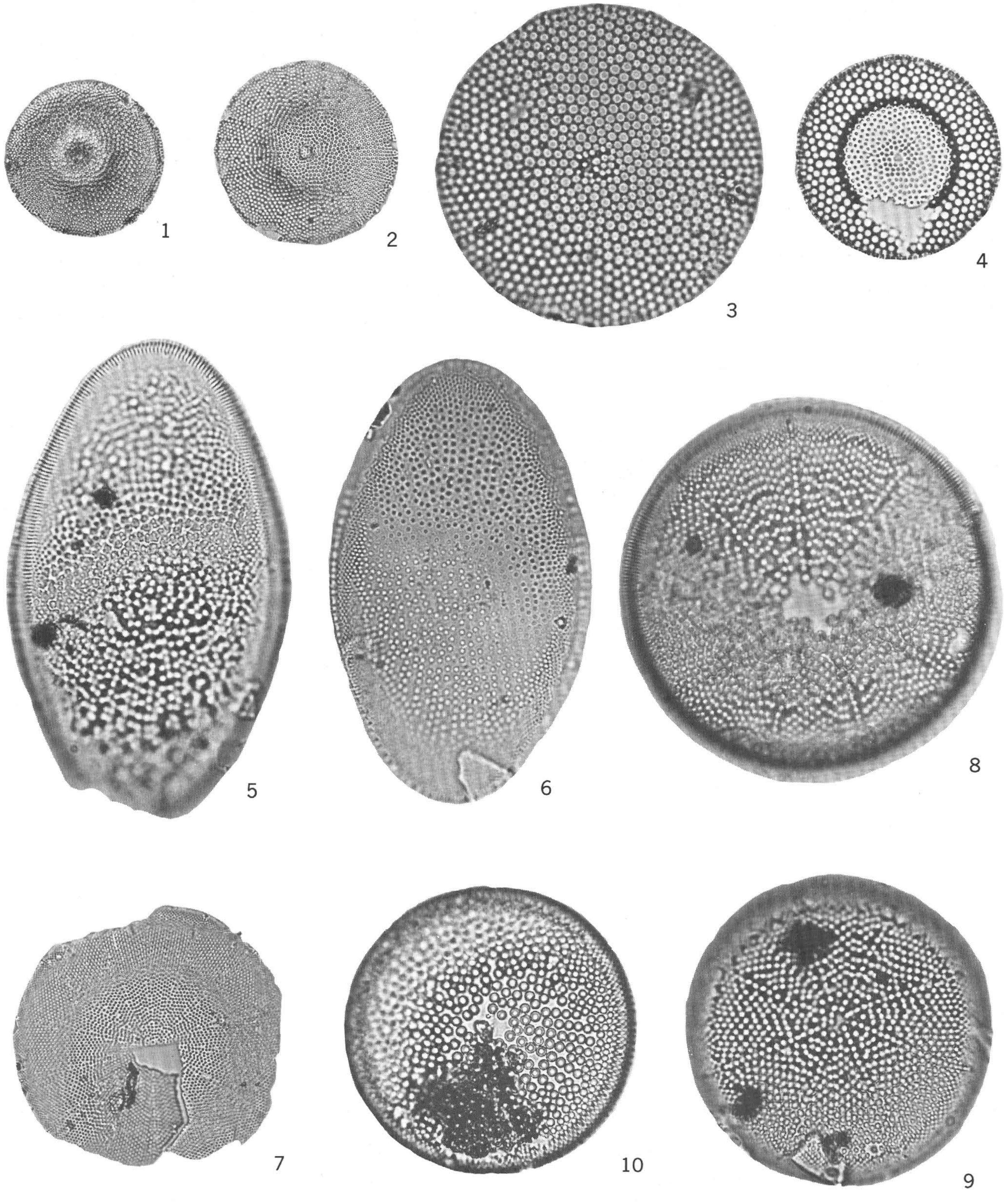
4. *Craspedodiscus coscinodiscus* Ehrenberg, × 475, (p. 13).
USGS diatom cat. No. 3772–13. Diameter, 74μ.

5, 6. *Actinocyclus ellipticus* Grunow, × 960, (p. 13).
5. USGS diatom cat. No. 3900–39. Length, 75μ.
6. USGS diatom cat. No. 3901–33. Length, 79μ.

7. *Actinocyclus octonarius* Ehrenberg, × 475, (p. 14).
USGS diatom cat. No. 3771–26. Diameter, 98μ.

8, 9. *Actinocyclus tenellus* (Brébisson) Andrews, × 960, (p. 14).
8. USGS diatom cat. No. 3901–18. Diameter, 70μ.
9. USGS diatom cat. No. 3901–46. Diameter, 56μ.

10. *Actinocyclus ingens* Rattray, × 960, (p. 13).
USGS diatom cat. No. 3902–4. Diameter, 53μ.



COSCINODISCUS, CRASPEDODISCUS, AND *ACTINOCYCLUS*

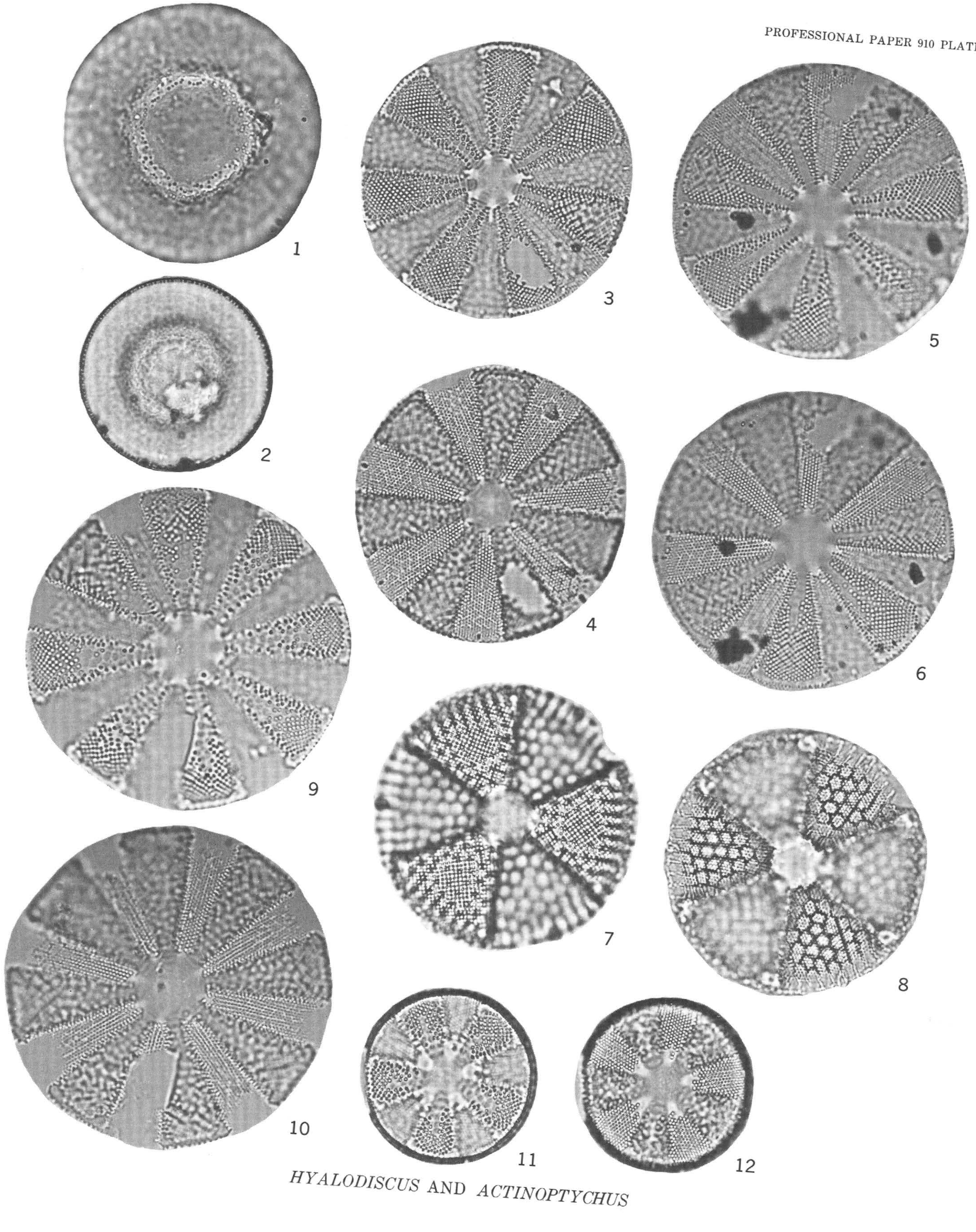
PLATE 4

FIGURE 1, 2. *Hyalodiscus laevis* Ehrenberg, × 960, (p. 14).
- 1. USGS diatom cat. No. 3903–6. Diameter, 53μ.
- 2. USGS diatom cat. No. 3904–5. Diameter, 40μ.

3–6. *Actinoptychus marylandicus* Andrews, × 960, (p. 14).
- 3, 4. Holotype, USGS diatom cat. No. 3904–12. Diameter, 54μ.
- 5, 6. Paratype, USGS diatom cat. No. 3901–28. Diameter, 59μ.

7, 8. *Actinoptychus senarius* (Ehrenberg) Ehrenberg, × 960, (p. 15).
USGS diatom cat. No. 3902–15. Diameter, 51μ.

9–12. *Actinoptychus virginicus* (Grunow) Andrews, × 960, (p. 15).
- 9, 10. USGS diatom cat. No. 3901–27. Diameter, 65μ.
- 11, 12. USGS diatom cat. No. 3902–1. Diameter, 35μ.



HYALODISCUS AND *ACTINOPTYCHUS*

PLATE 5

FIGURE 1, 2. *Rattrayella inconspicua* (Rattray) Hanna, × 475, (p. 16).
- 1. USGS diatom cat. No. 3772–1. Diameter, 74μ.
- 2. USGS diatom cat. No. 3772–43. Diameter, 70μ.

3–5. *Liradiscus asperulus* Andrews, × 960, (p. 16).
- 3. Holotype, USGS diatom cat. No. 3903–7. Length, 40μ.
- 4. Paratype, USGS diatom cat. No. 3904–6. Length, 43μ.
- 5. Paratype, USGS diatom cat. No. 3902–4. Length, 23μ.

6, 7. *Liradiscus ovalis* Greville, × 960, (p. 16).
- 6. USGS diatom cat. No. 3904–7. Length, 22μ.
- 7. USGS diatom cat. No. 3903–8. Length, 30μ.

8. *Biddulphia aurita* var. *obtusa* (Kützing) Hustedt, × 475, (p. 16).
USGS diatom cat. No. 3772–34. Length, 47μ.

9, 10. *Biddulphia semicircularis* (Brightwell) Boyer, × 960, (p. 16).
- 9. USGS diatom cat. No. 3901–20. Length, 45μ.
- 10. USGS diatom cat. No. 3771–5. Length, 70μ.

11. *Biddulphia tuomeyi* (Bailey) Roper, × 960, (p. 17).
USGS diatom cat. No. 3901–13. Length, 57μ.

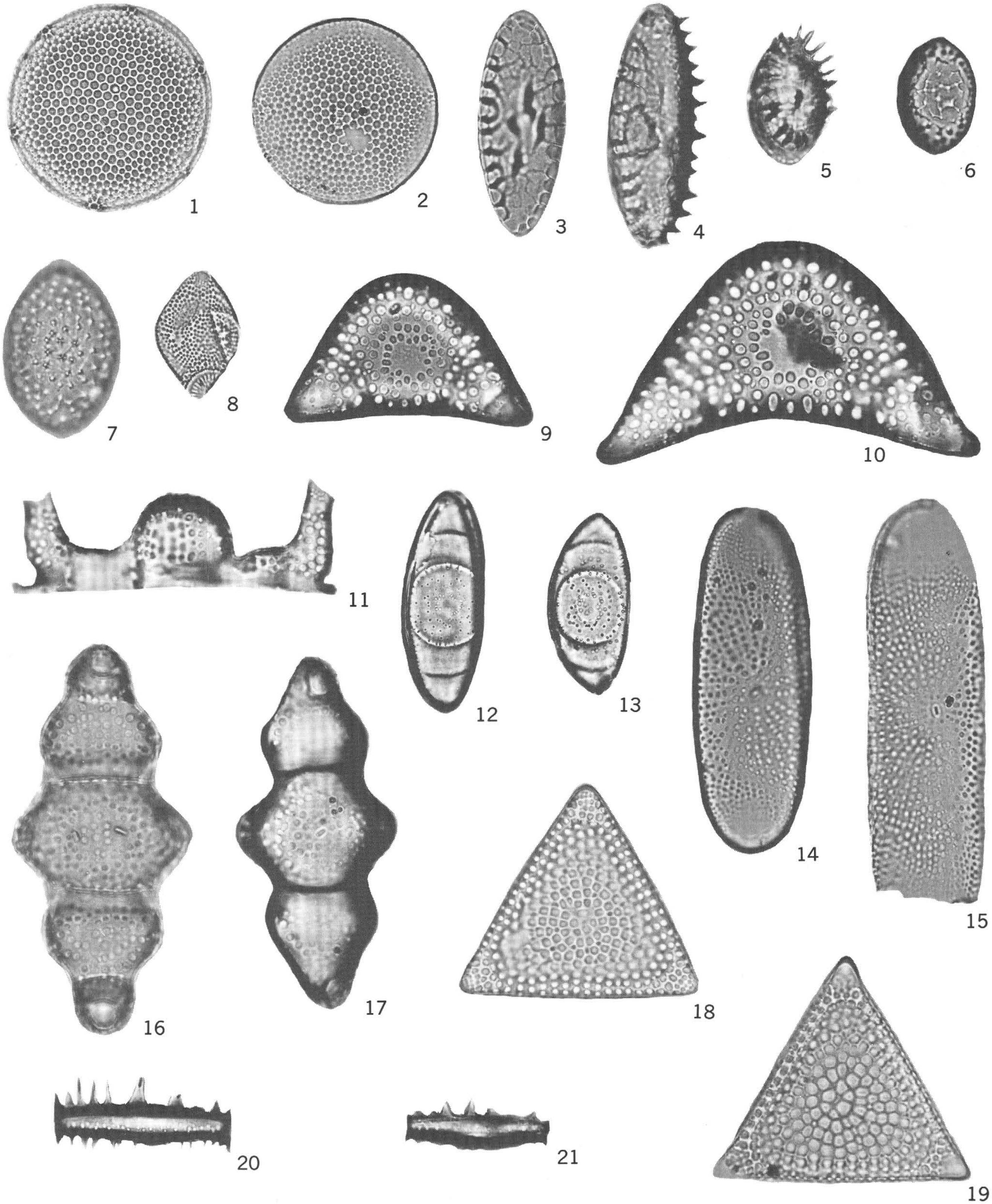
12, 13. *Goniothecium rogersii* Ehrenberg, × 475, (p. 17).
- 12. USGS diatom cat. No. 3771–11. Length, 80μ.
- 13. USGS diatom cat. No. 3771–17. Length, 68μ.

14, 15. *Eucampia virginica* Grunow, × 960, (p. 17).
- 14. USGS diatom cat. No. 3900–40. Length, 62μ.
- 15. USGS diatom cat. No. 3772–54. Length, 76μ.

16, 17. *Terpsinoë americana* (Bailey) Ralfs, × 960, (p. 17).
- 16. USGS diatom cat. No. 3772–16. Length, 71μ.
- 17. USGS diatom cat. No. 3772–32. Length, 61μ.

18, 19. *Triceratium condecorum* Ehrenberg, × 960, (p. 18).
- 18. USGS diatom cat. No. 3771–23. Side, 44μ.
- 19. USGS diatom cat. No. 3900–49. Side, 46μ.

20, 21. *Periptera tetracladia* Ehrenberg, × 960, (p. 19).
- 20. USGS diatom cat. No. 3903–2. Length, 32μ.
- 21. USGS diatom cat. No. 3905–3. Length, 28μ.



RATTRAYELLA, LIRADISCUS, BIDDULPHIA, GONIOTHECIUM, EUCAMPIA, TERPSINOË, TRICERATIUM, AND *PERIPTERA*

PLATE 6

FIGURE 1–3. *Xanthiopyxis microspinosa* Andrews, × 960, (p. 18).

1. Holotype, USGS diatom cat. No. 3901–43. Length, 52μ.
2. Paratype, USGS diatom cat. No. 3772–37. Length, 32μ.
3. Paratype, USGS diatom cat. No. 3900–46. Length, 32μ.

4–7. *Dossetia hyalina* Andrews, × 960, (p. 19).

4. Holotype, USGS diatom cat. No. 3901–38. Length, 45μ.
5. Paratype, USGS diatom cat. No. 3901–19. Length, 37μ.
6. Paratype, USGS diatom cat. No. 3901–29. Length, 40μ.
7. Paratype, USGS diatom cat. No. 3904–3. Length, 42μ.

8. *Stephanogonia actinoptychus* (Ehrenberg) Grunow, × 960, (p. 19). USGS diatom cat. No. 3771–28. Length, 62μ.

9–12. *Pseudopyxilla americana* (Ehrenberg) Forti, × 960, (p. 19).

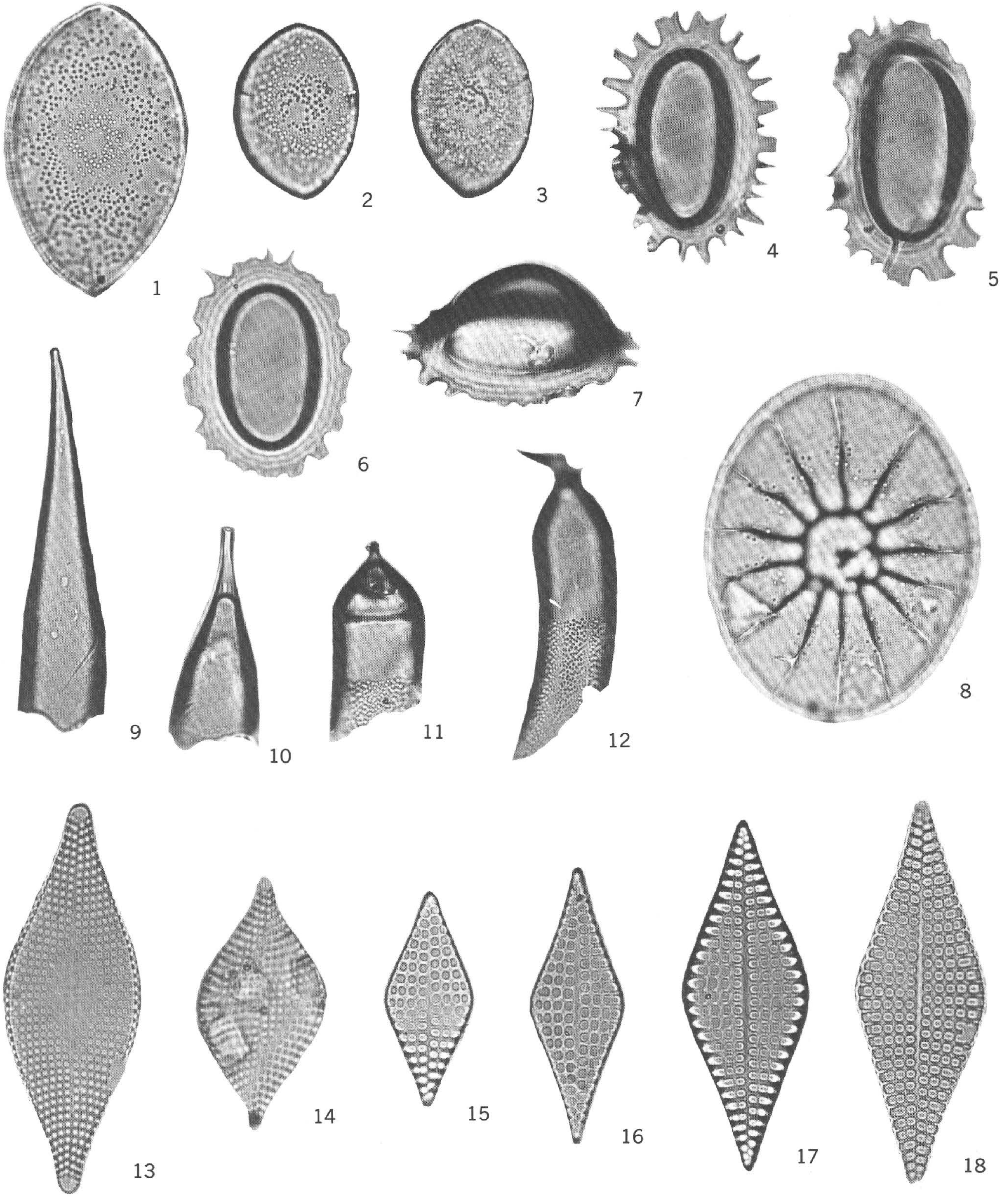
9. USGS diatom cat. No. 3902–5. Length, 73μ.
10. USGS diatom cat. No. 3903–11. Length, 41μ.
11. USGS diatom cat. No. 3902–9. Length, 35μ.
12. USGS diatom cat. No. 3904–10. Length, 55μ.

13, 14. *Rhaphoneis amphiceros* Ehrenberg, × 960, (p. 20).

13. USGS diatom cat. No. 3772–22. Length, 71μ.
14. USGS diatom cat. No. 3772–2. Length, 45μ.

15–18. *Rhaphoneis diamantella* Andrews, n. sp. × 960, (p. 20).

15. Paratype, USGS datom cat. No. 3771–9. Length, 40μ.
16. Paratype, USGS diatom cat. No. 3772–52. Length, 50μ.
17. Holotype, USGS diatom cat. No. 3772–29. Length, 62μ.
18. Paratype, USGS diatom cat. No. 3900–14. Length, 70μ.



XANTHIOPYXIS, DOSSETIA, STEPHANOGONIA,
PSEUDOPYXILLA, AND *RHAPHONEIS*

PLATE 7

FIGURE 1, 2. *Rhaphoneis angustata* Pantocsek, × 960, (p. 20).
- 1. USGS diatom cat. No. 3772–25. Length, 53μ.
- 2. USGS diatom cat. No. 3901–51. Length, 58μ.

3. *Rhaphoneis immunis* Lohman, × 960, (p. 21).
USGS diatom cat. No. 3772–50. Length, 45μ.

4, 5. *Rhaphoneis lancettula* Grunow, × 960, (p. 21).
- 4. USGS diatom cat. No. 3771–25. Length, 68μ.
- 5. USGS diatom cat. No. 3771–31. Length, 70μ.

6–8. *Thalassionema obtusa* (Grunow) Andrews, × 960, (p. 21).
- 6. USGS diatom cat. No. 3771–10. Length, 36μ.
- 7. USGS diatom cat. No. 3771–2. Length, 35μ.
- 8. USGS diatom cat. No. 3772–55. Length, 32μ.

9, 10. *Thalassiothrix longissima* Cleve and Grunow, × 960, (p. 21).
- 9. USGS diatom cat. No. 3904–13. Length of fragment, 76μ.
- 10. USGS diatom cat. No. 3905–4. Length of fragment, 75μ.

11–13. *Grammatophora angulosa* Ehrenberg, × 960, (p. 21).
- 11. USGS diatom cat. No. 3900–15. Length, 51μ.
- 12. USGS diatom cat. No. 3900–45. Length, 38μ.
- 13. USGS diatom cat. No. 3901–41. Length, 27μ.

14, 15. *Grammatophora marina* (Lyngbye) Kützing, × 960, (p. 22).
- 14. USGS diatom cat. No. 3903–5. Length, 44μ.
- 15. USGS diatom cat. No. 3901–39. Length, 38μ.

16. *Cocconeis* sp., × 960, (p. 22).
USGS diatom cat. No. 3902–16. Length, 41μ.

17, 18. *Navicula hennedyi* W. Smith, × 960, (p. 22).
- 17. USGS diatom cat. No. 3900–44. Length, 58μ.
- 18. USGS diatom cat. No. 3900–32. Length, 48μ.

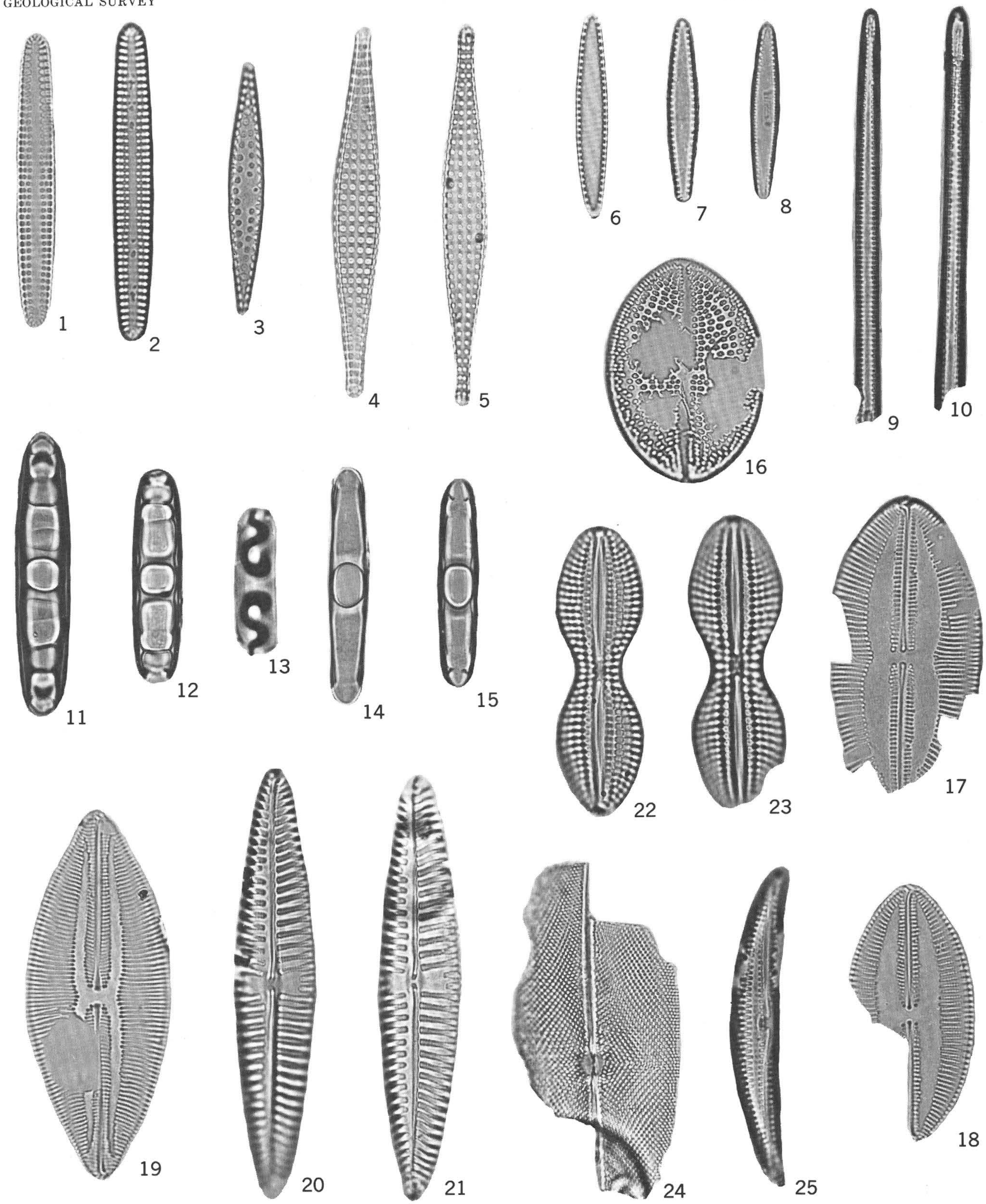
19. *Navicula lyra* Ehrenberg, × 960, (p. 22).
USGS diatom cat. No. 3772–61. Length, 67μ.

20, 21. *Navicula pennata* Schmidt, × 960, (p. 22).
- 20. USGS diatom cat. No. 3772–57. Length, 78μ.
- 21. USGS diatom cat. No. 3771–32. Length, 79μ.

22, 23. *Diploneis crabro* (Ehrenberg) Ehrenberg, × 960, (p. 23).
- 22. USGS diatom cat. No. 3900–41. Length, 51μ.
- 23. USGS diatom cat. No. 3903–4. Length, 50μ.

24. *Pleurosigma affine* var. *marylandica* Grunow, × 960, (p. 23).
USGS diatom cat. No. 3902–6. Length of fragment, 60μ.

25. *Amphora* sp., × 960, (p. 23).
USGS diatom cat. No. 3901–49. Length, 56μ.



RHAPHONEIS, THALASSIONEMA, THALASSIOTHRIX, GRAMMATOPHORA, COCCONEIS, NAVICULA, DIPLONEIS, PLEUROSIGMA, AND *AMPHORA*