

Neogene diatoms from Petersburg, Virginia

ABSTRACT

Sixty-two diatom taxa have been identified from a diatomaceous sandy clay that crops out near the outlet of Wilcox Lake, Petersburg, Virginia. These diatoms are mostly cosmopolitan marine forms, but some species suggest deposition in brackish water that had a freshwater inflow. The regional stratigraphy, as well as the pelecypods and foraminifers, indicates that the beds may have been laid down in a lagoonal or estuarine environment. The diatom assemblage suggests that the deposit is of early Pliocene age, although previous biostratigraphic studies have considered it to be latest Miocene.

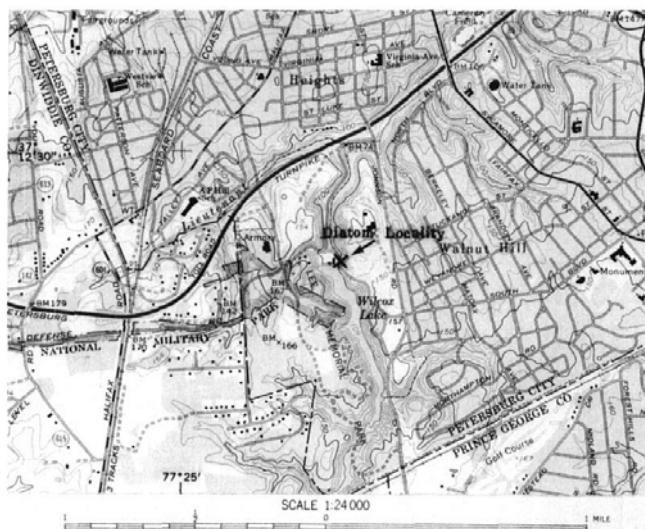
INTRODUCTION

In 1973, 1974, and 1975, the diatom-bearing samples studied for this report were collected from a locality in Petersburg, Virginia. Diatom-bearing strata at Petersburg were first reported by Bailey (1843), and diatoms from this area were studied by Bailey (1844, 1845) and by Ehrenberg (1844). These early workers did not give the precise source of their samples; however, I have examined the slides prepared by Bailey from his Petersburg material, that are now in the collection of the Farlow Herbarium of Harvard University, and have found the same diatom assemblage as that studied for the present report. Perhaps the same outcrop that provided the material reported here was sampled for the 19th-century studies, but of this we cannot be certain.

The Petersburg deposit has been considered to be correlative with the uppermost part of Zone 2 of the "St. Marys Formation of Virginia" as defined by Mansfield in Gardner (1943)—now the Eastover Formation of Ward and Blackwelder (in press). Although diatoms are common in the Calvert and Choptank Formations (Lower and Middle Miocene) of the Atlantic Coastal Plain, they seem to be extremely scarce in post-Choptank, pre-Pleistocene strata. Although I have sought diatoms in such strata for several years, those of the Petersburg area are the only ones to yield a meaningful diatom assemblage. The Calvert and Choptank diatom assemblages are well preserved, and this suggests that dissolution was not a serious problem in the Neogene strata. Probably some change, either in climate or the configuration of ocean currents, reduced the quantity of cool upwelling ocean water along the Atlantic coast in post-Choptank time. Such a change would effectively terminate the production of abundant diatom assemblages. The diatom assemblage studied here may have been deposited in a somewhat restricted estuary or lagoon, certainly well open to influx of marine water, but also probably receiving some silica-rich fresh water from the nearby land. Hence, the littoral marine to brackish-water diatom assemblage reported herein was able to flourish to a greater degree than were those in open-marine environments of similar age.

PETERSBURG DIATOM LOCALITY

The sampled outcrop is in Lee Memorial Park, City of Petersburg, Virginia, a short distance downstream from the outlet of Wilcox Lake (text-figure 1). The outflow from Wilcox Lake has been diverted to the right of the original channel, and a short distance below the dam it flows over a small waterfall into a narrow gully approximately 6 feet



TEXT-FIGURE 1
Location of diatomaceous deposits at Petersburg, Virginia. Base from USGS Petersburg quadrangle.

deep. The exposures in this narrow channel are relatively fresh and are usually scoured clean by the flow of the water. The upper foot or so of this section contains abundant small spiral gastropods, but no diatoms. About 2 feet below the lip of the waterfall is a bed containing abundant large pelecypods, mostly *Mulinia congesta*. The pelecypods become progressively sparser downsection and the base is essentially barren of macrofossils.

The diatom assemblages herein studied came from levels of 1, 2, 3, 4, 4½, 5, and 6 feet below the lip of the waterfall. The entire section consists of firm dark blue-gray sandy clay containing abundant shells near the top but few near the base. The outcrop continues downstream to the point where the outflow water reaches the main valley. However, the lack of shell bands and visible bedding makes precise stratigraphic control difficult in the lower reaches of the outlet channel. This study has, therefore, been restricted to the upper, nearly vertical part of the exposure. The basal contact of the deposit is not exposed.

The blue-gray sandy clay that bears the studied diatom assemblage is overlain with abrupt discontinuity by a 20-foot sequence of coarse, buff, ferruginous cross-bedded sand. A clast of buff clay in this deposit was examined for diatoms but was found to be barren. These sands appear to be of fluvial origin and are probably of later Pliocene or Pleistocene age.

W. H. Abbott (personal communication, 1978) has found a similar diatom assemblage from another locality in the Petersburg area. This material came from an outcrop in a road cut on the west side of Interstate Highway 85, immediately south of its junction with

Interstate Highway 95. This outcrop is approximately 1.35 miles (2.17 km) northeast of the Wilcox Lake outcrop, and it indicates a wider distribution of the diatom-bearing beds in the Petersburg area.

NEOGENE STRATIGRAPHY

Stratigraphic dating of the diatom-bearing beds exposed in the vicinity of Petersburg is difficult because this area lies at the extreme westward extension of several different marine transgressions. These beds have not been reported upon in any detail, and one is forced to rely on incidental references in regional geologic and paleontologic studies. Atlantic Coastal Plain stratigraphy was too poorly understood in the 19th century to make data from that time meaningful. Dall (1904, p. cxlvii) suggested, on the basis of paleontological data, that the strata at Petersburg were older than the Calvert Formation of early and middle Miocene age. However, taking into account the results of later biostratigraphic work (including this paper), he was either working from a faulty data base or on some other part of the stratigraphic section than that considered herein. Olsson (1917) placed the Petersburg beds in the upper Miocene (his Murfreesboro Stage), but at that time even the Pliocene Yorktown Formation was considered to be of late Miocene age.

Most modern biostratigraphers reporting on the Petersburg area have recognized beds of the "St. Marys Formation" as used in Virginia by Mansfield (in Gardner, 1943) as well as beds of Zone 2 of the "Yorktown Formation" of Mansfield (in Gardner, 1943). More recently Ward and Blackwelder (in press) have renamed the St. Marys Formation as used in Virginia as the Claremont Manor and Cobham Bay members of the Eastover Formation. Both the Eastover Formation and the Yorktown Formation in the Petersburg area contain deposits of blue-gray, sandy, shelly clay; these units are difficult to distinguish except on the basis of their fossils. However, in the beds exposed at the outlet of Wilcox Lake and studied for this report, T. G. Gibson (personal communication, 1978) has found specimens of a subspecies of *Chesapecten jeffersonius* (Say) which he regards as showing affinities to *C. middlesexensis* of the Eastover Formation. Gibson (in press) has indicated that in the highest part of the "Virginia St. Marys" of Mansfield (Cobham Bay Member of the Eastover Formation), the marine transgression extended westward as far as Petersburg. Also, Ward and Blackwelder (in press) reported a 3.6-m section of the Cobham Bay Member overlying a 9-m section of the Claremont Manor Member of the Eastover Formation in their locality 16—"just below the Wilcox Lake spillway, Petersburg, Va." The diatomaceous upper part of this section—asccribed to the upper part of the Cobham Bay Member—is considered in this report.

The dominant pelecypod in the Petersburg deposit herein studied is *Mulinia congesta*. This species is long ranging, from at least the Eastover Formation into Pleistocene deposits, and is apparently more useful as an indicator of very shallow marine to brackish-water environments than as a biostratigraphic marker. The dominant foraminifer in the Petersburg deposit is *Elphidium excavatum* (Terquem), and the assemblages show diversities of 10 to 20 species and very few planktonic species (T. G. Gibson, personal communication, 1978). Again, these assemblages are not diagnostic for precise stratigraphic age determination.

The Petersburg deposit has not been dated radiometrically, and the only specific dating of the deposit itself has been suggested by the stage of evolution of the contained *Chesapeake* fauna. This evidence indicates that we are here dealing with the youngest part of a unit that is equivalent to the Cobham Bay Member of the Eastover Formation. Ward and Blackwelder (in press) consider their Cobham Bay Member to be of late Tortonian Age (middle late Miocene) and approximately equivalent to planktonic foraminiferal zone N. 17. This conflicts with the evidence of the diatom biostratigraphy, which strongly suggests that the Petersburg deposit is no older than earliest Pliocene. The diatom biostratigraphy, the *Chesapeake* fauna, and the relative stratigraphic position indicate that these Petersburg strata were most probably deposited about 5 Ma (million years B.P.), approximately equivalent to planktonic foraminiferal zones N. 18 or N. 19, in the early part of the Zanclean Stage and immediately above the Miocene-Pliocene boundary as determined by Berggren and Van Couvering (1974). If this deposit is placed in the Cobham Bay Member of the Eastover Formation, then the member should be recognized to include deposits of early Pliocene age. It might be preferable to refer these beds to the Pliocene Yorktown Formation, but that is a stratigraphic problem beyond the scope of this report.

PREVIOUS DIATOM WORK

The occurrence of diatoms in sedimentary deposits at Petersburg was first reported by Bailey (1843), on the basis of a sample submitted by M. Tuomey, an amateur diatomist living at Petersburg. Bailey (1844) gave a more complete report on the diatom assemblage, but unfortunately did not state, or did not know, the exact provenance of his specimens. The diatoms that he reported in 1844 leave little doubt that, if his samples did not come from exactly the same sample locality as those studied for this report, they came at least from correlative strata. From Bailey's plate, the following taxa can be identified with certainty: *Biddulphia tuomeyi* (J. W. Bailey) Roper, *B. rhombus* (Ehrenberg) W. Smith, *Goniothecium odontella* Ehrenberg, *Chaeto-*

ceros lorenzianum Grunow, and *Pseudopyxilla americana* (Ehrenberg) Forti, all of which are represented in the Petersburg deposit studied for this report. Bailey (1843, 1844) made a definite distinction between these "infusorial marls," which he says do not contain foraminifera and the "miocene beds" or "tertiary beds of shells" from Petersburg from which he reported numerous foraminifera.

Bailey supplied a sample of his Petersburg material to Ehrenberg in Berlin, who (1844) published a much more complete list of the diatoms. This list, when modern synonyms are eliminated and the nomenclature is brought up to date, includes most of the taxa observed by the writer in the present study. There can be little doubt that the material studied by Bailey and Ehrenberg came from essentially the same deposit as that studied for this report. Unfortunately, the stratigraphy of the deposit was so poorly understood that both Ehrenberg (1844) and Bailey (1845) wasted a good deal of effort comparing the Petersburg deposit with those at Richmond, Virginia, and Piscataway, Maryland. These deposits are of quite different age, and the diatom assemblages are more remarkable in their differences than in their similarities.

Subsequent work on the Petersburg diatoms seems to have been done by Grunow, who published descriptions and figures of a few taxa from Petersburg in the Van Heurck Synopsis (1880-1885) and in Pantocsek (1886). Grunow had probably obtained his material from the Ehrenberg collection in Berlin because Bailey had died in 1857, most likely before Grunow had begun diatom work. However, some member of the active North American group of late 19th century amateur diatomists may have provided Grunow with a sample from Petersburg. The diatom assemblages from both the Wilcox Lake and Interstate 85 outcrops at Petersburg have been studied recently by Abbott (1978), who agrees with me that they are of Pliocene age.

DIATOM ASSEMBLAGE

Diatoms from 7 stratigraphic levels in the Petersburg deposit were studied for this report. The depths of the samples in the deposit were measured from the top of the firm blue-gray sandy clay of the Wilcox Lake outcrop. The following USGS diatom localities and their respective depths were examined for diatoms:

USGS diatom locality	Depth in feet (meters)
6515	1 (0.30)
6451	2 (0.61)
6452	3 (0.91)
6453	4 (1.22)
6519	4.5 (1.37)
6454	5 (1.52)
6520	5 (1.52)
6521	6 (1.83)

The samples were prepared for diatom study following standard procedures of the diatom laboratory of the U. S. Geological Survey as outlined by Lohman (1972) and Andrews (1976). All specimens for study under the light microscope were mounted in Caedax, a medium having a refractive index of 1.55. The relative abundance of each of the 62 diatom taxa is shown in table 1, in which the relative frequency of each taxon was estimated at each of 7 different stratigraphic levels, as observed under an 18-mm cover glass viewed at $\times 250$ magnification.

STRATIGRAPHIC SIGNIFICANCE

The most striking feature of the Petersburg diatom assemblage is its essential modernity in comparison with the previously described Miocene assemblages of the Atlantic Coastal Plain. A comparison of the numbers and percentages of different classes of taxa of this assemblage with those of the Calvert Formation of Lohman (1948) and of the Choptank Formation of Andrews (1976) is shown in table 2. The new taxa, or taxa known only from the studied deposit, are relatively constant in all 3 assemblages. However, the Petersburg assemblage as observed here contains only 12.9% of taxa confidently presumed to be extinct, whereas the Choptank Formation (middle Miocene) contains 40.0% and the Calvert Formation (lower to middle Miocene) contains 47.0%. On the other hand, the Petersburg assemblage contains 79.0% of taxa known to be still living as opposed to 48.3% and 40.5% in the Choptank and Calvert Formations, respectively. The modernity of the Petersburg assemblage is further indicated by the fact that 27.4% of the assemblage is made up of living taxa not (to the writer's knowledge) previously reported from the fossil record. This distribution of taxa is strong evidence for the relatively late date of the Petersburg diatom assemblage.

The Petersburg assemblage has much more in common with modern diatoms than with the studied assemblages of early and middle Miocene age. Unfortunately, no other post-Choptank Miocene or Pliocene diatom assemblages have yet been found in the Atlantic Coastal Plain region, so comparison with other diatom assemblages of those ages is not possible. Of the Petersburg taxa, 12.9% are generally considered to be extinct judging from their known occurrences; the 8.1% of the taxa known only from the Petersburg deposit may also be extinct. These amounts are, however, trivial compared with the 79.0% of the taxa that are also found in modern diatom assemblages. This seems to indicate an approximate date of 5 Ma for the Petersburg deposit, as opposed to the 12–14 Ma approximate age range of the Miocene Choptank and Calvert Formations.

Five taxa in the Petersburg assemblage—*Aulacodiscus rogersii* (Bailey) Schmidt, *Chaetoceros lorenzianum* Grunow var. *A. Nitzschia imperforata*, n. sp., *Rhaphoneis fusus* Ehrenberg, and *Rhaphoneis petropolitana* Grunow—have not been reported in the literature except at Petersburg. *Rhaphoneis fusus*, as reestablished in this report, seems to be an intermediate stage between *R. lancettula* Grunow from the upper part of the Calvert-Choptank sequence (middle Miocene) of Maryland and Virginia, and *R. fatula* Lohman described by Lohman (1938) from the San Joaquin Formation (Pliocene) of California. Lohman (1938) also described *Hemidiscus ovalis* from the San Joaquin Formation; this species occurs in the Petersburg assemblage and is known from modern brackish-water environments. *Hemidiscus ovalis* is found in the same San Joaquin deposit as *Rhaphoneis angularis*, which I have observed on the East Coast only in some assemblages of probable early Pleistocene age from the Charleston area of South Carolina. The stage of evolution of *Rhaphoneis fusus* as well as the lack of *Rhaphoneis angularis* in the Petersburg deposit, suggest that the strata in the deposit may be a bit older than the San Joaquin Formation of California.

The most definitive marker diatom in the Petersburg deposit is *Thalassiosira oestrupii* (Ostenfeld) Proschkina-Lavrenko. This species, which is found sparingly at Petersburg, is regarded as having a first occurrence in deposits of early Pliocene age throughout the Pacific Ocean basin and the circum-Pacific areas. Schrader (1973, p. 694) stated that the first evolutionary occurrence of *T. oestrupii* is at the base of his North Pacific Diatom Zone IX of early Pliocene age. Koizumi (1972) also reported it in the Tatsunokuchi Formation (lower Pliocene) of Japan. Barron (1976, p. 344) reported its first occurrence in Unit 18 of the *Bolivina obliqua* Zone of California, which he regarded as early Pliocene. Burckle and Opdyke (1977, p. 280) have indicated that *T. oestrupii* first appears in the earliest Pliocene, both in the equatorial and north Pacific Ocean basins.

The first occurrence of *Thalassiosira oestrupii* in the Atlantic Ocean basin is poorly known because there has been relatively little coring of deep-sea Miocene and Pliocene strata. Schrader and Fenner (1976, p. 927) reported the first occurrence of *T. oestrupii* in the upper part of their *Thalassiosira kryophila* Partial Range Zone in the Norwegian Sea basin between Norway and Greenland. The top of this zone is dated at 2.5 Ma, which suggests a somewhat later first occurrence for *T. oestrupii* than that common to the Pacific and Indian Ocean basins. However, the Norwegian Sea was strongly influenced by polar conditions and indeed cannot be representative of the Atlantic basin as a whole. Burckle (personal communication, 1978) has studied the Messinian strata (upper Miocene) of the

TABLE 1

Diatom taxa in the Petersburg deposit and their relative frequency at various levels measured from the top of the section.

A, abundant, at least one specimen in all fields of view; C, common, one specimen in many (but not all) fields of view; F, frequent, several specimens observed on slide, but seen only in a few fields of view; R, rare, one or two specimens on a slide.

Depth in feet (meters)	Relative frequency Depth in feet (meters)						
	1 (0.30)	2 (0.61)	3 (0.91)	4 (1.22)	4.5 (1.37)	6 (1.52)	(1.83)
<i>Actinocyclus octonarius</i>	F	F	F	F	F	F	F
<i>Actinocyclus tenellus</i>	—	—	—	—	F	—	R
<i>Actinopterychus australis</i>	R	—	R	F	—	—	—
<i>Actinopterychus senarius</i>	F	F	F	F	F	C	F
<i>Actinopterychus splendens</i>	—	R	R	R	—	—	—
<i>Amphora</i> aff. <i>A. cymbiformis</i>	—	—	—	—	—	R	—
<i>Amphora proteus</i>	—	—	R	R	—	—	—
<i>Aulacodiscus argus</i>	—	—	—	R	—	—	—
<i>Aulacodiscus crux</i>	—	—	—	—	—	—	R
<i>Aulacodiscus rogersii</i>	—	—	—	—	—	R	—
<i>Biddulphia rhombus</i>	R	R	F	R	F	C	F
<i>Biddulphia tuomeyi</i>	R	R	F	F	F	F	R
<i>Biddulphia</i> aff. <i>B. laevis</i>	—	—	—	—	—	R	—
<i>Chaetoceros lorenzianum</i>	R	—	R	R	—	R	R
<i>Chaetoceros lorenzianum</i> var. <i>A</i>	—	—	—	—	—	R	—
<i>Cocconeis sublittoralis</i>	—	—	—	—	—	R	—
<i>Coscinodiscus asteromphalus</i>	—	—	—	—	R	—	—
<i>Coscinodiscus curvatus</i>	—	—	—	—	—	R	—
<i>Coscinodiscus divisus</i>	—	—	R	R	—	F	R
<i>Coscinodiscus granii</i>	—	—	—	—	—	R	—
<i>Coscinodiscus marginatus</i>	F	R	F	F	R	F	F
<i>Coscinodiscus nitidus</i>	—	—	—	—	—	R	—
<i>Coscinodiscus radiatus</i>	R	—	R	R	—	—	—
<i>Cussea</i> aff. <i>C. paleacea</i>	—	—	—	—	R	R	R
<i>Cyclotella striata</i>	—	—	—	R	—	—	—
<i>Dimeregramma fulvum</i>	—	—	—	—	—	—	R
<i>Diploneis didyma</i>	R	F	F	F	F	F	F
<i>Diploneis eudoxia</i>	—	R	—	R	—	—	—
<i>Diploneis smithii</i>	—	R	—	R	—	R	—
<i>Dossetia hyalina</i>	—	—	—	—	—	R	—
<i>Epithemia argus</i> var. <i>alpestris</i>	—	—	—	—	—	R	—
<i>Goniothecium odontella</i>	—	R	F	R	R	R	R
<i>Grammatophora angulosa</i>	R	R	—	—	—	R	—
<i>Grammatophora marina</i>	—	R	—	R	R	R	—
<i>Hemidiscus ovalis</i>	—	—	—	—	—	R	R
<i>Hyalodiscus scoticus</i>	—	R	R	—	—	—	R
<i>Melosira westii</i>	F	C	C	C	C	A	F
<i>Navicula hennedyi</i>	—	—	—	—	—	R	—
<i>Navicula lyra</i>	—	—	—	—	—	R	R
<i>Navicula pennata</i>	R	R	R	R	R	F	F
<i>Nitzschia imperforata</i> , n. sp.	F	F	F	F	—	F	F
<i>Paralia sulcata</i>	F	C	C	C	C	C	C
<i>Paralia sulcata</i> var. <i>coronata</i>	F	C	C	C	C	C	C
<i>Pinnularia brevicostata</i>	—	R	—	—	—	—	—
<i>Pleurosigma normanii</i>	—	—	—	R	R	R	R
<i>Podosira stelligera</i>	R	R	F	F	F	F	F
<i>Pseudauliscus radiatus</i>	—	—	R	—	—	—	—
<i>Pseudopyxilla americana</i>	—	—	—	—	R	R	R
<i>Pyxidicula cruciata</i>	R	R	F	F	R	F	F
<i>Rhaphoneis amphiceros</i>	R	—	F	F	R	F	F
<i>Rhaphoneis fusus</i>	F	F	—	C	C	A	F
<i>Rhaphoneis petropolitana</i>	—	—	—	F	R	F	R
<i>Rhaphoneis rhombica</i>	—	—	—	—	R	F	—
<i>Stephanogonia actinopterychus</i>	—	—	—	—	R	—	R
<i>Stephanopyxis turris</i>	—	—	R	R	F	R	R
<i>Thalassionema nitzschioides</i>	—	—	—	—	R	—	R
<i>Thalassiosira eccentrica</i>	—	—	—	R	R	R	R
<i>Thalassiosira oestrupii</i>	—	—	—	—	—	R	—
<i>Thalassiothrix longissima</i>	—	—	—	—	R	R	—
<i>Triceratium hebetatum</i>	—	—	F	F	R	F	F
<i>Triceratium reticulum</i>	R	F	F	R	R	R	—
<i>Triceratium tessellatum</i>	—	—	F	F	F	F	F

Mediterranean basin extensively and has stated that *T. oestrupii* has not been observed in those deposits. A widespread and cosmopolitan planktonic diatom such

as *T. oestrupii* must have been distributed world-wide fairly rapidly so that its first occurrence in the Atlantic basin would be geologically indistinguishable from its

TABLE 2

Comparison of diatom taxa from Petersburg and from the Choptank and Calvert Formations (adapted from Andrews, 1976, table 1).

Taxa	Petersburg this report		Choptank Fm. Andrews (1976)		Calvert Fm. Lohman (1948)	
	Number of taxa	Percent	Number of taxa	Percent	Number of taxa	Percent
Not elsewhere reported	5	8.1	7	11.7	11	12.5
Extinct	8	12.9	24	40.0	42	47.0
Long ranging, fossil to Recent	49*	79.0*	29	48.3	36	40.5
Total	62	100.0	60	100.0	89	100.0

*Of these, 17 taxa and 27.4% of the assemblage have been previously reported only from Recent deposits.

first occurrence elsewhere. No evidence at present indicates that *T. oestrupii* occurs in rocks older than early Pliocene.

The presence of *Thalassiosira oestrupii* in the Petersburg deposit is a strong indication that the deposit is not older than early Pliocene in age. The occurrence of such species as *Rhaphoneis fusus*, *Rhaphoneis petropoli-tana*, and *Hemidiscus ovalis*, all unknown in the Miocene, also suggests a probable Pliocene age. This age is generally confirmed by the relative modernity of the assemblage, which does not, however, provide definitive evidence. On the basis of the diatom bio-stratigraphy, a strong case must be made for an early Pliocene age for the Petersburg strata herein studied.

The assemblages of the 7 stratigraphically collected samples vary as shown in table 1. No noticeable changes of appreciable substance occur within the studied section. The deposit appears to have been laid down under relatively constant conditions, without discernible stratigraphic breaks, and probably within a comparatively short period of time.

PALEOECOLOGIC INTERPRETATION

The Petersburg diatom assemblage is dominated by littoral and shallow marine taxa. Included are several cosmopolitan marine species, which suggests that during most of the time, there was open access to marine waters. Many of the cosmopolitan and littoral species here recorded are known to tolerate a degree of dilution from normal marine salinity. In most studies, the lack of specific data on salinity tolerances of diatoms does not permit any precise determination of the paleoecology. The occurrence of *Hemidiscus ovalis* living in water that has a salinity of 24 parts per thousand in Port Royal Sound, South Carolina (Abbott, personal communication, 1978), suggests that the Petersburg deposit may have been laid down partly under brackish-water conditions. Several of the cosmopolitan and littoral marine diatoms could have tolerated such an environment, and some are known to range into brackish waters.

The rare occurrence of 2 taxa of fresh-water diatoms in the sediments is of considerable interest. Although a few salt-tolerant fresh-water species may live in brackish environments, usually fresh-water assemblages are quite distinct from brackish-water or marine assemblages. Generally speaking, there are more marine diatom species that are able to tolerate abnormally low salinities than there are fresh-water diatom species that are able to tolerate abnormally high (to them) salinities. Neither of the 2 fresh-water diatom taxa observed in the Petersburg assemblage are remarkable for their tolerance of salinity. Hence, one may assume that they were probably transported by fresh-water runoff into the waters in which the Petersburg assemblage was deposited.

Gardner (1943, p. 113), quoting Dall (1898), stated that the pelecypod genus *Mulinia* is "widely distributed in estuaries of the tropics and temperate seas over most of the world." She did not comment specifically on the paleoecology of *Mulinia congesta*, the most abundant mollusk in the Petersburg deposit. T. G. Gibson (personal communication, 1978) has found foraminiferal assemblages dominated by *Elphidium excavatum*, a shallow marine species, in the Wilcox Lake deposit at Petersburg. The evidence suggests that the Petersburg deposit was laid down in a shallow marine to brackish-water environment that probably fluctuated in salinity—either in an estuary or lagoon partly cut off from open circulation with the sea.

SYSTEMATIC PALEONTOLOGY

The taxa of diatoms studied for this report are arranged alphabetically. The treatment of nomenclature in the generic and lower ranks is conservative, and is prejudiced in favor of a purely binomial system. This report is a chapter in a continuing series on the diatoms of the Atlantic Coastal Plain. Therefore, descriptions of taxa that have already been adequately described in earlier papers of this series are not repeated here. Such descriptions can be seen in the papers cited in the synonymies.

The first citation in each synonymy is to the original description of the taxon. The second citation contains chronologic references to the taxon, using the nomenclature adopted for this report. Subsequent citations refer to names regarded as synonymous for various reasons. These synonymies are not intended to be exhaustive, and further information may be sought in the general references cited.

Genus ACTINOCYCLUS Ehrenberg, 1838

Actinocyclus octonarius Ehrenberg
Plate 1, figure 1; plate 4, figure 1

Actinocyclus octonarius EHRENBURG, 1838, p. 172, pl. 21, fig. 7.—HENDEY, 1937, p. 262; 1964, p. 83, pl. 24, fig. 3.—LOHMAN, 1941, p. 77, pl. 16, fig. 4; 1948, p. 167, pl. 8, fig. 8.—ANDREWS, 1976, p. 14, pl. 3, fig. 7.—ABBOTT and ANDREWS, 1979, p. 231, pl. 1, fig. 4.
Actinocyclus ehrenbergii RALFS in Pritchard, 1861, p. 834.—HUSTEDT, 1929, pp. 525–533, fig. 298.

Discussion: Ehrenberg (1844) reported *A. octonarius* from the Petersburg deposit as several species, classified according to the number of sectors per valve. Hendey (1937) and Lohman (1941) have ably established the priority of *A. octonarius* over *A. ehrenbergii* Ralfs. This highly variable species is frequent throughout the Petersburg section.

Known geologic range: Miocene to Recent with a widespread occurrence in modern oceans.

Actinocyclus tenellus (Brébisson) Andrews

Eupodiscus tenellus BRÉBISSE, 1854, pl. 257, pl. 1, fig. 9.
Actinocyclus tenellus (Brébisson).—ANDREWS, 1976, p. 14, pl. 3, figs. 8, 9.—ABBOTT and ANDREWS, 1979, p. 231, pl. 1, fig. 9.
Actinocyclus moniliformis RALFS in Pritchard, 1861, p. 834.—GRUNOW in Van Heurck, 1883, pl. 124, fig. 9.—BOYER, 1904, pp. 502–503, pl. 134, fig. 2.
Actinocyclus ehrenbergii var. *tenella* (Brébisson).—HUSTEDT, 1929, p. 530, fig. 302.

Discussion: *A. tenellus* is closely related to *A. octonarius*, but it is smaller and somewhat more robustly marked. It is rare to frequent in the lower part of the Petersburg section.

Known geologic range: Miocene to Recent in modern marine environments.

Genus ACTINOPTYCHUS Ehrenberg, 1839

Actinoptychus australis (Grunow) Andrews
Plate 1, figure 2

Actinoptychus vulgaris var. *australis* GRUNOW in Van Heurck, 1883, pl. 121, fig. 8.
Actinoptychus australis (Grunow).—ANDREWS, 1978 [1979], p. 382, pl. 1, fig. 5.

Description: Valve round, flat, fragile, with margin

commonly missing or poorly preserved. Diameter 40 to 75 μm . Main part of valve divided into sectors, usually about 16 in specimens observed, but the number may vary. Sectors alternately elevated and depressed, each group with different markings. Group 1 (externally depressed) sectors: about 3 rows of fine pores at the margin, succeeded inwardly by a hyaline band about 2 μm in width but with blunt extensions about twice that width directed toward the center on each side of the sector; main part of the sector completely covered with straight rows of fine pores, about 12 in 10 μm , normal to the margin and arranged in a quincuncial pattern. Group 2 (externally raised) sectors: each sector has a finely punctate margin, with a single interior labiate process opening outward into a large pore with a raised rim; main part of the sector covered with straight rows of fine pores, about 12 in 10 μm , normal to the margin and arranged in a hexagonal pattern; a bladlike hyaline area, caused by the lack of 1 row of pores, extends from the hyaline central area about one-third to one-half the length of the sector. Central area hyaline, warped near the margin to join alternate sectors on different planes. Inside of valve smoothly porous; outside shows a coarse areolate net superimposed on the porous substructure.

Discussion: *A. australis* shows obvious affinities to *A. virginicus* (Grunow) Andrews and *A. marylandicus* Andrews reported from the Choptank Formation (middle Miocene) by Andrews (1976) and from the Hawthorn Formation by Abbott and Andrews (1979). However, it differs in at least 2 significant characteristics: (1) The bladlike hyaline rays are on the group 1 sectors of *A. marylandicus* and *A. virginicus*, whereas they are on the group 2 sectors of *A. australis*; (2) the fine pore structure is coarser in the group 1 sectors of *A. marylandicus* and *A. virginicus* than in the group 2 sectors, whereas the fine pore structure shows about the same spacing in all sectors of *A. australis*.

Grunow in Van Heurck (1883) figured but did not describe his *A. vulgaris* var. *australis*, and it appears to be identical with specimens in the Petersburg assemblage. He gave its provenance only as "southern Australia," with no indication whether it came from fossil or living material.

Actinoptychus australis is rare to frequent in the upper part of the Petersburg assemblage.

Known geologic range: Reported by Andrews [1978 (1979)] from the upper part of MLU3 of the Calvert Formation in Maryland. Observed in assemblages of probable early Pleistocene age from the Charleston, South Carolina, area. Not known with certainty in Recent diatom assemblages.

***Actinoptychus senarius* (Ehrenberg) Ehrenberg**

Plate 1, figure 3

Actinocyclus senarius EHRENBURG, 1838, p. 172, pl. 21, fig. 6.
Actinoptychus senarius (Ehrenberg).—EHRENBURG, 1843, p. 400, pl. 1, fig. 27.—HENDEY, 1937, pp. 271–272; 1964, p. 95, pl. 23, figs. 1, 2.—LOHMAN, 1941, pp. 80–81, pl. 16, fig. 9; 1948, p. 170.—ANDREWS, 1976, p. 15, pl. 4, figs. 7, 8.—ABBOTT and ANDREWS, 1979, p. 232, pl. 1, fig. 11.
Actinoptychus undulatus Kützing.—BOYER, 1904, pp. 499–500, pl. 134, fig. 4.
Actinoptychus undulatus (Bailey) Ralfs.—HUSTEDT, 1929, pp. 475–478, fig. 264.

Discussion: Scanning electron microscopy shows that the marginal process in each of the group 2 (externally raised) sectors consists of a single internal labiate process opening outwardly in a large pore with a raised rim. The valves are smoothly porous inside, but the outside shows a coarse, somewhat rugose, areolate net superimposed on the finely porous substructure. *Actinoptychus senarius* is frequent to common throughout the Petersburg section.

Known geologic range: Reported from beds as old as Cretaceous. Common throughout the Miocene section of the eastern United States. Common in Recent cool coastal waters.

***Actinoptychus splendens* (Shadbolt) Ralfs**

Plate 1, figure 4

Actinosphaenia splendens SHADBOLT, 1854, p. 16.
Actinoptychus splendens (Shadbolt).—RALFS in Pritchard, 1861, p. 840.—HUSTEDT, 1929, pp. 478–480, fig. 265.—LOHMAN, 1948, p. 170.—HENDEY, 1964, p. 95, pl. 22, fig. 1.

Discussion: *A. splendens* is similar to *A. australis* in structure, but it is much better known because of its widespread occurrence in modern environments. In *A. splendens* a narrow hyaline ray extends from the hyaline central area of the valve to the vicinity of the labiate process near the margin of each group 2 (externally raised) sector. *Actinoptychus splendens* is rare in the upper part of the Petersburg section.

Known geologic range: Although reported by Lohman (1948) from the Calvert Formation (Miocene) of Maryland, his description suggests *A. virginicus* or *A. marylandicus* rather than true *A. splendens*. Not observed by Andrews (1976) in the Choptank Formation (middle Miocene) of Maryland nor by Abbott and Andrews (1979) in the Hawthorn Formation of South Carolina and Georgia. The oldest known certain occurrence seems to be in this Petersburg deposit, and it is a common Recent littoral species.

Genus AMPHORA Ehrenberg, 1840

***Amphora* aff. *A. cymbifera* Gregory**

Plate 1, figure 8

Amphora cymbifera GREGORY, 1857, p. 526, pl. 14, figs. 97–97c.—HENDEY, 1964, p. 265.

Description: Valve half-lanceolate with smoothly rounded dorsal margin and nearly straight ventral margin with a low median swelling. Apices slightly produced, narrowly rounded. Length of observed specimen 60 μm . Ventral side of valve with about 14 transverse rows of fine pores in 10 μm . Hyaline axial area expanded near the center. Raphe close to the dorsal margin and flexed to parallel that margin.

Discussion: This form resembles *A. cymbifera* generally, but the apices are somewhat less produced, and it is more finely striated. Rare in the 5-foot level of the Petersburg section.

Known geologic range: *A. cymbifera* is reported to be of occasional occurrence on Recent sandy beaches of the west coast of Great Britain.

***Amphora proteus* Gregory**

Plate 1, figure 9

Amphora proteus GREGORY, 1857, pp. 518–519, pl. 13, figs. 81–81e.—BOYER, 1927, p. 254.—HENDEY, 1964, p. 262.

Description: Valve lunate with a nearly straight ventral margin, slightly flexed ventrally near bluntly rounded apices. Length of observed specimen 72 μm . Valve surface continuously striate on dorsal side of raphe, composed of 9 transverse rows of pores in 10 μm . Ventral side of raphe shows 2 rows of pores near the center, 1 row toward the apices, which appear to elongate into radiate transverse slits approaching the apices. Raphe segments curved, lying near the dorsal side of the valve. Hyaline area along ventral margin sometimes faintly punctate.

Discussion: *A. proteus* is rare in the 3- and 4-foot levels of the Petersburg section.

Known geologic range: Widely distributed in Recent coastal waters of Great Britain.

Genus AULACODISCUS Ehrenberg, 1844

***Aulacodiscus argus* (Ehrenberg) Schmidt**

Tripodiscus argus EHRENBURG, 1841, p. 159, pl. 3, fig. 6.
Aulacodiscus argus (Ehrenberg).—SCHMIDT, 1886, pl. 107, fig. 4.—RATTRAY, 1888a, p. 373.—HUSTEDT, 1929, pp. 503–505, fig. 281.—LOHMAN, 1948, p. 171.—HENDEY, 1964, p. 97.
Eupodiscus argus (Ehrenberg).—W. SMITH, 1853, p. 24, pl. 4, fig. 39.—WOLLE, 1894, pl. 76, figs. 1, 2, 4.

Discussion: *A. argus* is found only as distinctively marked fragments at the 4-foot (1.22-m) level in the Petersburg deposit. Valve appears to be very dense with a coarse areolation of angular cells overlying a lower lamina with finer pores.

Known geologic range: Reported by Ehrenberg from Miocene deposits at Richmond and Petersburg, Virginia, and Piscataway, Maryland (Rattray, 1888a).

Reported by Lohman (1948) from the Calvert Formation (Miocene) of Maryland. Miocene to Recent with a widespread neritic occurrence around the North Atlantic Ocean.

***Aulacodiscus crux* Ehrenberg**

Plate 1, figure 5

Aulacodiscus crux EHRENBURG, 1844, p. 76; 1854, pl. 18, fig. 47.—RATTRAY, 1888a, p. 350.

Description: Valve round, large, robustly marked, slightly convex with marked curvature near the margin. Diameter of observed specimen about 132 μm . Surface of valve covered with radial rows of fine pores, somewhat bundled into groups of about 4 rows near the margin, less distinctly so near the center of the valve. About 6 pores in 10 μm in the outer half of the valve; about 4 in 10 μm near the center. A distinct ring of coarse loculae are superimposed on the pore pattern about four-fifths the distance from the center to the margin. Immediately inside this ring are 4 large processes extending from the valve surface and equally spaced around the margin. These processes are connected to the valve center by distinct breaks in the radial pore pattern, producing a striking cruciform appearance.

Discussion: The overlying coarse areolate net in *A. argus* is much less strongly developed in *A. crux*. This species is rare in the 6-foot level of the Petersburg deposit.

Known geologic range: Originally described by Ehrenberg (1844) from Richmond, Virginia, and also reported by him from Petersburg, Virginia. This species has not been reported from the Recent and may possibly be restricted to beds of middle Miocene to early Pliocene age.

***Aulacodiscus rogersii* (Bailey) Schmidt**

Podiscus rogersi BAILEY, 1844, pl. 138, pl. 3, figs. 1, 2.

Aulacodiscus rogersii (Bailey).—SCHMIDT, 1886, pl. 107, fig. 3.—RATTRAY, 1888a, pp. 372–373.—non BOYER, 1904, pp. 497–498, pl. 134, fig. 5.

Eupodiscus rogersii (Bailey).—EHRENBURG, 1844, p. 81.

Eupodiscus baileyi EHRENBURG, 1844, p. 81.

Description: Valve large, round, nearly flat in center, slightly raised in an annular ring enclosing the processes, abruptly convex near the margin. Diameter of observed specimen about 150 μm . Valve covered with radial rows of pores, about 4 to 5 in 10 μm , extending from near the rim to the center of the valve. About 6 prominent processes extend from the valve surface near the margin. Rays connecting these processes to the center somewhat obscure.

Discussion: This species, first described by Bailey

(1844) and observed by Ehrenberg (1844) in the Petersburg deposit, is rare at the 5-foot level in the studied section.

Known geologic range: Reported from unspecified deposits in Maryland by Rattray (1888a). Boyer (1904) misidentified *A. argus* as *A. rogersii* in the Miocene of Maryland. The only authenticated occurrence seems to be in the Petersburg deposit.

Genus BIDDULPHIA Gray, 1821

***Biddulphia rhombus* (Ehrenberg) W. Smith**

Plate 1, figures 6, 7; plate 4, figures 2, 3

Zygoceros rhombus EHRENBURG, 1841, p. 160, pl. 4, fig. 11.

Biddulphia rhombus (Ehrenberg).—W. SMITH, 1856, pp. 49–50, pl. 45, fig. 320; pl. 61, fig. 320.—VAN HEURCK, 1882, pl. 99, figs. 1, 3.—HUSTEDT, 1930, pp. 842–844, figs. 496–497.—HENDEY, 1964, p. 103, pl. 25, fig. 8.

Denticella rhombus (Ehrenberg).—EHRENBURG, 1844, p. 79.

Biddulphia seticulosa GRUNOW in Van Heurck, 1882, pl. 101, figs. 7–8.

Description: Valves convex, elliptical-lanceolate with produced apices. Apices have short tubular processes sometimes deflected slightly from median line of the valve. Length 54 to 105 μm . Surface of valve covered with slightly irregular rows of fine pores, about 10 rows in 10 μm . This pore pattern is sometimes interrupted by a narrow hyaline band outlining a narrowly lanceolate porous area at the center of the valve; however, this hyaline band is incomplete or lacking in some specimens. Outer valve surface shows numerous scattered small spines and several larger spines irregularly placed near the margin. These large external spines are probably connected to scattered labiate processes on the interior of the valve.

Discussion: Although Grunow (in Van Heurck, 1882) named and figured a species *B. seticulosa* from Petersburg material, I can see no substantial difference in this species from *B. rhombus*. Ehrenberg (1844) identified the species *rhombus* in his early work on the Petersburg deposit. The specimens seen in this deposit more closely resemble the elongate form illustrated by Hustedt (1930) than the rotund form illustrated by Hendey (1964). *Biddulphia rhombus* is rare to common throughout the Petersburg section.

Known geologic range: Not observed in previously studied assemblages of early to middle Miocene age in eastern United States. A widely distributed neritic species in Recent cool to temperate seas.

***Biddulphia tuomeyi* (J. W. Bailey) Roper**

Plate 1, figures 10, 11; plate 4, figure 5

Zygoceros tuomeyi J. W. BAILEY, 1844, p. 138, pl. 3, figs. 3–9.

Biddulphia tuomeyi (J. W. BAILEY).—ROPER, 1859, p. 8, pl. 1, figs. 1, 2.—GRUNOW in Van Heurck, 1882, pl. 98, figs. 2–3;

HUSTEDT, 1930, pp. 834–836, fig. 491.—LOHMAN, 1948, p. 174.—ANDREWS, 1976, p. 17, pl. 5, fig. 11.—ABBOTT and ANDREWS, 1979, p. 234, pl. 2, fig. 4; pl. 6, fig. 8.

Description: Valve markedly convex, with a swollen bulbous central process, usually 2 less swollen intermediate processes, and elongate, outwardly deflected, longer blunt horns with closed ends at the apices. The valve is usually trinodal with produced apices in valve view. Length 42 to 123 μm . Surface of valve is covered with coarse pores, about 6 to 8 in 10 μm , very roughly radial from the center of the valve. Prominent raised rim around intermediate and terminal processes of the valve. Prominently depressed sutures between the central process and intermediate processes. One or two long hollow spines on outside of the bulbous central process apparently open to interior labiate processes.

Discussion: The intermediate processes may range from prominent to virtually nonexistent. *Biddulphia tuomeyi* in valve view has been mistaken for *Terpsinoë americana*, which it resembles in outline. The protruding hornlike apical processes do not occur in *T. americana*. *Biddulphia tuomeyi* is rare to frequent throughout the Petersburg section.

Known geologic range: Previously reported from deposits of early to middle Miocene age in eastern United States. It is widespread in the warmer coastal waters of Recent oceans.

***Biddulphia* aff. *B. laevis* Ehrenberg**

Plate 1, figure 12

Biddulphia laevis EHRENBURG, 1843, p. 410.—HUSTEDT, 1930, pp. 852–855, figs. 506, 507.—HENDEY, 1964, p. 105, pl. 25, fig. 7.

Discussion: A single specimen resembling *B. laevis* was observed in the 5-foot level of the Petersburg deposit. According to Hustedt (1930), *B. laevis* has about 16 rows of pores in 10 μm , whereas the Petersburg specimen has about 10 rows in 10 μm . In all other respects it appears to be identical with *B. laevis*.

Known geologic range: Not previously reported as fossil. *Biddulphia laevis* is a littoral form found in waters of reduced salinity in modern estuaries.

Genus CHAETOCEROS Ehrenberg, 1845

***Chaetoceros lorenzianum* Grunow**

Plate 1, figure 13

Chaetoceros lorenzianum GRUNOW, 1863, p. 157, pl. 5, fig. 13.—HUSTEDT, 1930, pp. 679–680, fig. 385.—HENDEY, 1964, p. 124, pl. 16, fig. 1.

Dicladia capreolus EHRENBURG, 1844, p. 79; 1854, pl. 35A, XVII, fig. 8; XVIII, fig. 5.—GRUNOW in Van Heurck, 1883, pl. 106, figs. 14–16.—ABBOTT and ANDREWS, 1979, p. 243, pl. 4, fig. 5; pl. 7, fig. 7.

Chaetoceros dicladia CASTRACANE, 1886, p. 82, pl. 8, fig. 1; pl. 19, figs. 7, 8.

Description: Only resting spores observed in this deposit. Valve oval in outline with dissimilar surfaces, the one nearly flat with 2 low central swellings, the other with 2 hyaline hornlike processes, evenly spaced along the longitudinal axis, and branched at their apices. Length of observed specimens 15 to 35 μm , and individuals may be taller than long.

Discussion: It is apparent that the form-taxon described by Ehrenberg (1844) as *Dicladia capreolus* represents the resting spore stage of *Chaetoceros lorenzianum* Grunow (1863). Although Ehrenberg's name has priority, he originally described the form-genus *Dicladia* on the basis of fossil material. It would seem, therefore, that Article 59 of the 1972 International Code of Botanical Nomenclature is applicable in this case and that, if *Dicladia capreolus* is combined with *Chaetoceros lorenzianum* (as I here propose), the species name of the perfect state of the diatom should be adopted. The resting spores of *C. lorenzianum* resemble those of *C. mitra*. However, those of *C. mitra* have broader based, more nearly conical, and relatively longer processes. The resting spores of *C. lorenzianum* occur rarely and sporadically throughout the Petersburg section.

Known geologic range: The resting spores of the species were originally described by Ehrenberg from middle Miocene deposits at Richmond and the deposit at Petersburg, Virginia. *Chaetoceros lorenzianum* has a widespread Recent occurrence in coastal and neritic plankton, particularly in warmer waters.

***Chaetoceros lorenzianum* Grunow var. A**

Plate 1, figure 14

Discussion: This form is similar to the resting spore of the type variety of *C. lorenzianum*, except that the valve is ornamented with 1 hornlike process rather than 2. Whether this is an aberrant form of *C. lorenzianum* or should properly be classed as a variety of that species or as a new species is not known. This variety is rare in the 5-foot level of the Petersburg section.

Known geologic range: This form does not seem to have been previously reported from either fossil or living material.

***Chaetoceros* spp.**

Discussion: Several specimens, some finely spinose, that resemble resting spores of *Chaetoceros* were observed. They occur only rarely in the Petersburg section and cannot be positively identified as to species.

Until their relationships are better known, taxonomic treatment does not seem justified.

Genus COCCONEIS Ehrenberg, 1838

Cocconeis sublittoralis Hendey

Plate 1, figure 15

Cocconeis sublittoralis HENDEY, 1951, p. 44, pl. 13, figs. 1–9; 1964, p. 181, pl. 28, figs. 14–17.

Description: Only the raphe valve observed. Valve flat, elliptical-lanceolate with bluntly rounded apices. Length of observed specimen 70 μm . Narrow axial area widens to a large, transversely orbicular central area. Surface covered with slightly radiate transverse rows of pores, about 6 in 10 μm . Pores near the axial area are also secondarily arranged in longitudinal rows.

Discussion: *C. sublittoralis* is rare at the 5-foot level of the Petersburg deposit.

Known geologic range: Not previously reported from fossil material. Described by Hendey (1964) from Recent British coastal waters.

Genus COSCINODISCUS Ehrenberg, 1838

Coscinodiscus asteromphalus Ehrenberg

Coscinodiscus asteromphalus EHRENBURG, 1844, p. 77.—HUSTEDT, 1928, pp. 452–454, fig. 250.—LOHMAN, 1941, p. 70, pl. 13, fig. 11; 1948, p. 159.—HENDEY, 1964, p. 78, pl. 24, fig. 2.—ABBOTT and ANDREWS, 1979, p. 235, pl. 2, fig. 8.

Discussion: Found only as rare fragments at the 4.5-foot level of the Petersburg section.

Known geologic range: Named by Ehrenberg from the Miocene at Richmond, Virginia, and reported widely from lower and middle Miocene deposits of the eastern United States. A pelagic plankton diatom with world-wide distribution in Recent oceans.

Coscinodiscus curvatus Grunow

Plate 4, figure 4

Coscinodiscus curvatus GRUNOW in Schmidt, 1878, pl. 57, fig. 33.—HUSTEDT, 1928, pp. 406–410, fig. 214.—LOHMAN, 1941, p. 74, pl. 15, fig. 8; 1948, p. 160.—ANDREWS, 1976, p. 10, pl. 2, fig. 4.—ABBOTT and ANDREWS, 1979, p. 236, pl. 2, fig. 12.

Discussion: Observed rarely in scanning electron microscope preparations from the 5-foot level of the Petersburg section.

Known geologic range: Throughout the Tertiary to a frequent pelagic occurrence in present oceans.

Coscinodiscus divisus Grunow

Plate 1, figure 16

Coscinodiscus divisus GRUNOW, 1878, p. 125.—RATTRAY, 1889, p. 499.—HUSTEDT, 1928, pp. 410–412, fig. 218.—

LOHMAN, 1941, pp. 75–76, pl. 15.—ABBOTT and ANDREWS, 1979, p. 236, pl. 2, fig. 13.

Discussion: *C. divisus* is rare to frequent in the lower two-thirds of the Petersburg section.

Known geologic range: Reported by Abbott and Andrews (1979) from the Coosawhatchie Member (middle Miocene) of the Hawthorn Formation. It has a widespread occurrence in modern littoral and neritic environments.

Coscinodiscus granii Gough

Coscinodiscus granii GOUGH, 1905, p. 338, fig. 313.—HUSTEDT, 1928, pp. 436–438, fig. 237. HENDEY, 1964, p. 79.

Discussion: Observed only as fragments of fragile valves. Rare in the 5-foot level of the Petersburg section.

Known geologic range: Previously reported from the Recent cooler coastal waters of western Europe.

Coscinodiscus marginatus Ehrenberg

Plate 1, figure 17

Coscinodiscus marginatus EHRENBURG, 1843, pp. 329, 371; 1854, pl. 18, fig. 44; pl. 33, XII, fig. 13; pl. 38, XXII, fig. 8.—HUSTEDT, 1928, pp. 416–418, fig. 233.—LOHMAN, 1941, pp. 71–72, pl. 14, figs. 1, 6; 1948, p. 162, pl. 7, fig. 4.—HENDEY, 1964, p. 78, pl. 22, fig. 2. ANDREWS, 1976, p. 11, pl. 2, figs. 6, 7.—ABBOTT and ANDREWS, 1979, p. 238, pl. 3, fig. 2.

Discussion: *C. marginatus* is a heavy, robust species of rare to frequent occurrence throughout the Petersburg section.

Known geologic range: Reported from deposits as old as the Moreno Shale of California—Cretaceous and Paleocene. The species is common in Recent marine waters.

Coscinodiscus nitidus Gregory

Plate 1, figure 18

Coscinodiscus nitidus GREGORY, 1857, pp. 499–500, pl. 10, fig. 45.—RATTRAY, 1889, pp. 478–479.—HUSTEDT, 1928, pp. 414–416, fig. 221.—HENDEY, 1964, p. 76, pl. 23, fig. 12.

Description: Valve round, nearly flat at center, but sharply convex near the margin. Diameter of observed specimens 37 to 81 μm . Surface of valve covered with large pores, about 3 to 4 in 10 μm , widely spaced in some specimens, in a loose areolate net in others and arranged in a roughly radial pattern. Often a single small pore near the center of the valve, seen to be cruciform in shape under the scanning electron microscope. Some specimens show other small pores scattered on the valve. Margin with distinctly radial rows of pores, about 5 rows in 10 μm .

Discussion: *C. nitidus* is rare in the 5-foot level of the Petersburg deposit.

Known geologic range: Widespread and common in Recent coastal marine environments.

Coscinodiscus radiatus Ehrenberg

Plate 2, figure 1

Coscinodiscus radiatus EHRENBURG, 1841, p. 148, pl. 3, figs. 1a-c.—RATTRAY, 1889, pp. 514–515.—HUSTEDT, 1928, pp. 420–421, fig. 225.—LOHMAN, 1941, p. 73, pl. 14, figs. 7, 8; 1948, p. 164.—HENDEY, 1964, p. 76, pl. 22, fig. 7.—ABBOTT and ANDREWS, 1979, p. 239, pl. 3, fig. 8.

Discussion: *C. radiatus* is rare in the upper part of the Petersburg section.

Known geologic range: From Eocene to a Recent common worldwide distribution in marine waters.

Genus CUSSIA Schrader, 1974

Cussia* aff. *C. paleacea (Grunow) Schrader

Plate 2, figure 2; plate 4, figure 6

Stoschia? paleacea GRUNOW in Van Heurck, 1883, pl. 128, fig. 6.

Cussia paleacea (Grunow).—SCHRADER, 1974, p. 914.—ABBOTT and ANDREWS, 1979, p. 241, pl. 3, fig. 15.

Coscinodiscus paleaceus (Grunow).—RATTRAY, 1889, p. 597.—SCHRADER, 1973, p. 703, pl. 3, figs. 10–12.

Description: Valve flat, lanceolate, with slight longitudinal asymmetry. Length of observed specimens 40 to 65 μm . Single row of large pores, about 6 to 7 in 10 μm around the margins. Central area filled with similar pores, arranged in irregularly longitudinal rows. Apices narrowly rounded, sometimes slightly attenuate.

Discussion: This form more closely resembles *C. paleacea* than the other described species of this genus. It lacks the zigzag mid-line of *C. praepaleacea* and the distinctly attenuate apices of *C. tatsunokuchien-sis*. The pores, however, seem to be less distinct than in previously figured specimens of *C. paleacea*. The species is rare throughout the lower part of the Petersburg section.

Known geologic range: *C. paleacea* was reported by Schrader (1973) from his North Pacific Diatom Zones XVII to XX, in the middle to late Miocene Serravallian and Tortonian Stages; observed by Abbott and Andrews (1979) from the Hawthorn Formation (middle Miocene) of South Carolina and Georgia. The forms here reported may be a younger variety or possibly a distinct species.

Genus CYCLOTELLA Kützing, 1834

Cyclotella striata (Kützing) Grunow

Plate 1, figure 19

Coscinodiscus striatus KÜTZING, 1844, p. 131, pl. 1, fig. 8.

Cyclotella striata (Kützing).—GRUNOW in Cleve and Grunow,

1880, p. 119.—HUSTEDT, 1928, pp. 344–347, fig. 176.—HENDEY, 1964, p. 74.

Description: Valve round, sharply divided by a strong diametrical fold in the central area. Diameter of observed specimen 21 μm . Center of valve covered with irregularly distributed pores. Margin of valve covered with radial striae, about 14 in 10 μm .

Discussion: *C. striata* occurs rarely in the 4-foot level of the Petersburg deposit.

Known geologic range: Previously reported as a common marine and brackish-water species, often frequenting Recent estuaries.

Genus DIMEREGRAMMA Ralfs in Pritchard, 1861

Dimeregramma fulvum (Gregory) Ralfs

Plate 2, figure 3

Denticula fulva Gregory, 1857, p. 496, pl. 10, figs. 38, 38b.

Dimeregramma fulvum (Gregory).—RALFS in Pritchard, 1861, p. 790.—HUSTEDT, 1931, pp. 120–121, fig. 643.—HENDEY, 1964, p. 155.

Description: Valve lanceolate with slightly constricted, subcapitate, bluntly rounded apices. Length of observed specimen 45 μm . Valve surface covered with transverse rows of pores, parallel in the center to slightly radiate at the ends, 10 rows in 10 μm . Axial area so narrow as to be obscure, and rows of pores are aligned across it. Structure of apical pseudocelli too fine for resolution with the light microscope.

Discussion: *D. fulvum* is rare in the 6-foot level of the Petersburg deposit.

Known geologic range: Reported to be of rare to frequent occurrence in Recent marine coastal waters.

Genus DIPLONEIS Ehrenberg, 1840

Diploneis didyma (Ehrenberg) Cleve

Plate 2, figures 4, 5; plate 4, figures 7, 8

Navicula (Pinnularia) didymus EHRENBURG, 1841, p. 155.

Diploneis didyma (Ehrenberg).—CLEVE, 1894, p. 90.—HUSTEDT, 1937, pp. 685–686, fig. 1075a, b.—HENDEY, 1964, p. 266, pl. 32, fig. 12.

Description: Valve panduriform, slightly to moderately constricted in the middle, dividing the valve into 2 tongue-shaped parts. Length 26 to 52 μm . Central nodule quadrate, often elongate longitudinally, extended into siliceous horns that converge slightly toward the apices. Surface of valve covered with large pores arranged in transverse rows, about 6 to 7 in 10 μm . Scanning electron microscopy shows that a single longitudinal row of pores on either side of the raphe opens only to the outside of the valve and is closed to the interior; other pores penetrate the valve.

Discussion: *D. didyma* is frequent throughout the Petersburg section.

Known geologic range: Reported to be widespread and common in present marine and brackish coastal waters.

***Diploneis eudoxia* (Schmidt) Mills**

Plate 2, figure 6

Navicula eudoxia SCHMIDT, 1875, pl. 8, fig. 40.

Diploneis eudoxia (Schmidt).—MILLS, 1934, p. 611.—HUSTEDT, 1937, pp. 595–596, fig. 1013.

Description: Valve broadly elliptical with rounded ends. Length of observed specimens 45 to 47 μm . Hyaline central area quadrate, with slightly convergent siliceous horns on either side of the raphe. Axial area wide, encompassing one-third (or slightly more) the width of the valve. Transverse striae composed of rows of fine pores, about 7 in 10 μm . A single longitudinal row of closed pores present in the axial area on both sides of raphe; these pores are not aligned with the transverse striae.

Discussion: The specimens observed are relatively broader than those described by Hustedt (1937); hence, the valve shape is more nearly elliptical and the siliceous horns somewhat more convergent toward the apices. *Diploneis eudoxia* is rare at the 2- and 4-foot levels of the Petersburg section.

Known geologic range: Previously reported as occurring rarely in present coastal waters.

***Diploneis smithii* (Brébisson) Cleve**

Plate 2, figure 7

Navicula smithii BRÉBISSE, 1854, p. 253.

Diploneis smithii (Brébisson).—CLEVE, 1894, p. 96.—HUSTEDT, 1937, pp. 647–654, fig. 1051.—HENDEY, 1964, p. 225, pl. 32, fig. 10.

Description: Valve broadly elliptical with rounded apices. Length of observed specimens 50 to 77 μm . Central area narrow, longitudinally elongate, extending to narrow, parallel siliceous horns on either side of the raphe. Furrows narrow, with transverse rows of fine pores, tapering toward the apices. Main part of valve covered with transverse double rows of pores alternating with siliceous costae, about 7 in 10 μm .

Discussion: *D. smithii* is rare in the 2-, 4-, and 5-foot levels of the Petersburg section.

Known geologic range: Widespread in Recent marine and brackish waters.

Genus DOSSETIA Azpeitia, 1911

***Dossetia hyalina* Andrews**

Plate 6, figure 1

Dossetia hyalina ANDREWS, 1976, p. 19, pl. 6, figs. 4–7.—ABBOTT and ANDREWS, 1979, p. 244, pl. 4, fig. 8; pl. 7, fig. 8.

Discussion: Observed rarely in scanning electron microscope preparation from the 5-foot level of the Petersburg section.

Known geologic range: Previously reported only from middle Miocene strata from the eastern United States.

Genus EPITHEMIA Brébisson, 1838

***Epithemia argus* var. *alpestris* (W. Smith) Grunow**

Plate 2, figure 8

Epithemia alpestris W. SMITH, 1853, p. 7 (non Kützing).

Epithemia argus var. *alpestris* (W. Smith).—GRUNOW, 1862, p. 329.—HUSTEDT, 1930a, p. 383, fig. 727b.

Description: Valve with very slightly concave ventral side and convex dorsal side, tapering smoothly to rounded noncapitate apices. Length of observed specimen 42 μm . Surface of valve with transverse costae, about 3 in 10 μm , slightly radial from the center of the ventral side. About 3 to 5 transverse rows of fine pores between costae. Raphe in sweeping curves from the ends to an angular flexure near the dorsal margin.

Discussion: *E. argus* var. *alpestris* is a fresh-water taxon, one of two observed in this assemblage. It is rare in the 5-foot level of the Petersburg section.

Known geologic range: Reported as occurring widely in Recent fresh-water environments.

Genus GONIOTHECIUM Ehrenberg, 1843

***Goniothecium odontella* Ehrenberg**

Plate 2, figure 9; plate 4, figure 9

Goniothecium odontella EHRENBURG, 1844, p. 82; 1854, pl. 18, fig. 94; pl. 33, XV, fig. 16.

Description: Valve irregularly elliptical with bluntly pointed to subrounded apices, highly convex. Length 40 to 96 μm . Valve has a tiered surface with 3 or 4 levels of surface elevation. These levels are defined by circular "escarpments" with narrow raised rims; the larger of these "escarpments" are truncated by the lateral margins of the valve. Valve surface shows very fine pores, randomly distributed on the round central area but arranged in roughly radial rows on the raised rims of the successive "escarpments."

Discussion: This species is distinct from *G. rogersii* in its radially porous raised rims on the edges of the "escarpments". Whether *Goniothecium* is produced by ordinary vegetative reproduction or is some type of spore is uncertain at present. *Goniothecium odontella* is rare to frequent throughout most of the Petersburg section.

Known geologic range: Originally described by Ehrenberg (1844) from a deposit of presumably Miocene age

at Richmond, Virginia. It may be restricted to deposits of late Miocene and early Pliocene age, as it has not been reported from the middle Miocene by Andrews (1976) or by Abbott and Andrews (1979), nor has it been reported in modern assemblages.

Genus GRAMMATOPHORA Ehrenberg, 1841

Grammatophora angulosa Ehrenberg

Plate 2, figures 12, 13

Grammatophora angulosa EHRENBURG, 1841, p. 153.—HUSTEDT, 1931, pp. 39–40, fig. 564.—HENDEY, 1964, p. 171.

Description: Valve narrowly elliptical with rounded apices. Length of observed specimens 36 to 65 μm . Valve surface with striae composed of transverse rows of pores, about 8 in 10 μm , secondarily arranged in longitudinal rows. Valve rectangular in girdle view, showing heavy, deeply undulate or hooklike septa. Hyaline axial area very narrow.

Discussion: *G. angulosa* is rare in the 1-, 2-, and 5-foot levels of the Petersburg section.

Known geologic range: Frequent in Recent marine coastal waters.

Grammatophora marina (Lyngbye) Kützing

Plate 2, figure 14

Diatoma marinum LYNGBYE, 1819, pl. 62A.

Grammatophora marina (Lyngbye).—KÜTZING, 1844, p. 128, pl. 17, figs. XXIV, 1–6; pl. 18, figs. I, 1–5.—HUSTEDT, 1931, pp. 43–44, fig. 569.—HENDEY, 1964, p. 170.—ANDREWS, 1976, p. 22, pl. 7, figs. 14, 15.—ABBOTT and ANDREWS, 1979, p. 245, pl. 4, fig. 14.

Discussion: *G. marina* has a rare but sporadic occurrence through most of the Petersburg section.

Known geologic range: Observed by Andrews (1976) and Abbott and Andrews (1979) in samples from middle Miocene deposits of the eastern United States. A common Recent littoral marine species.

Genus HEMIDISCUS Wallich, 1860

Hemidiscus ovalis Lohman

Plate 2, figure 10; plate 5, figure 9

Hemidiscus ovalis LOHMAN, 1938, pp. 91–92, pl. 22, fig. 9.

Description: Valve small, broadly elliptical, and slightly asymmetrical in outline. Surface slightly convex. Length of observed specimens 23 to 31 μm . Outer edge of valve has a finely striated marginal rim. Inside this rim is a network of fine pores arranged in irregularly curved decussating rows, about 20 pores in 10 μm near the margin. Pores are larger and more widely spaced near the center of the valve, about 12 in 10 μm . Center of the valve hyaline with a few randomly scattered larger pores. Pseudonodulus absent or obscure.

Several internal labiate processes around the margin can be observed indistinctly under the light microscope.

Discussion: Specimens of *H. ovalis* observed in the Petersburg deposit are virtually identical with the species as described by Lohman (1938). Although Lohman mentioned a single larger pore near the center of the valve, I have not found this to be a consistent feature in specimens I examined from his Kettleman Hills locality, nor have I seen it in the Petersburg specimens. *Hemidiscus ovalis* is rare in the 5- and 6-foot levels of the Petersburg deposit.

Known geologic range: Reported and described by Lohman (1938) from the *Neverita* Zone and the overlying tuffaceous sandstone of the San Joaquin Formation (Pliocene) of the Kettleman Hills, California. J. A. Barron (personal communication, 1978) has found this species in the lower Pliocene part of the Sisquoc Formation east of Lompoc, California. A similar but distinct species, *H. margaritaceus*, was described by Brun in Brun and Tempère (1889) from Pliocene deposits of Yedo, Japan. Koizumi (1972) has more recently reported the occurrence of *H. weissflogii*, which is similar in appearance to *H. ovalis*, from the Tatsunokuchi Formation (Pliocene) of Japan. W. H. Abbott (personal communication, 1978) has observed *H. ovalis* in lower Pleistocene strata in Atlantic Margin Coring Project core 6013, taken about 425 km east of the New Jersey coast. He has also observed the species in a plankton sample of living material taken in Port Royal Sound, Beaufort County, South Carolina, on October 5, 1973. This sample was taken in water having a salinity of 24 parts per thousand, a pH of 8.2, and at a temperature of 28°C. These facts suggest that *H. ovalis* may be restricted to brackish-water environments.

Genus HYALODISCUS Ehrenberg, 1845

Hyalodiscus scoticus (Kützing) Grunow

Plate 2, figure 11

Cyclotella scotica KÜTZING, 1844, p. 50, pl. 1, figs. 2, 3.

Hyalodiscus scoticus (Kützing).—GRUNOW, 1879, p. 690, pl. 21, fig. 5.—HUSTEDT, 1928, pp. 293–294, fig. 133.—HENDEY, 1964, p. 90.

Description: Valve round, convex, with center flattened or slightly depressed. Diameter of observed specimens 26 to 40 μm . Surface of valve shows a roughly circular umbilicus at about half the radius. Valve covered with fine pores, but patterns of porosity could not be resolved in specimens observed under the light microscope. Narrow marginal rim is finely striate.

Discussion: *H. scoticus* is rare at the 2-, 3-, and 6-foot levels of the Petersburg section.

Known geologic range: Reported from Recent marine and brackish-water coastal environments.

Genus MELOSIRA Agardh, 1824

Melosira westii W. Smith

Plate 2, figure 15

Melosira westii W. SMITH, 1856, p. 59, pl. 52, fig. 333.—HUSTEDT, 1927, pp. 268–269, fig. 113.—HENDEY, 1964, p. 73, pl. 1, fig. 4; pl. 22, fig. 8.—ANDREWS, 1976, p. 8, pl. 1, figs. 1, 2.—ABBOTT and ANDREWS, 1979, p. 246, pl. 4, fig. 23.

Discussion: This species is frequent to abundant throughout the Petersburg section.

Known geologic range: Extremely common throughout the marine Miocene section along the east coast of the United States. Common in Recent marine coastal waters.

Genus NAVICULA Bory, 1822

Navicula hennedyi W. Smith

Plate 2, figure 17

Navicula hennedyi W. SMITH, 1856, p. 93.—HENDEY, 1964, pp. 212–213, pl. 33, fig. 14.—HUSTEDT, 1964, pp. 453–455, fig. 1516.—ANDREWS, 1976, p. 22, pl. 7, figs. 17, 18.—ABBOTT and ANDREWS, 1979, pp. 246–247, pl. 4, fig. 24.

Discussion: *N. hennedyi* is rare in the 5-foot level of the Petersburg section.

Known geologic range: Previously reported from deposits of middle Miocene age in the eastern United States. Frequent and widespread occurrence in Recent littoral marine waters.

Navicula lyra Ehrenberg

Plate 2, figure 18

Navicula lyra EHRENBURG, 1843, p. 419, pl. 1, l, fig. 9a.—LOHMAN, 1948, pp. 185–186.—HENDEY, 1964, p. 209, pl. 33, fig. 2.—HUSTEDT, 1964, pp. 500–502, fig. 1548a.—ANDREWS, 1976, p. 22, pl. 7, fig. 19.—ABBOTT and ANDREWS, 1979, p. 247.

Discussion: *N. lyra* is rare in the 5- and 6-foot levels of the Petersburg section.

Known geologic range: Early Miocene to a common occurrence in Recent marine coastal waters.

Navicula pennata Schmidt

Plate 2, figure 16

Navicula pennata SCHMIDT, 1876, pl. 48, figs. 41–43.—LOHMAN, 1938, p. 84, pl. 22, fig. 16; 1941, pp. 83–84, pl. 17, fig. 14.—HENDEY, 1964, p. 203, pl. 30, fig. 21.—ANDREWS, 1976, pp. 22–23, pl. 7, figs. 20, 21.—ABBOTT and ANDREWS, 1979, p. 247, pl. 4, fig. 25.

Discussion: *N. pennata* is rare to frequent throughout the Petersburg section.

Known geologic range: Early Miocene to a common occurrence in Recent marine benthonic environments.

Genus NITZSCHIA Hassall, 1845

Nitzschia imperforata Andrews, n. sp.

Plate 2, figures 19–22; plate 5, figure 1

Description: Valve linear-lanceolate, slightly constricted at the center of the dorsal margin, with bluntly pointed apices. Length 59 to 109 μm ; width 12 to 15 μm . Keel pores 6 to 6½ in 10 μm at the dorsal margin of the valve and elongate normal to that margin. Keel pores consist of elongate slits on outside of valve, but close abruptly to oval pores that open to the inside of valve. Valve surface hyaline, imperforate. With no pore structure visible at high magnification under the scanning electron microscope. Keel structure truncated by the tapering margin of the valve and absent at the apices.

This truncated keel structure is overlapped, in a few specimens, by a loosely attached plate showing rows of fine pores analogous to the truncated keel slits. These apical plates are of undetermined nature; perhaps they derive from an expanded girdle near the apices (see pl. 5, fig. 1).

Discussion: The imperforate valve and the apically truncated keel seem to make this species a distinctive form of *Nitzschia*. I am uncertain of its classification within the subdivisions of *Nitzschia* proposed by Grunow in Cleve and Grunow (1880). *Nitzschia imperforata* is frequent throughout the Petersburg section. If it proves to be sufficiently wide in distribution, it should be a distinctive marker diatom.

Holotype: USGS diatom catalog no. 3946–29; from USGS diatom locality 6454, at the 5-foot level of the section at Petersburg, Virginia. Length, 109 μm .

Genus PARALIA Heiberg, 1863

Paralia sulcata (Ehrenberg) Cleve

Plate 2, figure 23

Gaillonella sulcata EHRENBURG, 1838, p. 170, pl. 21, fig. 5. *Paralia sulcata* (Ehrenberg).—CLEVE, 1873, p. 7.—BOYER, 1904, p. 491, pl. 135, fig. 9.—HENDEY, 1964, p. 73, pl. 23, fig. 5.—ANDREWS, 1976, pp. 8–9, pl. 1, figs. 5, 6.—ABBOTT and ANDREWS, 1979, p. 247, pl. 4, figs. 27–28. *Melosira sulcata* (Ehrenberg).—KÜTZING, 1844, p. 55, pl. 2, fig. 7.—HUSTEDT, 1928, pp. 276–279, fig. 119.—LOHMAN, 1941, p. 64, pl. 12, fig. 1; 1948, pp. 156–157.

Discussion: *P. sulcata* is frequent to common throughout the Petersburg section.

Known geologic range: A variety as old as Cretaceous is known, and the species ranges throughout the Tertiary (Lohman, 1948). Extremely common through-

out the Miocene section of the eastern United States. Common in Recent marine coastal waters.

Paralia sulcata* var. *coronata (Ehrenberg) Andrews
Plate 3, figure 1

Gaillonella coronata EHRENBURG, 1845c, p. 154; 1854, pl. 38, XXII, fig. 5.

Paralia sulcata var. *coronata* (Ehrenberg).—ANDREWS, 1976, p. 9, pl. 1, figs. 7, 8.—ABBOTT and ANDREWS, 1979, pp. 247–248, pl. 4, fig. 29.

Melosira (Paralia) sulcata var. *coronata* (Ehrenberg).—GRUNOW in Van Heurck, 1882, pl. 91, fig. 17.

Melosira sulcata forma *coronata* Grunow.—HUSTEDT, 1928, p. 278, fig. 119d.

Discussion: This variety is frequent to common throughout the Petersburg section, as is the type variety.

Known geologic range: Extremely common throughout the marine Miocene deposits of the eastern U. S. Occurs with the type variety in Recent marine coastal waters.

Genus PINNULARIA Ehrenberg, 1840

Pinnularia brevicostata Cleve
Plate 3, figure 2

Pinnularia brevicostata CLEVE, 1891, p. 25, pl. 1, fig. 5.—HUSTEDT, 1930a, pp. 329–330, fig. 609.—ANDREWS, 1970, p. A17, pl. 3, fig. 2; 1971, p. E11, pl. 1, figs. 18, 19.—PATRICK and REIMER, 1966, p. 623, pl. 60, fig. 1.

Description: Valve linear with parallel sides and rounded apices. Length of observed specimen, 110 μm . Hyaline axial area relatively wide, about half the width of the valve. Terminal fissures of the raphe flexed into a comma shape. Transverse striae fine, about 12 in 10 μm . Parallel in the center to slightly radial at the ends.

Discussion: *P. brevicostata* is rare in the 2-foot level of the Petersburg section. It is a fresh-water diatom species.

Known geologic range: Reported by Andrews (1970, 1971) from nonmarine deposits of early and late Miocene age in Nebraska. Found in modern, cool, fresh-water environments.

Genus PLEUROSIGMA W. Smith, 1852

Pleurosigma normanii Ralfs
Plate 3, figure 3

Pleurosigma normanii RALFS in Pritchard, 1861, p. 919–920.—BOYER, 1927, p. 471.—HENDEY, 1964, p. 244.

Description: Valve lanceolate, sigmoid, tapering to narrowly rounded apices. Length of observed specimen, 96 μm , but fragile tips of most specimens are broken. Valve surface covered with a network of pores arranged in both transverse and oblique rows. About 19 transverse rows of pores in 10 μm near the center;

about 15 oblique rows of pores in 10 μm . Oblique rows of pores cross each other at an angle of about 90°. Small, hyaline central area, sometimes expanded transversely.

Discussion: The form of *Pleurosigma* in this assemblage seems to conform most closely to that of *P. normanii*, as it is slightly more finely marked than the middle Miocene form identified as *P. affine* var. *fossile*. *Pleurosigma normanii* is rare throughout the lower part of the Petersburg section.

Known geologic range: Reported as common in Recent marine coastal waters and frequently observed in plankton.

Genus PODOIRA Ehrenberg, 1840

Podosira stelligera (J. W. Bailey) Mann
Plate 3, figure 4

Hyalodiscus stelliger J. W. BAILEY, 1854, p. 7, fig. 10.

Podosira stelliger (J. W. Bailey).—MANN, 1907, p. 242.—HUSTEDT, 1928, pp. 286–287, fig. 128.—HENDEY, 1964, p. 90, pl. 22, fig. 6.

Description: Valves round, strongly convex. Diameter 31 to 62 μm . Surface of valve divided into a raggedly circular central area with fine, indistinct pores and an outer annular area covered with distinct pores. Outer area divided into distinct fascicles in which the pores are arranged in radial as well as oblique rows. About 16 radial rows of pores in 10 μm , about 13 pores in 10 μm along the row. Margin between the porous outer area and the central area is very irregular in some specimens, and small isolated patches of porosity may occur within the central area.

Discussion: *P. stelligera* is rare to frequent throughout the Petersburg section.

Known geologic range: A common planktonic form in Recent open marine and coastal waters.

Genus PSEUDAILISCUS Schmidt, 1875

Pseudauliscus radiatus (J. W. Bailey) Rattray
Plate 3, figure 5

Auliscus radiatus J. W. BAILEY, 1854, p. 6, fig. 13.

Pseudauliscus radiatus (J. W. Bailey).—SCHMIDT, 1885, pl. 32, fig. 28.—RATTRAY, 1888b, p. 902.—BOYER, 1916, p. 29, pl. 5, fig. 9.—BOYER, 1927, p. 96.—ABBOTT and ANDREWS, 1979, pp. 248–249, pl. 5, fig. 3.

Discussion: A single specimen of *P. radiatus*, length 42 μm , width 39 μm , was observed at the 3-foot level of the Petersburg section.

Known geologic range: Reported from deposits as old as early Miocene in the eastern United States by Rattray (1888b). It has been reported, though not

widely, from Recent marine coastal waters of eastern North America.

Genus PSEUDOPYXILLA Forti, 1909

Pseudopyxilla americana (Ehrenberg) Forti
Plate 3, figure 6

Rhizosolenia americana EHRENBURG, 1843, p. 422; 1854, pl. 18, fig. 98; pl. 33, XIII, fig. 20, XVII, fig. 14.

Pseudopyxilla americana (Ehrenberg).—FORTI, 1909, pl. 1, figs. 6, 7.—ANDREWS, 1976, pp. 19–20, pl. 6, figs. 9–12.—ABBOTT and ANDREWS, 1979, p. 249, pl. 5, fig. 6.

Discussion: Both gently tapered and more bluntly tapered forms were observed. Rare in the lower part of the Petersburg section.

Known geologic range: Previously reported from middle Miocene deposits of the eastern United States. It does not seem to have been observed in Recent marine deposits.

Genus PYXIDICULA Ehrenberg, 1833

Pyxidicula cruciata Ehrenberg
Plate 3, figure 7

Pyxidicula cruciata EHRENBURG, 1843, pl. 3, VII, fig. 6.—HUSTEDT, 1928, pp. 301–302.—ANDREWS, 1976, p. 9, pl. 1, figs. 9, 10.—ABBOTT and ANDREWS, 1979, p. 249, pl. 5, fig. 7; pl. 8, fig. 5.

Stephanopyxis cruciata (Ehrenberg).—EHRENBURG, 1845a, p. 267; 1854, pl. 33, XIII, fig. 7; XV, fig. 12; XVII, fig. 7.

Stephanopyxis turris var. *arctica* f. *inermis* GRUNOW, 1884, p. 89, pl. 5, figs. 18, 21.—CLEVE-EULER, 1951, p. 38, fig. 40, pl. 1, fig. 0.

Discussion: *P. cruciata* is similar to species of *Stephanopyxis* but lacks protruding spines in the center of the valve. The species is rare to frequent throughout the Petersburg section.

Known geologic range: Previously reported from deposits of early to middle Miocene age. It has not, apparently, been observed in Recent marine diatom assemblages, if indeed it can always be differentiated from *Stephanopyxis*.

Genus RHAPHONEIS Ehrenberg, 1845

Rhaphoneis amphiceros (Ehrenberg) Ehrenberg
Plate 3, figure 8; plate 5, figure 2

Cocconeis amphiceros EHRENBURG, 1840, p. 206.
Rhaphoneis amphiceros (Ehrenberg).—EHRENBURG, 1844, p. 87; 1854, pl. 18, fig. 82; pl. 33, XIV, fig. 22.—HUSTEDT, 1931, p. 174, fig. 680.—LOHMAN, 1948, p. 180; 1974, p. 352, pl. 5, fig. 15.—HENDEY, 1964, p. 154, pl. 26, figs. 1–4.—ANDREWS, 1975, pp. 204–205, pl. 1, figs. 9–12; 1976, p. 20, pl. 6, figs. 13, 14; 1978 (1979), p. 385, pl. 2, figs. 7–8; pl. 6, fig. 8.

Discussion: *R. amphiceros* is distinguished by its curving transverse rows of pores, which are unaligned

across the hyaline axial area. It is rare to frequent throughout the Petersburg section.

Known geologic range: From the upper part of the Calvert Formation (middle Miocene) of Maryland to a wide distribution in Recent marine waters.

Rhaphoneis fusus Ehrenberg

Plate 3, figures 10, 11; plate 5, figures 3–5

Rhaphoneis fusus EHRENBURG, 1844, pp. 71, 81.—RALFS in Pritchard, 1861, p. 791.

Description: Valve flat, narrowly lanceolate, tapered to produced and sometimes slightly expanded apices. Length 36 to 105 μm ; width 10 to 13 μm . Surface of valve covered with relatively large round pores arranged in transverse rows, about 5 to 5½ in 10 μm , parallel in the center to slightly radial near the apices. Pores also arranged in nearly parallel longitudinal rows, about 6 to 7 in 10 μm . Hyaline axial area very narrow, usually discernible, but sometimes barely wider than spaces between other longitudinal rows of pores. Transverse rows of pores are aligned across the axial area. Finely porous pseudocelli on apices of valve. A single labiate process is present internally on each end of the valve.

Discussion: The identification of this species as *R. fusus* is somewhat problematical in that Ehrenberg (1844) gave an inadequate description and did not figure the species. Considering the relative abundance of the species in the Petersburg section, Ehrenberg could hardly have overlooked it. *Rhaphoneis fusus* is his only description that fits, so I am convinced that the above-described taxon is what Ehrenberg intended as *R. fusus*.

Rhaphoneis fusus appears to be somewhat intermediate between *R. lancettula* from beds of middle Miocene age of the eastern United States and *R. fatula*, described by Lohman (1938) from beds of Pliocene age. In terms of size and coarseness of punctuation, *R. fusus* more closely resembles *R. lancettula*. The hyaline axial area in *R. fusus* ranges in width, from indistinct as in *R. lancettula* to definitely present as in *R. fatula*. However, *R. fusus* resembles *R. fatula* in that the longitudinal spacing of pores is greater than the transverse spacing. The coarse punctuation and distinctive pore spacing should make this species a useful guide fossil. *Rhaphoneis fusus* is frequent to abundant throughout the Petersburg section.

Known geologic range: Previously reported only from the Petersburg deposit by Ehrenberg (1844); this occurrence was cited by Ralfs in Pritchard (1861). J. A. Barron (personal communication, 1978) has observed a similar-appearing form in the lower Pliocene part of the Sisquoc Formation east of Lompoc, California, which he considers to be closely related to *R. fatula*.

Rhaphoneis petropolitana Grunow

Plate 3, figures 12–14; plate 5, figures 6–8

Rhaphoneis petropolitana GRUNOW in Pantocsek, 1886, pt. 1, p. 36, pl. 27, fig. 268.—ANDREWS, 1975, p. 210, pl. 2, fig. 32.

Description: Valve lanceolate with attenuated, sometimes slightly capitate apices. Length 42 to 72 μm ; width 10 to 12 μm . Valve with short transverse striae, about 7 in 10 μm , along the margin. These transverse striae are formed by 2 or 3 pores that are secondarily arranged in longitudinal rows curved to parallel the margin. Broad hyaline axial area is lanceolate in outline, in some specimens showing a faint pore structure extending the transverse striae toward the median line of the valve. The transverse striae are aligned across the hyaline axial area. Apical pseudocelli made up of rows of extremely fine pores parallel to the transverse striae of the valve, radial only at the very tip. Internal fine structure of valve tips not observed.

Discussion: *R. petropolitana* is a distinctive species, which, if sufficiently widespread in distribution, could be a useful marker. It is rare to frequent in the lower part of the Petersburg section.

Known geologic range: Previously reported only by Grunow from the Petersburg deposit. W. H. Abbott (personal communication, 1978) has observed this species in the Atlantic Margin Coring Project well 6007, which suggests a wider distribution.

Rhaphoneis rhombica (Grunow) Andrews

Plate 3, figure 9

Rhaphoneis ampiceros var. *rhombica* GRUNOW in Van Heurck, 1881, pl. 36, figs. 20, 21.

Rhaphoneis rhombica (Grunow).—ANDREWS, 1975, pp. 210–211, pl. 2, figs. 33, 34; 1978 (1979), p. 388–389, pl. 3, figs. 30–31.—ABBOTT and ANDREWS, 1979, p. 251, pl. 5, fig. 22.

Rhaphoneis rhombus EHRENBURG, 1844, p. 87 (part); 1854, pl. 18, figs. 84, 85 (not Pl. 33, XIII, fig. 19).

Rhaphoneis obesa HANNA, 1932, p. 214, pl. 16, fig. 1.

Discussion: *R. rhombica* is closely related to *R. ampiceros* but is a more rotund form with only slightly extended apices. It is rare to frequent in the 4.5- and 5-foot levels of the Petersburg section.

Known geologic range: Middle Miocene to a common association with *R. ampiceros* in Recent marine waters.

Genus STEPHANOGONIA Ehrenberg, 1845

Stephanogonia actinoptychus (Ehrenberg) Grunow

Plate 6, figure 2

Mastogonia actinoptychus EHRENBURG, 1845a, p. 269; 1854, pl. 18, fig. 109; pl. 33, XIII, fig. 16.

Stephanogonia actinoptychus (Ehrenberg).—GRUNOW in Van Heurck, 1882, pl. 83 ter, figs. 2–4.—LOHMAN, 1948, p. 178.—

ANDREWS, 1976, p. 19, pl. 6, fig. 8.—ABBOTT and ANDREWS, 1979, p. 252, pl. 5, fig. 26.

Stephanogonia polyachantha Forti, 1913, p. 1560, pl. 12, fig. 11.—HANNA, 1932, p. 218, pl. 16, fig. 8.

Discussion: *S. actinoptychus* is rare in the 4.5- and 6-foot levels of the Petersburg section.

Known geologic range: Miocene diatom assemblages in North America and Europe.

Genus STEPHANOPYXIS Ehrenberg, 1844

Stephanopyxis turris (Greville) Ralfs

Plate 3, figure 15

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

Stephanopyxis turris (Greville).—RALFS in Pritchard, 1861, p. 826, pl. 5, fig. 74.—HENDEY, 1964, p. 92.—ABBOTT and ANDREWS, 1979, pp. 252–253, pl. 6, figs. 1–2; pl. 8, fig. 6.

Stephanopyxis turris (Greville and Arnott) Ralfs.—HUSTEDT, 1928, pp. 304–307, fig. 140.—LOHMAN, 1948, p. 185.—ANDREWS, 1976, p. 10, pl. 2, figs. 1, 2.

Discussion: *S. turris* is rare to frequent from the 3- to 6-foot levels of the Petersburg deposit.

Known geologic range: A long-ranging pelagic marine species, from Cretaceous deposits to a frequent occurrence in Recent marine waters.

Genus THALASSIONEMA Grunow, 1881

Thalassionema nitzschioides (Grunow) Hustedt

Plate 3, figure 17

Synedra nitzschioides GRUNOW, 1862, p. 403.

Thalassiothrix nitzschioides (Grunow).—GRUNOW in Van Heurck, 1881, pl. 43, figs. 7, 10.

Thalassionema nitzschioides (Grunow).—HUSTEDT, 1932, pp. 244–246, fig. 725.—HENDEY, 1964, p. 165.—ABBOTT and ANDREWS, 1979, p. 253, pl. 6, fig. 11.

Discussion: *T. nitzschioides* is rare and sporadic in occurrence in the lower part of the Petersburg section.

Known geologic range: Reported by Abbott and Andrews (1979) from the Hawthorn Formation of middle Miocene age. A common and widespread neritic species in Recent coastal waters.

Genus THALASSIOSIRA Cleve, 1873

Thalassiosira eccentrica (Ehrenberg) Cleve

Plate 3, figure 16

Coscinodiscus eccentricus EHRENBURG, 1841, p. 146; 1854, pl. 18, fig. 32; pl. 21, fig. 6.—HENDEY, 1964, pp. 80–81, pl. 24, fig. 7.

Thalassiosira eccentrica (Ehrenberg).—CLEVE, 1904, p. 216.—FRYXELL and HASLE, 1972, pp. 297–317, pls. 1–4.—ABBOTT and ANDREWS, 1979, p. 254, pl. 6, fig. 12.

Coscinodiscus excentricus Ehrenberg.—HUSTEDT, 1928, pp. 388–391.—LOHMAN, 1941, pp. 67–68, pl. 12, fig. 7; pl. 13, fig. 8; 1948, p. 161.

Discussion: *T. eccentrica* is rare throughout the 4- to 6-foot interval in the Petersburg section.

Known geologic range: From the Calvert Formation of early and middle Miocene age in Maryland to a very common and widespread occurrence in modern neritic plankton.

Thalassiosira oestrupii (Ostenfeld) Proschkina-Lavrenko
Plate 6, figures 3–4

Coscinosira oestrupii OSTENFELD, 1900, p. 52.—HUSTEDT, 1928, p. 318, fig. 156.—HENDEY, 1964, p. 89.

Thalassiosira oestrupii (Ostenfeld).—PROSCHKINA-LAVRENKO, 1956, p. 57.—HASLE, 1960, pp. 8–10, pl. 1, figs. 5–7, 11.—SCHRADER, 1973, p. 712, pl. 11, figs. 16–22, 26–33, 36, 39–45.—SIMONSEN, 1974, p. 10, pl. 1, figs. 3–5.—BARRON, 1976, fig. 7b.—SCHRADER and FENNER, 1976, p. 1002, pl. 17, figs. 6, 7, 14, 15.

Description: Valve round, small, slightly convex in center with greater curvature near the margin. Diameter of observed specimens 10 to 24 μm . Valve surface covered with round pores arranged in an irregular hexagonal areolate net, about 6 to 8 pores in 10 μm . Margin of valve with about 18 radial rows of fine pores in 10 μm . In center of valve are one or more small mucous pores intercalated in the areolate net. These show a small cruciform or rosette opening on the inside of the valve.

Discussion: Although this species was not observed under the light microscope, it did occur rarely in scanning electron microscope preparations of material from the 5-foot level of the Petersburg deposit.

Known geologic range: *T. oestrupii* has been reported widely from deep-sea sediments, and only a few references to its occurrence are included in the above synonymy. The consensus of marine biostratigraphers is that it does not occur in sediments older than early Pliocene in age. Schrader (1973, p. 694) stated that his North Pacific Diatom Zone IX (lower Pliocene) contains the first evolutionary appearance of *T. oestrupii*. Barron (1976, table 1) reported the first occurrence of *T. oestrupii* in Unit 18 of the type *Bolivina obliqua* Zone of California, which he regarded as of probable early Pliocene age. Burckle and Opdyke (1977, p. 280) have stated "... data from the equatorial Pacific ... indicates that *T. oestrupii* first appears in the earliest Pliocene (early Gilbert Epoch) approximately equivalent in time with the North Pacific first occurrence." *Thalassiosira oestrupii* is reported as a cosmopolitan marine diatom in Recent environments ranging from subpolar to tropical. It is more abundant at present in the subequatorial Pacific, according to Hasle (1960, p. 9).

Genus THALASSIOTHRIX Cleve and Grunow, 1880

Thalassiothrix longissima Cleve and Grunow

Synedra thalassiothrix CLEVE, 1873, p. 22, pl. 4, fig. 24.
Thalassiothrix longissima CLEVE and GRUNOW, 1880, p. 108.—HUSTEDT, 1932, p. 247, fig. 726.—LOHMAN, 1948, p. 185.—ANDREWS, 1976, p. 21, pl. 7, figs. 9, 10.—ABBOTT and ANDREWS, 1979, p. 254, pl. 6, fig. 13.

Discussion: *T. longissima* is found as rare fragments in the 4.5- and 5-foot levels of the Petersburg deposit.

Known geologic range: Miocene to an abundant occurrence in Recent cold-water marine environments.

Genus TRICERATIUM Ehrenberg, 1841

Triceratium hebetatum (Grunow) Andrews, n. comb.
Plate 3, figures 20–21; plate 6, figure 6

Triceratium (Biddulphia) irregulare var. *hebetata* GRUNOW in Van Heurck, 1883, pl. 111, fig. 10.

Triceratium impar A. SCHMIDT, 1890, pl. 151, figs. 31–34.

Biddulphia hebetata (Grunow).—BOYER, 1901, pp. 722–723.

Description: Valve flat, triangular, sharply convex at the margins. The 3 sides are slightly uneven, slightly convex in most specimens but may be straight to slightly concave in some specimens. Length of side 41 to 102 μm . Surface of valve covered by a network of large round to subpolygonal areolae, about 4 in 10 μm , arranged in a pattern both roughly concentric to the center and roughly radial to the margins. Single fine pores are interspersed randomly in the areolate net. Areolae continue to the margin on the sides of the valve and on 2 of the 3 corners. One corner of the valve shows an apical pseudocellus composed of subparallel rows of fine pores, about 18 in 10 μm , oriented normal to that corner of the valve. Internal processes, if any, not observed.

Discussion: *T. hebetatum*, with its interpunctate areolate net, has obvious affinities to *T. condecorum* of early and middle Miocene age. The single pseudocellus is, however, sufficient to distinguish *T. hebetatum*. This feature may be unique to this species of the genus *Triceratium*. *Triceratium hebetatum* is frequent from the 3- to 6-foot levels in the Petersburg section.

Known geologic range: Previously reported only from Petersburg and from an unspecified Miocene deposit at Richmond, Virginia. If sufficiently widespread, it should be an excellent marker diatom for deposits of late Tertiary age.

Triceratium reticulum Ehrenberg
Plate 3, figure 22

Triceratium reticulum EHRENBURG, 1845b, p. 88; 1854, pl. 18, fig. 50; pl. 33, XVI, fig. 13.—HUSTEDT, 1930, pp. 823–825, figs. 485, 486.

Biddulphia reticulum (Ehrenberg).—BOYER, 1901, pp. 724–725; 1927, p. 138.—HENDEY, 1964, pp. 102–103, pl. 25, fig. 6.

Description: Valve triangular with straight to moderately concave sides and slightly produced corners. Valve somewhat raised at center and corners. Length of side 30 to 62 μm . Surface of valve covered with an areolate network of large irregular pores, about 4 to 5 in 10 μm sometimes arranged in 3 small circular groups or clusters but otherwise of random distribution. A few very fine pores are also scattered at random on the surface of the valve. The raised corners contain finely porous pseudocelli. Three or four internal labiate processes are scattered at random about halfway between the margin and center of the valve, and these open in small external slits.

Discussion: *T. reticulum* is rare to frequent throughout the Petersburg section, with the exception of the 6-foot level.

Known geologic range: A common and widespread species in Recent littoral marine waters, particularly in warmer waters.

***Triceratium tessellatum* Greville**

Plate 3, figures 18–19; plate 6, figure 5

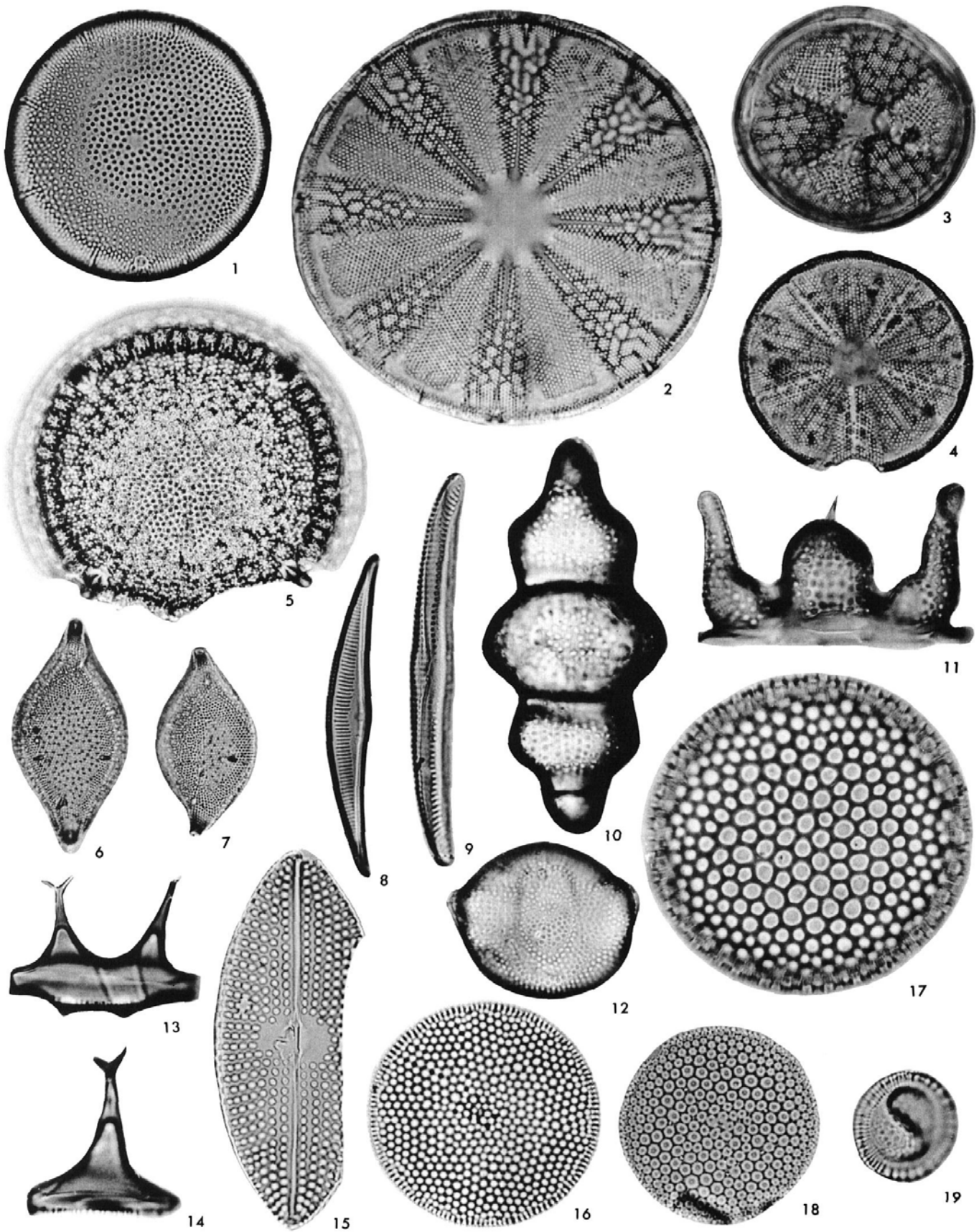
Triceratium tessellatum GREVILLE, 1861, p. 71, pl. 8, fig. 14.—SCHMIDT, 1882, pl. 76, fig. 33.

Biddulphia tessellata (Greville).—BOYER, 1901, pp. 723–724.

Description: Valve triangular with nearly straight sides and bluntly rounded corners. A large circular area in the center is very slightly raised, and the rounded corners are somewhat more raised. Length of side 28 to 44 μm . Surface of valve covered with subpolygonal large pores, about 5 in 10 μm , with random distribution. Occasional fine pores scattered throughout surface. Frustule rectangular to quadrangular with a relatively

PLATE 1

- 1 *Actinocyclus octonarius* Ehrenberg
USGS diatom cat. no. 4011–25, $\times 1000$, diameter 52 μm .
- 2 *Actinoptychus australis* (Grunow) Andrews
USGS diatom cat. no. 3945–28, $\times 1000$, diameter 79 μm .
- 3 *Actinoptychus senarius* (Ehrenberg) Ehrenberg
USGS diatom cat. no. 3946–1, $\times 1000$, diameter 45 μm .
- 4 *Actinoptychus splendens* (Shadbolt) Ralfs
USGS diatom cat. no. 3944–6, $\times 1000$, diameter 44 μm .
- 5 *Aulacodiscus crux* Ehrenberg
USGS diatom cat. no. 4012–1, $\times 500$, diameter 133 μm .
- 6–7 *Biddulphia rhombus* (Ehrenberg) W. Smith
6, USGS diatom cat. no. 3946–4, length 89 μm ; 7, USGS diatom cat. no. 3946–16, length 71 μm . Both $\times 500$.
- 8 *Amphora* aff. *A. cymbifera* Gregory
USGS diatom cat. no. 3946–75, $\times 1000$, length 60 μm .
- 9 *Amphora proteus* Gregory
USGS diatom cat. no. 3945–6, $\times 1000$, length 72 μm .
- 10–11 *Biddulphia tuomeyi* (J. W. Bailey) Roper
10, valve view, USGS diatom cat. no. 3946–21, length 75 μm ; 11, girdle view, USGS diatom cat. no. 3946–59, length 50 μm . Both $\times 1000$.
- 12 *Biddulphia* aff. *B. laevis* Ehrenberg
USGS diatom cat. no. 3946–49, $\times 1000$, width 35 μm .
- 13 *Chaetoceros lorenzianum* Grunow
Resting spore, USGS diatom cat. no. 3945–48, $\times 1000$, width 34 μm .
- 14 *Chaetoceros lorenzianum* Grunow var. A
Resting spore, USGS diatom cat. no. 3946–61, $\times 1000$, width 30 μm .
- 15 *Cocconeis sublittoralis* Hendey
Raphe valve, USGS diatom cat. no. 4011–52, $\times 1000$, length 70 μm .
- 16 *Coscinodiscus divisus* Grunow
USGS diatom cat. no. 4011–20 $\times 1000$, diameter 42 μm .
- 17 *Coscinodiscus marginatus* Ehrenberg
USGS diatom cat. no. 4011–1, $\times 1000$, diameter 60 μm .
- 18 *Coscinodiscus nitidus* Gregory
USGS diatom cat. no. 3946–11, $\times 1000$, diameter 37 μm .
- 19 *Cyclotella striata* (Kützinger) Grunow
USGS diatom cat. no. 3945–37, $\times 1000$, diameter 21 μm .



deep mantle normal to the plane of the valves, so that the frustule is often seen in girdle view. Mantle covered with radial rows of pores, about 5 in 10 μm . Large raised corners show pseudocelli of fine pores, about 20 in 10 μm , on outer shoulders. Three or four internal labiate processes open as slits on the exterior of the valve.

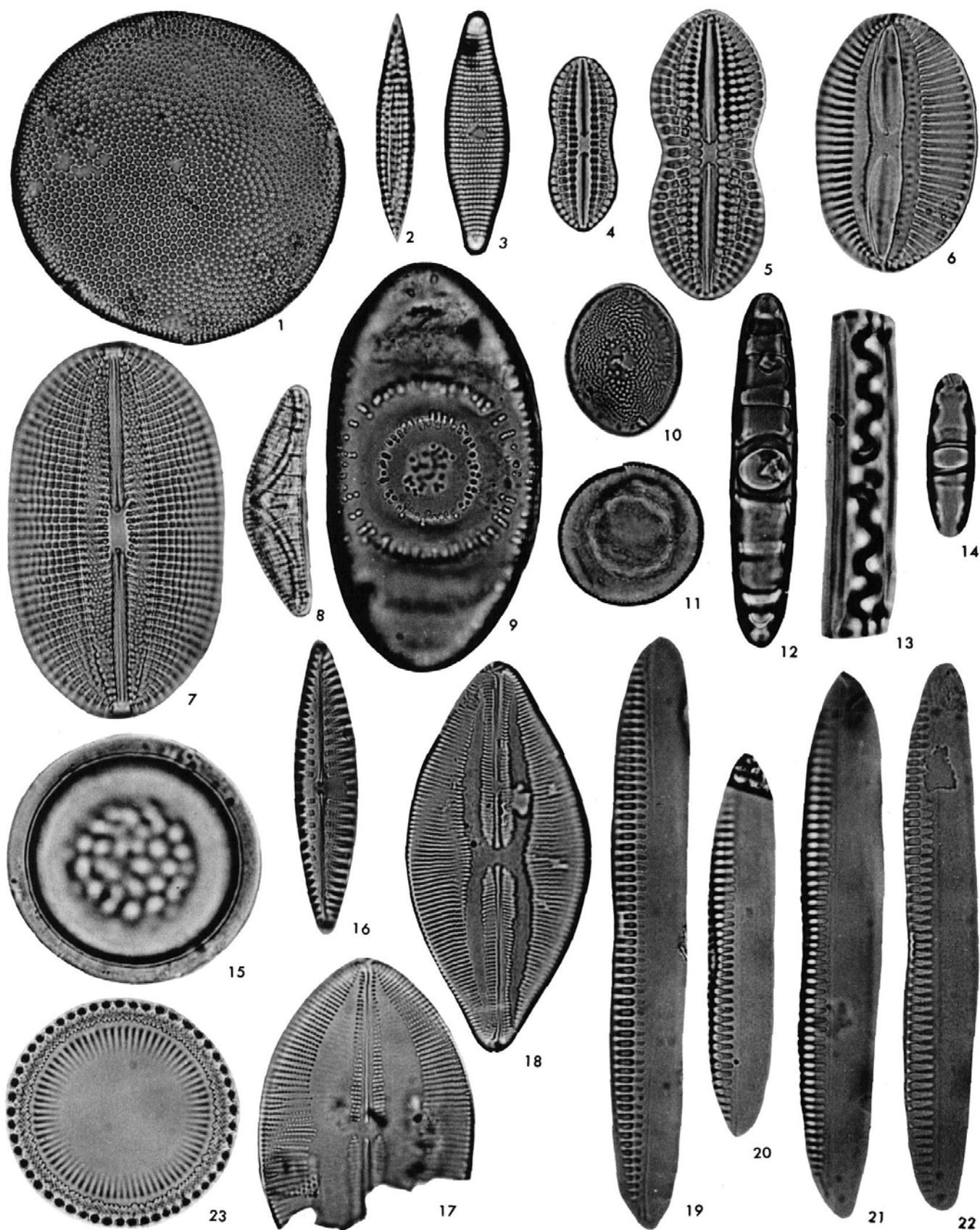
Discussion: Although this species shows affinities to *T. reticulum*, as noted by Boyer (1901), the generally

small size, straight sides, and broadly rounded corners are sufficient to distinguish it. *Triceratium tessellatum* is frequent from the 3- to 6-foot levels of the Petersburg deposit.

Known geologic range: Previously reported only from the lower Miocene deposit at Nottingham, Maryland, and related deposits. Not known in Recent marine assemblages.

PLATE 2

- 1 *Coscinodiscus radiatus* Ehrenberg
USGS diatom cat. no. 3944-34, $\times 500$, diameter 125 μm .
- 2 *Cussia* aff. *C. paleacea* (Grunow) Schrader
USGS diatom cat. no. 3946-24, $\times 1000$, length 40 μm .
- 3 *Dimeregramma fulvum* (Gregory) Ralfs
USGS diatom cat. no. 4012-35, $\times 1000$, length 45 μm .
- 4-5 *Diploneis didyma* (Ehrenberg) Cleve
4, USGS diatom cat. no. 4012-19, length 32 μm ; 5, USGS diatom cat. no. 4012-29, length 52 μm . Both $\times 1000$.
- 6 *Diploneis eudoxia* (Schmidt) Mills
USGS diatom cat. no. 3943-21, $\times 1000$, length 47 μm .
- 7 *Diploneis smithii* (Brébisson) Cleve
USGS diatom cat. no. 3946-74, $\times 1000$, length 70 μm .
- 8 *Epithemia argus* var. *alpestris* (W. Smith) Grunow
USGS diatom cat. no. 3946-73, $\times 1000$, length 42 μm .
- 9 *Goniothecium odontella* Ehrenberg
USGS diatom cat. no. 3944-32, $\times 1000$, length 75 μm .
- 10 *Hemidiscus ovalis* Lohman
USGS diatom cat. no. 3946-72, $\times 1000$, length 28 μm .
- 11 *Hyalodiscus scoticus* (Kützing) Grunow
USGS diatom cat. no. 3943-17, $\times 1000$, diameter 26 μm .
- 12-13 *Grammatophora angulosa* Ehrenberg
12, valve view, USGS diatom cat. no. 3943-23, length 65 μm ; 13, girdle view, USGS diatom cat no. 3943-25, length 60 μm . Both $\times 1000$.
- 14 *Grammatophora marina* (Lyngbye) Kützing
Valve view. USGS diatom cat. no. 4011-49, $\times 1000$, length 23 μm .
- 15 *Melosira westii* W. Smith
USGS diatom cat. no. 3946-53, $\times 1000$, diameter 47 μm .
- 16 *Navicula pennata* Schmidt
USGS diatom cat. no. 4012-25, $\times 1000$, length 51 μm .
- 17 *Navicula hennedyi* W. Smith
USGS diatom cat. no. 3946-79, $\times 1000$, length about 60 μm .
- 18 *Navicula lyra* Ehrenberg
USGS diatom cat. no. 4012-43, $\times 1000$, length 71 μm .
- 19 *Nitzschia imperforata* Andrews, n. sp.
Holotype, USGS diatom cat. no. 3946-26, $\times 1000$, length 109 μm .
- 20 *Nitzschia imperforata* Andrews, n. sp.
USGS diatom cat. no. 4011-16, $\times 1000$, length 75 μm .
- 21 *Nitzschia imperforata* Andrews, n. sp.
USGS diatom cat. no. 3944-37, $\times 1000$, length 98 μm .
- 22 *Nitzschia imperforata* Andrews, n. sp.
USGS diatom cat. no. 3943-8, $\times 1000$, length 96 μm .
- 23 *Paralia sulcata* (Ehrenberg) Cleve
USGS diatom cat. no. 4012-23, $\times 1000$, diameter 43 μm .



Genus XANTHIOPYXIS Ehrenberg, 1845

Xanthiopyxis spp.

Discussion: As in the older Miocene deposits of the eastern United States, a variety of specimens pertaining to the form-genus *Xanthiopyxis* were observed in the Petersburg deposit. Although the morphologic forms are numerous, each is unique or rare in any given sample. Whether the morphologic variation is significant is not known. These specimens probably are resting spores, but they cannot be related to the perfect stage of the proper species. In view of the doubtful

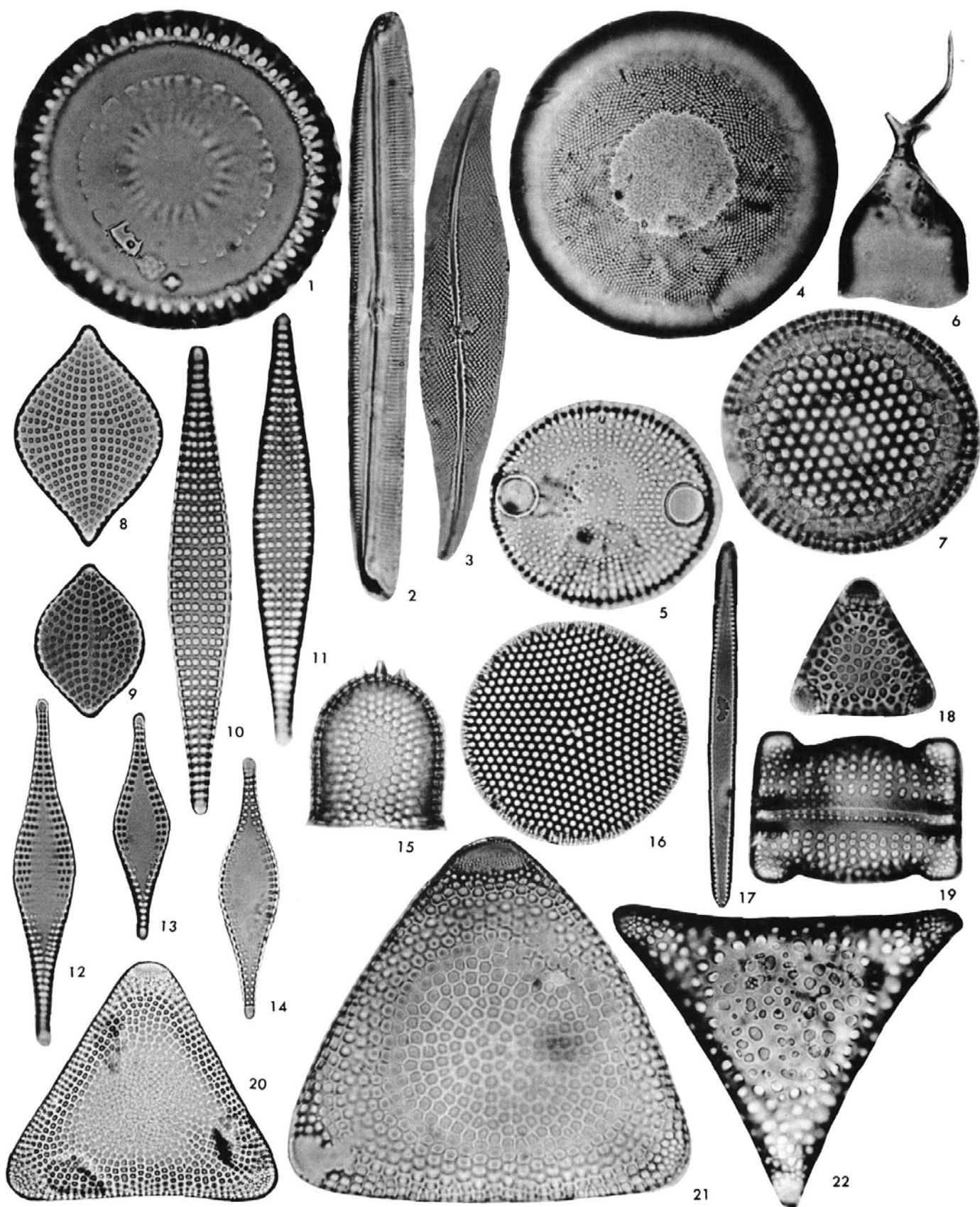
stratigraphic value of these *Xanthiopyxis* spp., I have not attempted their taxonomic treatment.

ACKNOWLEDGMENTS

I wish to express my appreciation to John L. Stone, Washington D. C., who examined the Petersburg material and made many helpful suggestions regarding the diatoms. Thomas G. Gibson, U. S. Geological Survey, Washington, D. C., gave helpful advice on the stratigraphy of the Petersburg area. Thanks also go to William H. Abbott, South Carolina Division of Geology.

PLATE 3

- 1 *Paralia sulcata* var. *coronata* (Ehrenberg) Andrews
USGS diatom cat. no. 4011-4, $\times 1000$, diameter 61 μm .
- 2 *Pinnularia brevicostata* Cleve
USGS diatom cat. no. 3943-18, $\times 1000$, length 110 μm .
- 3 *Pleurosigma normanii* Ralfs
USGS diatom cat. no. 3946-32, $\times 1000$, length 96 μm .
- 4 *Podosira stelligera* (J. W. Bailey) Mann
USGS diatom cat. no. 3945-29, $\times 1000$, diameter 62 μm .
- 5 *Pseudauliscus radiatus* (J. W. Bailey) Rattray
USGS diatom cat. no. 3944-7, $\times 1000$, length 40 μm .
- 6 *Pseudopyxilla americana* (Ehrenberg) Forti
USGS diatom cat. no. 4012-41, $\times 1000$, width 24 μm .
- 7 *Pyxidicula cruciata* Ehrenberg
USGS diatom cat. no. 3946-30, $\times 1000$, length 46 μm .
- 8 *Rhaphoneis amphiceros* (Ehrenberg) Ehrenberg
USGS diatom cat. no. 3946-25, $\times 1000$, length 42 μm .
- 9 *Rhaphoneis rhombica* (Grunow) Andrews
USGS diatom cat. no. 4011-54, $\times 1000$, length 34 μm .
- 10-11 *Rhaphoneis fusus* Ehrenberg
10, USGS diatom cat. no. 3946-41, length 90 μm ; 11, USGS diatom cat. no. 3945-18, length 83 μm . Both $\times 1000$.
- 12-14 *Rhaphoneis petropolitana* Grunow
12, USGS diatom cat. no. 3946-64, length 65 μm ; 13, USGS diatom cat. no. 3945-22, length 42 μm ; 14, USGS diatom cat. no. 3945-52, length 50 μm . All $\times 1000$.
- 15 *Stephanopyxis turris* (Greville) Ralfs
USGS diatom cat. no. 3945-54, $\times 1000$, width 27 μm .
- 16 *Thalassiosira eccentrica* (Ehrenberg) Cleve
USGS diatom cat. no. 4011-41, $\times 1000$, diameter 40 μm .
- 17 *Thalassionema nitzschioides* (Grunow) Hustedt
USGS diatom cat. no. 4012-24, $\times 1000$, length 68 μm .
- 18-19 *Triceratium tessellatum* Greville
18, valve view, USGS diatom cat. no. 3946-57, side 30 μm ; 19, girdle view, USGS diatom cat. no. 4011-26, side 40 μm . Both $\times 1000$.
- 20-21 *Triceratium hebetatum* (Grunow) Andrews
USGS diatom cat. no. 3946-80 $\times 500$, side 102 μm ; 21, USGS diatom cat. no. 4011-55, $\times 1000$, side 73 μm .
- 22 *Triceratium reticulum* Ehrenberg
USGS diatom cat. no. 3945-33, $\times 1000$, side 65 μm .



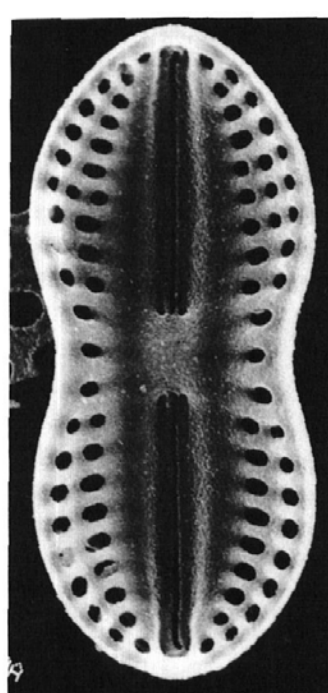
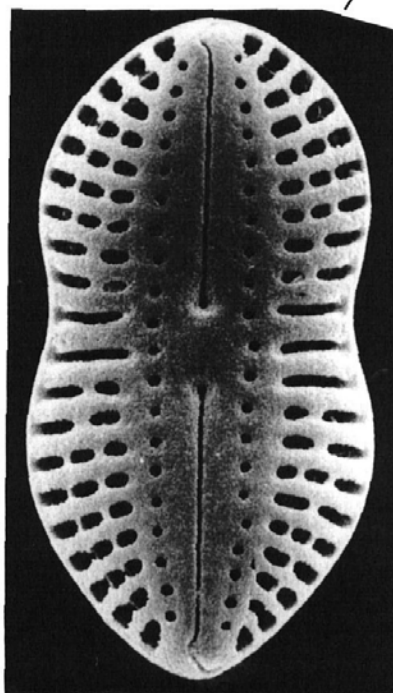
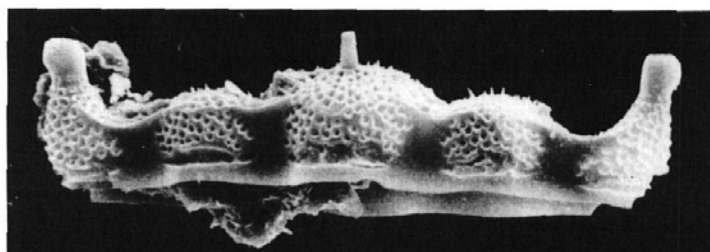
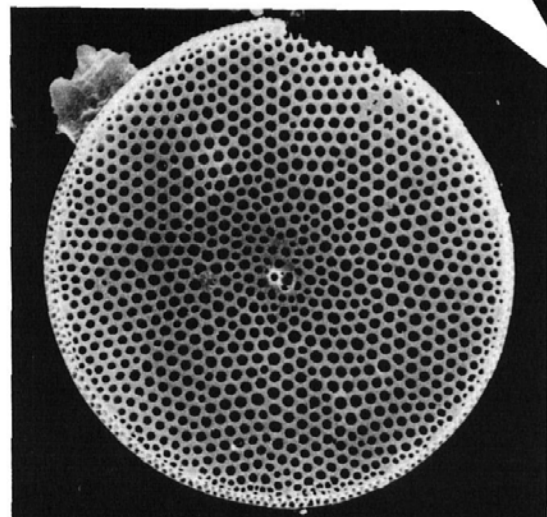
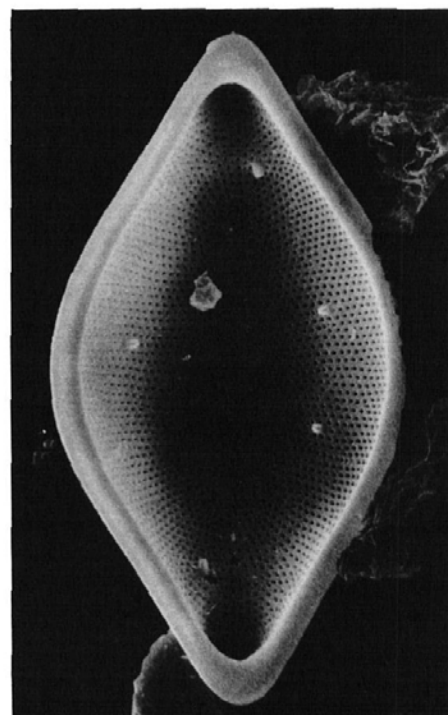
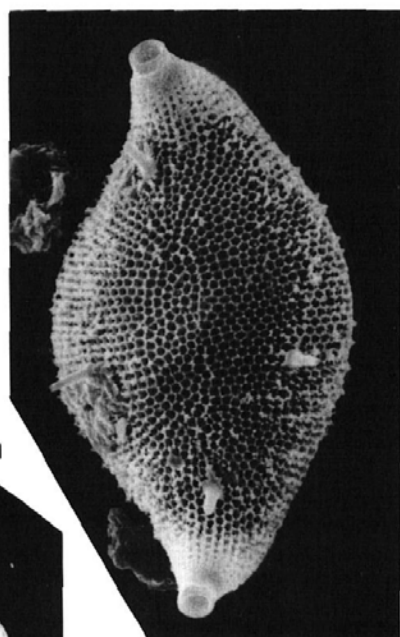
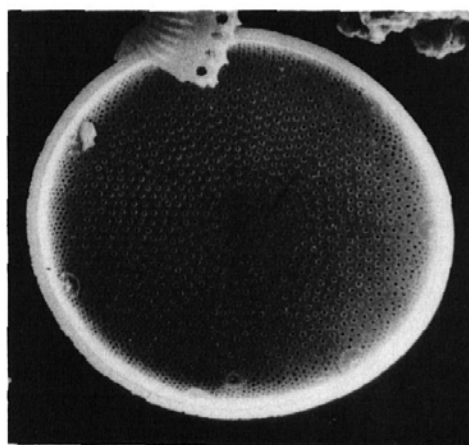
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PLATE 4

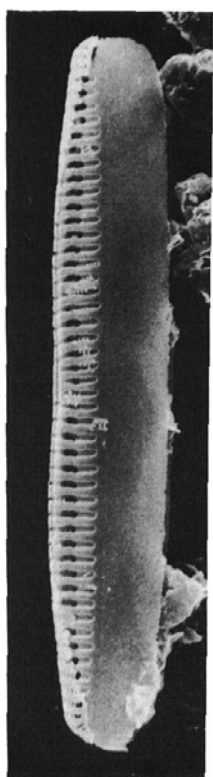
- 1 *Actinocyclus octonarius* Ehrenberg
Interior, USGS diatom locality 6454, $\times 1000$, diameter 56 μm .
- 2-3 *Biddulphia rhombus* (Ehrenberg) W. Smith
2, exterior, USGS diatom locality 6454, $\times 1250$, length 62 μm ; 3, interior, USGS diatom locality 6454, $\times 1000$, length 89 μm .
- 4 *Coscinodiscus curvatus* Grunow
Exterior, USGS diatom locality 6454, $\times 1250$, diameter 50 μm .
- 5 *Biddulphia tuomeyi* (J. W. Bailey) Roper
Exterior, girdle view. USGS diatom locality 6454, $\times 750$, length 111 μm .
- 6 *Cussia* aff. *C. paleacea* (Grunow) Schrader
Interior, USGS diatom locality 6454, $\times 2500$, length 32 μm .
- 7-8 *Diploneis didyma* (Ehrenberg) Cleve
7, exterior, USGS diatom locality 6454, $\times 3000$, length 29 μm ; 8, interior, USGS diatom locality 6520, $\times 3100$, length 28 μm .
- 9 *Goniothecium odontella* Ehrenberg
Exterior, USGS diatom locality 6454, $\times 1000$, length 72 μm .



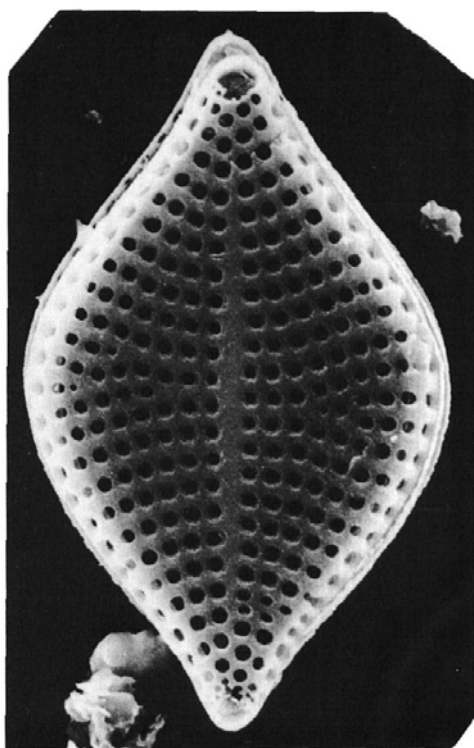
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PLATE 5

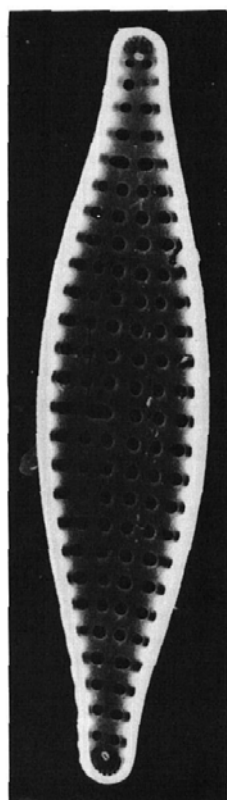
- 1 *Nitzschia imperforata* Andrews, n. sp.
Exterior, USGS diatom locality 6454, \times 1300, length 73 μ m.
- 2 *Rhaphoneis ampiceros* (Ehrenberg) Ehrenberg
Exterior, USGS diatom locality 6520, \times 2000, length 47 μ m.
- 3–5 *Rhaphoneis fusus* Ehrenberg
3, interior, USGS diatom locality 6520, \times 2000, length 50 μ m; 4, exterior, USGS diatom locality 6454, \times 1400, length 57 μ m; 5, exterior, USGS diatom locality 6454, \times 1000, length 87 μ m.
- 6–8 *Rhaphoneis petropolitana* Grunow
USGS diatom locality 6520. 6, exterior, \times 3700, length 21 μ m; 7, interior, \times 3400, length 27 μ m; 8, exterior, \times 1700, length 57 μ m.
- 9 *Hemidiscus ovalis* Lohman
Exterior. USGS diatom locality 6454, \times 2000, length 33 μ m.



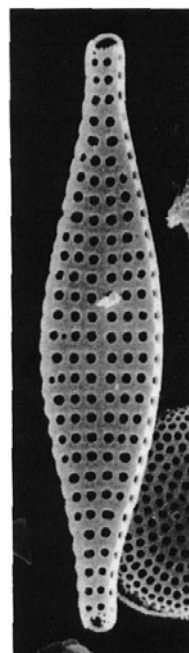
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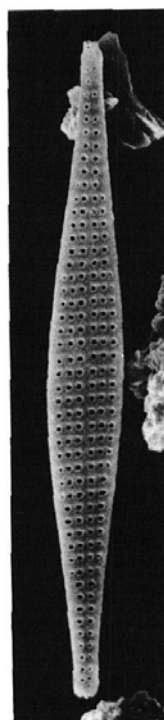
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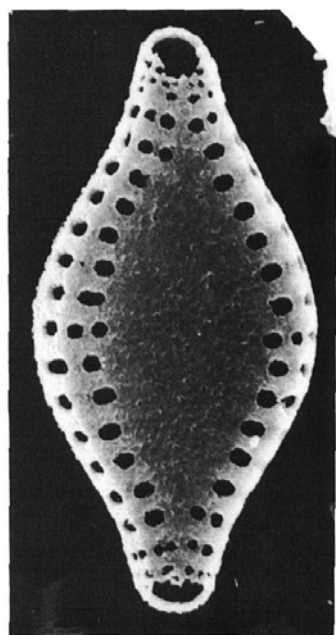
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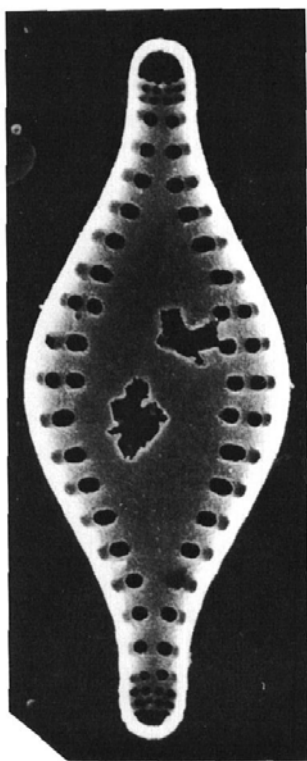
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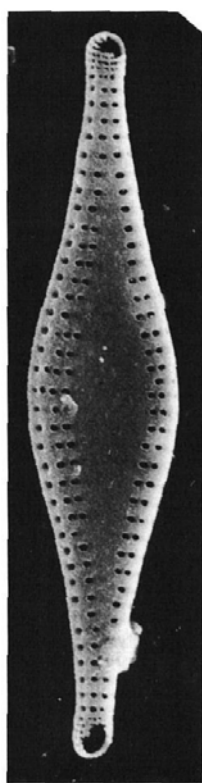
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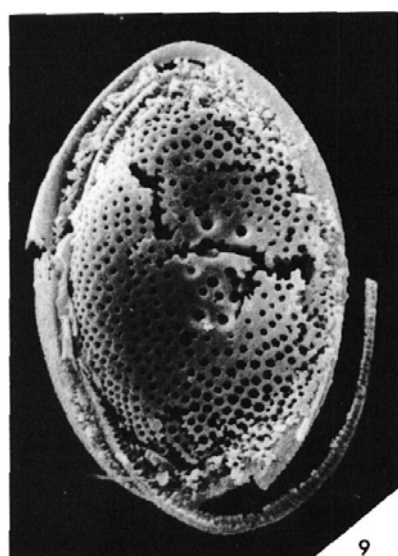
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7



8

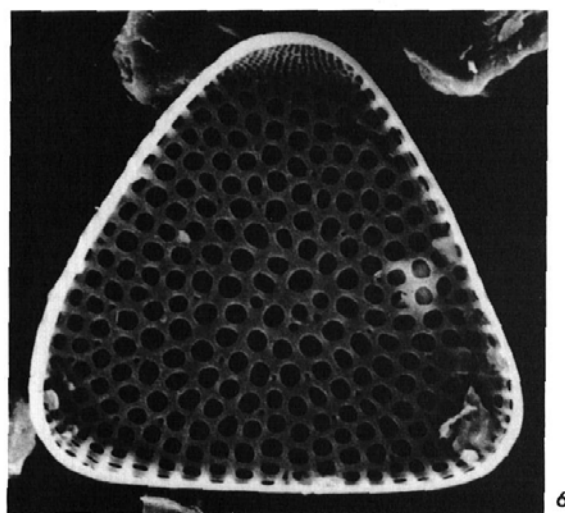
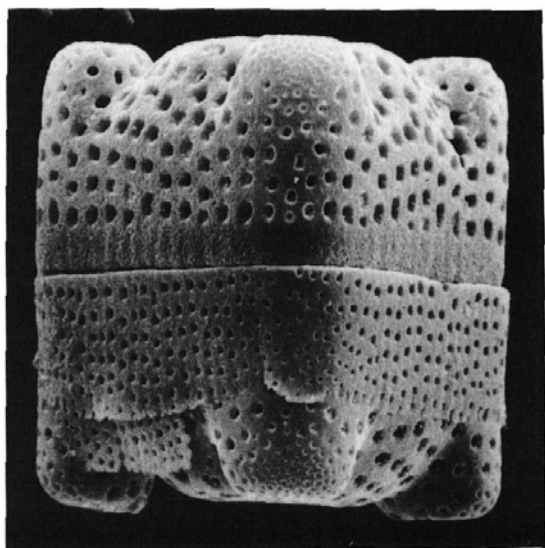
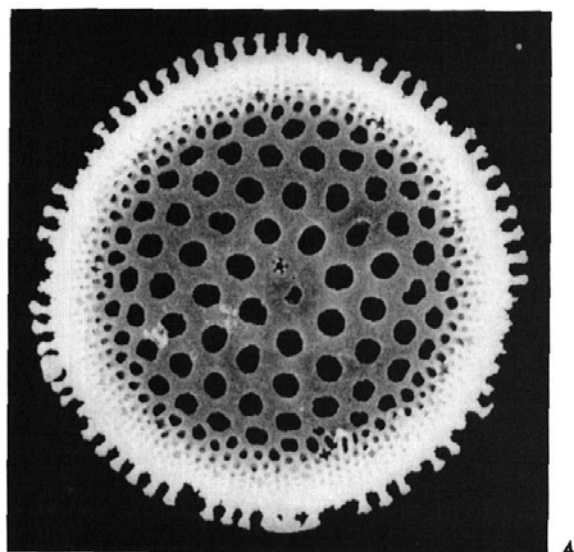
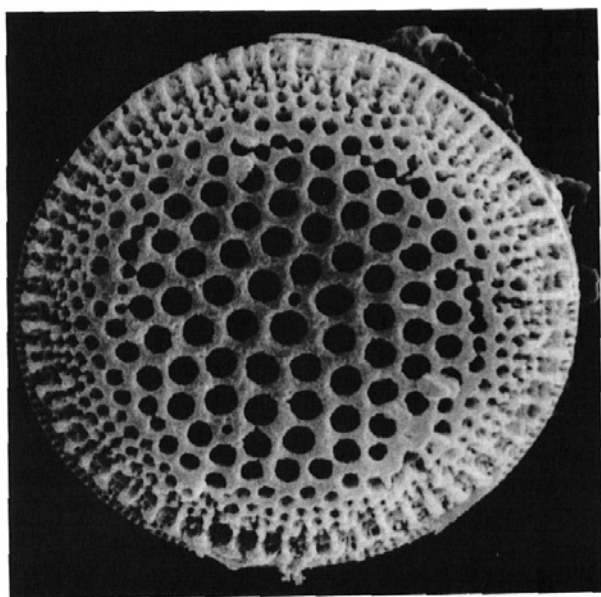
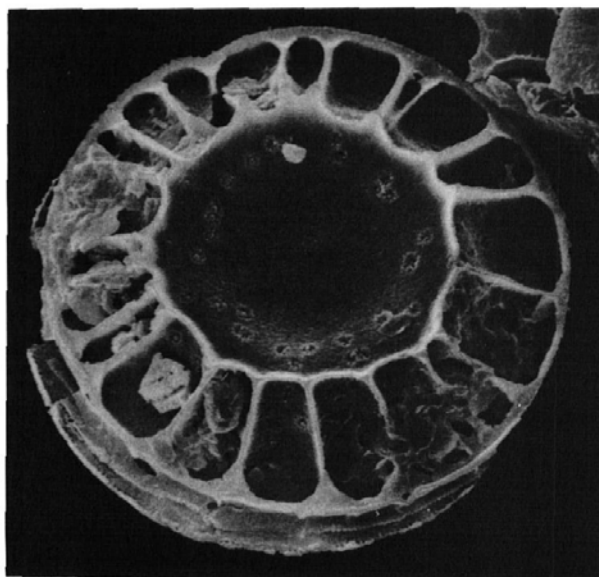
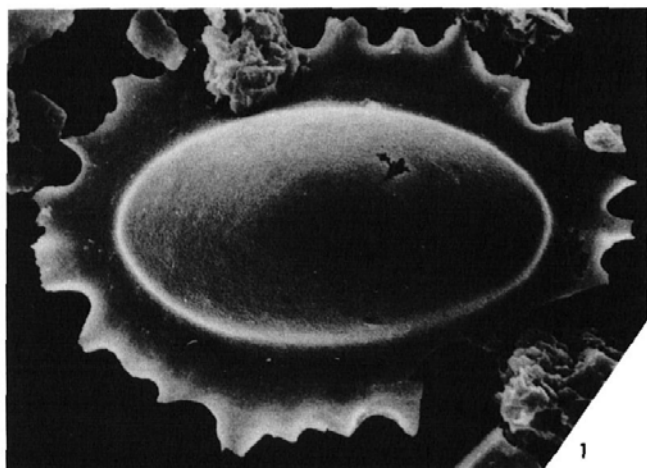


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PLATE 6

- 1 *Dossetia hyalina* Andrews
Exterior, USGS diatom locality 6454, $\times 1200$, length 67 μm .
- 2 *Stephanogonia actinoptychus* (Ehrenberg) Grunow
Exterior, USGS diatom locality 6454, $\times 2300$, diameter 30 μm .
- 3–4 *Thalassiosira oestrupii* (Ostenfeld) Proschkina-Lavrenko
USGS diatom locality 6454. 3, exterior, $\times 3400$, diameter 22 μm ; 4, interior, $\times 3000$, diameter 22 μm .
- 5 *Triceratium tessellatum* Greville
Exterior, girdle view of frustule, USGS diatom locality 6454, $\times 2000$, side 31 μm .
- 6 *Triceratium hebetatum* (Grunow) Andrews
Interior, USGS diatom locality 6520, $\times 1500$, side 43 μm .



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