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ROGERS C. B. MORTON, *Secretary*

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Late Miocene Nonmarine Diatoms From the Kilgore Area, Cherry County, Nebraska

By GEORGE W. ANDREWS

CONTRIBUTIONS TO PALEONTOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 683-A

A description of a late Miocene nonmarine diatom assemblage from the Great Plains region and its stratigraphic and paleoecologic significance

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CONTRIBUTIONS TO PALEONTOLOGY

LATE MIOCENE NONMARINE DIATOMS FROM THE KILGORE AREA, CHERRY COUNTY, NEBRASKA

By GEORGE W. ANDREWS

ABSTRACT

The Valentine Formation of A. L. Lugn, which is of late Miocene and early Pliocene age, contains diatomaceous and plant-bearing sediments at a locality on the north bluff of the Niobrara River, about 10 miles south of Kilgore, Cherry County, Nebr. The fossil flora has been studied by H. D. MacGinitie, who concluded that the deposit is of late Miocene age. Correlative strata near Valentine, Nebr., several miles east of this locality, are reported to contain a vertebrate fauna of late Miocene age.

The Kilgore diatom assemblage consists of 45 taxa of nonmarine diatoms. Of these, four species are herein recorded as new, one species has been previously reported from the middle Pliocene of France, and the remaining 40 taxa are identified as still living in modern nonmarine environments. The diatom assemblage suggests deposition in a relatively shallow, small lake. The waters of this lake were probably hard, and perhaps at times somewhat alkaline or saline. It is difficult to separate the influences of ecology and geologic age on the composition of the diatom assemblage, but this problem should be resolved as other Tertiary assemblages are studied. The five presumably extinct species may prove to be useful for stratigraphic correlation when their geologic ranges are better known. The composition of the assemblage, the relative number of taxa, and the absence of several widespread modern genera and species of nonmarine diatoms should be of value in identifying other late Miocene assemblages and in distinguishing them from assemblages of different age.

INTRODUCTION

GENERAL FEATURES

The Kilgore diatomaceous beds crop out among the small and discontinuous exposures of the Valentine Formation of Lugn (1938) found along the highly dissected north bluff of the Niobrara River in Cherry County, Nebr. Diatomite and diatomaceous shale containing a well-preserved fossil flora are exposed at a site about 10 miles south of the village of Kilgore. The plant remains were described and dated as late Miocene by MacGinitie (1962). The diatomaceous deposit has also been correlated with a late Miocene vertebrate fauna from Valentine, Nebr.

The Kilgore deposit contains the first Tertiary nonmarine diatom assemblage from the Great Plains area of North America to be systematically studied. The preservation of the diatom assemblage is good. The age of the deposit is confirmed by two independent lines of evidence. The Kilgore diatom assemblage occurs in a deposit of known and stratigraphically significant age close to the Miocene-Pliocene boundary. This provides a valuable reference marker for understanding and determining the stratigraphic ranges of the Tertiary nonmarine diatoms.

This occurrence of diatomite was called to the attention of the writer by a sample submitted by Dr. Morton Green of the Museum of Geology, the South Dakota School of Mines and Technology, Rapid City, in 1962. The fossil-plant locality was examined in 1965 and samples were taken for diatom study. An unsuccessful search for additional diatomiferous sediments was made in the vicinity of Valentine, Nebr., in 1966.

ACKNOWLEDGMENTS

The helpfulness of Morton Green in transmitting a sample of the Kilgore diatomite is gratefully acknowledged. The owners of the Drinkwalter Ranch kindly permitted access to their property so that the outcrops could be studied. Thanks are expressed to Kenneth E. Lohman, Division of Paleobotany, The Smithsonian Institution, and to Sergius H. Mamay, U.S. Geological Survey, for their critical review of the manuscript.

KILGORE DIATOMITE DEPOSIT

LOCATION

Diatomaceous sediments of Lugn's Valentine For-

mation crop out on the north valley wall of the Niobrara River, approximately 10 miles south of the village of Kilgore, Cherry County, Nebr. The location of the Kilgore area in north-central Nebraska is shown in figure 1. The sample of diatomite submitted by Morton Green was described as coming from the

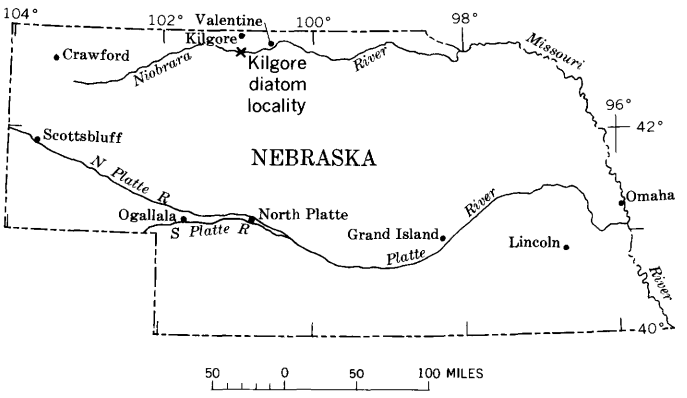

FIGURE 1.—Kilgore area, Nebraska.

SW¼NW¼ sec. 33, T. 33 N., R. 31 W. The samples of diatomaceous sediments collected by the writer came from the fossil-plant locality, described by MacGinitie (1962), in the W½NE¼ sec. 34, T. 33 N., R. 31 W. (fig. 2).

The Kilgore diatomite locality is readily accessible from a road skirting the base of the north bluff along the Niobrara River. The fossil-plant-bearing bed at the base of the diatomaceous section occurs at approximately the 2,700-foot contour level (fig. 2) and about 85 feet above the average water level of the Niobrara River (MacGinitie, 1962, p. 69–70). The outcrops exposed in 1965 were by no means as extensive as suggested by MacGinitie's map (1962, p. 70). The hard siliceous plant-bearing shale containing fossil plants crop out discontinuously in the area, but the soft overlying diatomaceous sediments are seen only in new excavations. Considerable sand slumped from overlying deposits covers the diatomaceous section in many areas and prevents the lateral tracing of beds for any distance.

STRATIGRAPHIC SECTION

The geology and stratigraphic section of the Kilgore fossil-plant locality have been accurately described by MacGinitie (1962, p. 72–76), and the following discussion is modified from his work. The diatomaceous section is underlain by about 75 feet of fine calcareous sands of the Valentine Formation, which lie disconformably on siltstones of Hemingfordian age equivalent to the Rosebud Formation of South Dakota and the Marsland Formation of western Nebraska according to Webb (1969, p. 7). The section is overlain by an unknown thickness of fine sands and sandstones of the Valentine Formation. The diatomaceous interval is considered to be in the lower part of the Valentine Formation as more of the Valentine is above the interval than below it. It consists of 8 or 9 feet of shaly sediments containing some diatomaceous layers.

The following beds can be identified at the Kilgore locality:

	Thickness Ft	Thickness in
7. Tan silty diatomite (fig. 3*A*). USGS diatom locality 5837, sample from 2 to 5 in. above base of unit	1	0
6. Massive sandy silt	2	6
5. Soft buff diatomaceous shale with carbonaceous specks (fig. 3*B*). USGS diatom locality 5836, sample from about 15 in. above base of unit	2	7
4. Hard greenish-gray finely laminated siliceous shale with hackly fracture	0	4
3. Soft white very fissile diatomite with carbonaceous matter (fig. 3*C*). USGS diatom locality 5835; sample from 5 to 6 in. above base of unit. USGS diatom locality 5834, sample from 2 to 3 in. above base of unit	1	0
2. Soft brown fissile diatomaceous organic matter immediately overlying the plant-bearing shale (fig. 3*C*). USGS diatom locality 5833; sample from first inch above the plant-bearing shale	0	2
1. Hard gray finely laminated siliceous calcareous shale with platy fracture (fig. 3*C*, *D*). This is the main fossil leaf bed of the Kilgore locality, and plant remains are abundant and well preserved. USGS diatom locality 5832; sample from upper 2 in. of unit	0	6

The sample taken from unit 1, the plant-bearing shale (USGS diatom locality 5832) did not contain diatoms. The overlying organic matter of unit 2 (USGS diatom locality 5833) was relatively poor in diatoms. It is thought that both of these units were originally highly diatomaceous, but that the diatoms were leached from them by percolating alkaline waters. Perhaps some of the diatom silica was leached from the highly organic unit 2 and redeposited in the underlying plant-bearing shale. This would account for the partial silicification of the plant-bearing bed and the remarkable preservation of the Kilgore flora. Units 4 and 6 were not thought suitable for diatom preservation, and were not studied.

The outcrop that furnished the sample submitted by Morton Green was not located because of the limited time available for fieldwork. The sample

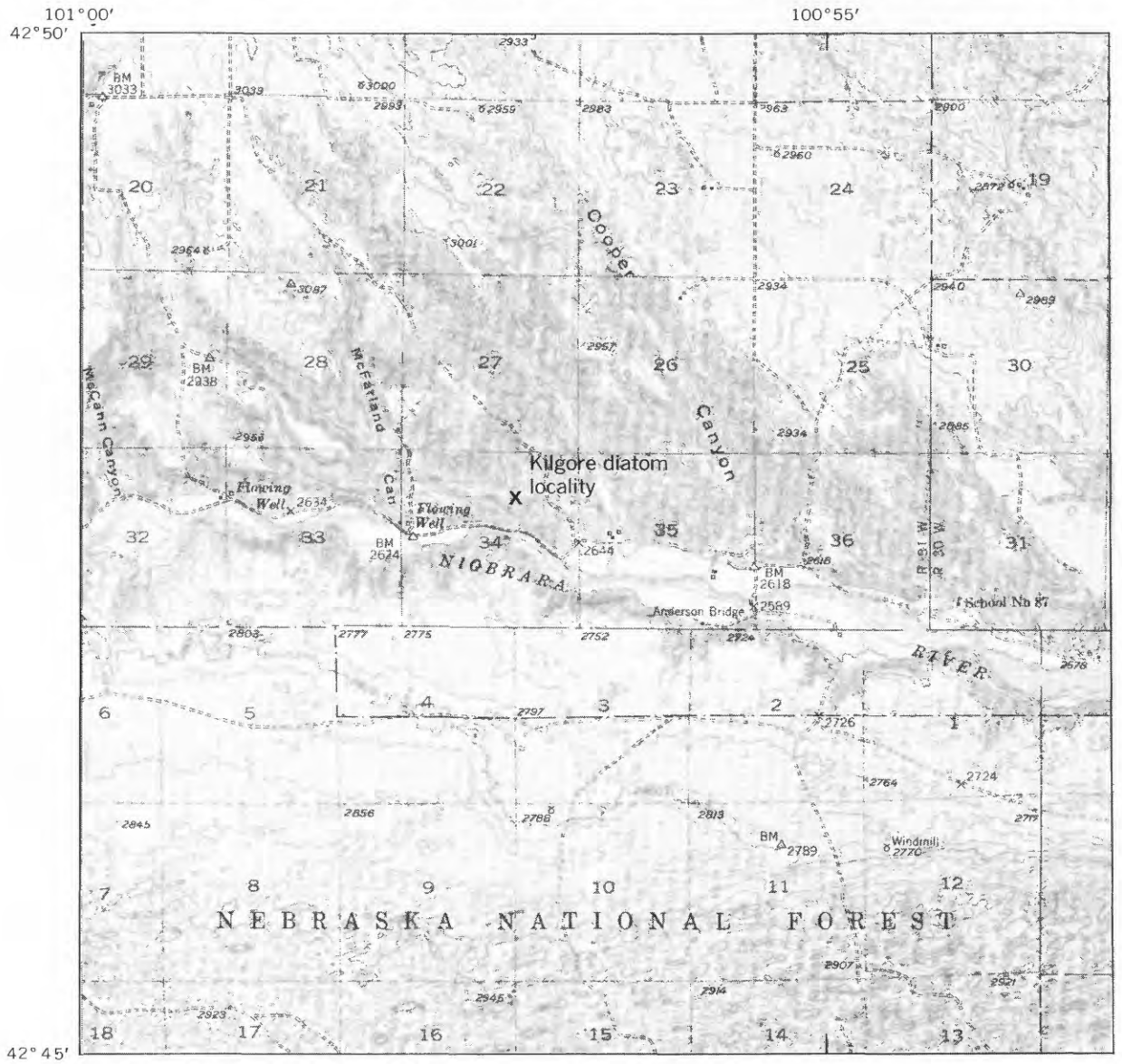

FIGURE 2.—Kilgore fossil-diatom locality, Cherry County, Nebr.

(USGS diatom locality 5419) consists of a soft white fissile diatomite with fish scales and poorly preserved leaf fragments. MacGinitie (1962, p. 76) states that the plant-bearing shales merge into pure diatomite about a mile to the west, that is, in the direction of locality 5419. He also indicates that these sediments are restricted in lateral distribution by stating (p. 76), "The lake sediments are exposed in the Niobrara River bluffs for a distance of about 1¾ miles, and they end abruptly both at the east and west boundary."

VALENTINE FORMATION

GENERAL FEATURES

The Kilgore diatomite deposit occurs in the Valen-

A

C

B

D

FIGURE 3.—Kilgore fossil-plant locality. *A*, Tan silty diatomite of unit 7, uppermost diatomaceous layer. *B*, Soft buff diatomaceous shale of unit 5. *C*, Units 1–3. *D*, Slabby, siliceous shale of unit 1 containing the Kilgore fossil flora.

tine Formation, which is the lowermost unit of the Ogallala Group as redefined by Lugn (1939, p. 1258–1264) from the original Ogallala Formation of Darton (1898). The Ogallala Group of Lugn (1938) contains the following subdivisions (in ascending order): Valentine Formation, Ash Hollow Formation, Sidney Gravel, and Kimball Formation. The Valentine Formation was originally defined as the "Valentine beds" by Barbour and Cook (1917, p. 173) and was redefined as a formation in the Ogallala Group by Lugn (1938). The lower boundary of the Valentine Formation was tenuously suggested by

Lugn as the base of the Pliocene, but he recognized the necessity of further fossil data before a positive age determination could be made.

VERTEBRATE PALEONTOLOGY

The Kilgore fossil-plant and diatom locality occurs about 75 feet above the base of the Valentine Formation. The nearest vertebrate remains at approximately the same stratigraphic level in the lower part of the Valentine Formation occur near Valentine, Nebr., about 22 miles east of the Kilgore locality. This fauna has been designated the Niobrara River fauna by Stirton and McGrew (1935, p. 129), who state as follows: "Although we have called the Niobrara River fauna an Upper Miocene fauna, it is practically transitional between the Upper Miocene and the Lower Pliocene, but nearer to the Miocene than the Pliocene." The Niobrara River fauna of Stirton and McGrew (1935) is distinctly older than the Valentine fauna of these authors and others, and the Valentine fauna occurs in the Ash Hollow Formation. This confusion between the Valentine fauna, a fossil zone, and the Valentine Formation, a rock unit, has been ably discussed by Johnson (1936), Lugn (1939), and MacGinitie (1962). The Niobrara River local fauna has been designated as Barstovian, and the lower part of the Valentine Formation is shown as late Miocene age by Wood and others (1941).

The correlation of the Kilgore diatomite assemblage with the Niobrara River fauna of Stirton and McGrew (1935) on the basis that they both occur about 75 feet above the base of the Valentine Formation is not without peril. Moreover, the diatomite deposit is of relatively small extent and cannot be traced laterally for more than 2 miles. There is no lithologic equivalent to the diatomite at Valentine, for the vertebrate fossils occur in sandy sediments which are not likely to contain diatoms. On the other hand, both the Kilgore deposit and Niobrara River fauna at Valentine occur in approximately the same relative stratigraphic position, in the lower beds of the Valentine Formation. Although it is impossible to assure an exact correlation, the probability of their near age equivalence is strong. The Kilgore diatomite deposit is, therefore, probably very late Miocene in age on the basis of vertebrate paleontological evidence.

PALEOBOTANY

The fossil plants of the Kilgore locality have been ably described by MacGinitie (1962), who discussed the ecologic and climatic aspects of the flora. He has also examined thoroughly the relationships of the Kilgore flora to possible correlative floras, but he recognizes the difficulties imposed by the great distances from Kilgore to other well-known fossil-plant localities. However, on the basis of the flora alone, he concludes that the Kilgore flora is more modern than the Mascall flora of Oregon described by Chaney and Axelrod (1959) but not as advanced as the Weiser flora of Idaho described by Dorf (1936). The Mascall flora is considered to be Barstovian (late Miocene) in age. The Weiser flora, partly on stratigraphic and vertebrate fossil evidence, is considered to be earliest Pliocene in age. MacGinitie (1962, p. 105) concludes that the most probable age of the Kilgore flora is late Miocene or Barstovian. Taking into consideration that it appears to be younger than the Mascall flora, it may be considered to be latest Miocene on the basis of the floral evidence.

DIATOM ASSEMBLAGE

GENERAL FEATURES

The samples were prepared for diatom study following standard laboratory procedures. All the samples were noncalcareous, and they disintegrated readily in distilled water. Organic matter was removed chemically, and coarse particles were eliminated by decantation of the diatoms and other suspended sediment. The cleaned samples were mounted as strewn slides in kollolith, a synthetic resin with approximately the same refractive index as canada balsam. Specimens were located by systematic traversing with a mechanical stage, and their locations were recorded as coordinates of the mechanical stage. The relative abundance of each diatom taxon in the six studied assemblages is shown in table 1. USGS diatom localities 5833–5837 represent collections from different stratigraphic levels at the Kilgore fossil-plant locality of MacGinitie (1962), and the exact position of these collections is given in the discussion of the stratigraphic section. USGS locality 5419 is a collection made about a mile west of MacGinitie's fossil-plant locality.

STRATIGRAPHIC SIGNIFICANCE

This report represents the first stratigraphic study of a Tertiary nonmarine diatom assemblage from the Great Plains region of North America. Although fossil marine diatoms have been extensively studied in many parts of the world, little has been published on fossil nonmarine diatom assem-

TABLE 1.—*Relative abundance of diatoms from six collections in the Kilgore diatomaceous deposits*
[A, abundant; C, common; F, frequent; R, rare]

	USGS diatom locality					
	5419	5833	5834	5835	5836	5837
Melosira granulata (Ehrenberg) Ralfs	C	C	A	A	--	--
var. *angustissima* Müller	C	C	A	A	--	--
italica (Ehrenberg) Kützing	A	--	C	C	A	A
distans (Ehrenberg) Kützing	C	R	--	R	--	--
Tetracyclus lacustris Ralfs	R	R	R	F	--	--
pagesi Héribaud	F	--	R	R	R	--
tripartitus Brun and Héribaud	R	--	--	R	--	--
rupestris (A. Braun) Grunow	R	R	--	R	--	--
cruciformis Andrews, n. sp.	--	--	--	--	F	--
Fragilaria brevistriata Grunow	A	R	--	R	A	--
gigantea Lauby	F	--	R	R	--	--
Synedra rumpens Kützing	--	--	--	R	--	--
ulna (Nitzsch) Ehrenberg	F	--	F	F	--	R
Eunotia parallela Ehrenberg	F	--	R	R	--	--
pectinalis var. *minor* (Kützing) Rabenhorst	F	--	--	R	R	--
Achnanthes hungarica (Grunow) Grunow	--	--	--	R	--	--
Stauroneis phoenicenteron (Nitzsch) Ehrenberg	F	--	--	F	--	--
anceps Ehrenberg	F	--	--	--	--	--
smithii Grunow	--	--	--	--	R	--
lauenburgiana Hustedt	--	--	--	--	F	R
Anomoeoneis sphaerophora (Ehrenberg) Pfitzer	--	--	--	--	R	--
Neidium iridis var. *ampliata* (Ehrenberg) Cleve	--	--	--	--	F	--
Navicula amphibola Cleve	F	--	F	R	C	R
niobrara Andrews, n. sp	F	--	--	--	C	C
actinota Andrews, n. sp	--	--	--	--	R	--
cuspidata (Kützing) Kützing	--	--	--	--	R	R
bacillum Ehrenberg	F	--	R	--	R	R
radiosa Kützing	--	--	--	R	--	--
graciloides A. Mayer	R	--	--	R	--	--
anglica var. *subsalsa* (Grunow) Cleve	--	--	R	--	--	--
elginensis (Gregory) Ralfs	F	R	R	R	C	R
elginensis var. *rostrata* (A. Mayer) Patrick	F	--	--	--	--	--
Pinnularia subcapitata var. *paucistriata* (Grunow) Cleve	--	R	--	--	--	--
brevicostata Cleve	R	--	--	--	--	--
clevei Patrick	--	--	--	R	--	--
torta (Mann) Patrick	R	--	R	--	R	--
viridis (Nitzsch) Ehrenberg	F	--	--	F	--	--
Cymbella naviculiformis Auerswald	F	--	--	R	--	F
ehrenbergii Kützing	C	--	R	R	--	--
cistula (Hemprich) Grunow	A	R	R	F	A	C
var. *maculata* (Kützing) Van Heurck	C	--	F	F	F	--
tumida (Brébisson) Van Heurck	--	--	--	--	--	F
Gomphonema affine var. *insignis* (Gregory) Andrews, n. comb	C	F	F	F	C	F
Hantzschia elongata (Hantzsch) Grunow	--	--	--	--	F	--
Nitzschia calva Andrews, n. sp	--	--	--	--	R	--

blages. The late Eocene nonmarine diatoms of the Beaver Divide area of Wyoming have been reported upon by Lohman and Andrews (1968). This assemblage, however, is considerably older than the late Miocene deposit studied here, and it has a distinctly different composition. A late Pleistocene diatom assemblage from Wisconsin was studied by Andrews (1966) and proved to be mainly modern in aspect. The Kilgore assemblage falls between these extremes in time, and it seems to show some intermediate aspects.

Lauby (1910) published a report on Tertiary nonmarine diatoms from several localities in the Massif Central of France. On the basis of his studies, he extended the stratigraphic ranges of many modern taxa of nonmarine diatoms back to the Miocene and Oligocene Epochs. A critical examination of Lauby's work shows that most of his "Oligocene" nonmarine diatoms came from the Aquitanian Stage, which is lower Miocene in modern terminology. Aside from this change in stratigraphic nomenclature, many of Lauby's claims on stratigraphic ranges of diatom taxa seem extravagant in comparison to the known ranges in North America. Although it appears that Lauby was a competent diatomist, he correlated the volcanic rocks and lake sediments of the Massif Central primarily on the basis of fossil plants. A critical reevaluation of these paleobotanical correlations should be made before any of Lauby's diatom ranges can be accepted.

The Kilgore diatom assemblage consists of 45 species and varieties of nonmarine diatoms. Of these, four species (*Tetracyclus cruciformis, Navicula niobrara, Navicula actinota,* and *Nitzschia calva*) are new, and one species, *Fragilaria gigantea,* has been found in beds of possible middle Pliocene age in France. A form similar to *Tetracyclus cruciformis* has been reported from Miocene deposits in the U.S.S.R. The remaining 40 taxa are still living in modern nonmarine environments.

The absence of many modern genera and species from the Kilgore diatom assemblage may be of as much significance as the composition of the assemblage. It is difficult to ascertain, on the basis of only one studied assemblage, whether some forms had not yet evolved or whether they are missing only because of ecological factors. When the Kilgore assemblage is contrasted with modern assemblages, there are obvious differences that should be pointed out. The significance of these differences must be considered at present as tentative and subject to modification when other Tertiary fossil diatom assemblages are investigated.

The genera *Cyclotella* and *Stephanodiscus,* centric diatoms common in modern assemblages, are both absent from the Kilgore assemblage. Of the subfamily Tabellarioideae, the genera *Tabellaria, Diatoma,* and *Meridion,* all common in modern assemblages, are absent, although the subfamily is represented by *Tetracyclus.* The Eunotiaceae are represented only by two relatively simple species of *Eunotia. Cocco-*

neis is missing from the assemblage, and *Achnanthes* is rare. The naviculoid genera, *Mastogloia, Caloneis,* and *Diploneis* are missing although the family is well represented. Even the genus *Navicula,* however, does not show the rich variety common in modern assemblages. *Amphora* has not been recorded although its near relative *Cymbella* occurs with notable abundance though without much variety. *Gomphonema* is represented by only one taxon, and that is highly variable in composition. There is nothing to suggest the wide variation shown by modern Gomphonemas as, *G. affine* var. *insignis* is a rather generalized, possibly primitive, form. Perhaps of most significance is the total lack of the Epithemiaceae—*Denticula, Epithemia,* and *Rhopalodia.* These genera are common and widespread in modern assemblages, and their lack in the Kilgore assemblage is of importance. The Surirellaceae have not been noted in the Kilgore assemblage, but they are less often abundant in modern assemblages.

The Kilgore assemblage has 45 species and varieties which are included in 15 genera. A late Pleistocene assemblage of virtually modern aspect described by Andrews (1966) contains 73 species and varieties included in 23 genera. In contrast, the late Eocene diatom assemblage from the Beaver Divide locality of Lohman and Andrews (1968) has only 34 species and varieties included in nine genera. The Kilgore assemblage is intermediate both in age and in number of taxa with respect to these described assemblages. Perhaps this suggests a trend toward increasing complexity in progressively younger nonmarine assemblages.

The Kilgore diatom assemblage is significant in that it contains five extinct species. The total number of forms represented in the assemblage is also significant. A substantial number of the modern genera are present, but this Miocene assemblage does not have the richness of variation found in most Pleistocene and modern assemblages. The absence of certain genera and species in the Kilgore deposit may be the result of ecology, but the lack of whole families and subfamilies can hardly be explained on this basis alone. The modern ecology of those forms still living suggests that these missing categories could have lived in the Kilgore environment had they been in existence at that time. The changes in nonmarine diatom assemblages from the late Miocene to the present are perhaps more the result of the development of new species than of the extinction of old species.

PALEOECOLOGIC INTERPRETATION

The modern ecology of the 40 long-ranging taxa in the Kilgore diatom assemblage furnishes clues about the paleoecology of the deposit. The relative abundance of planktonic forms indicates deposition in standing water, probably in a shallow lake. The abundance and variety of benthonic diatoms confirm deposition in a comparatively shallow lacustrine environment with relatively clear water. MacGinitie (1962, p. 76) states that the lake sediments are exposed for a distance of about 1¾ miles, which gives an order of geographic magnitude for the lake. The lake probably filled slowly with sediments as long as it existed and provided an increasingly shallow environment with time. The total thickness of the diatomaceous and intercalated sediments at the fossil-plant locality is about 8 feet, and the initial depth of water was probably not much greater.

Many of the taxa in the Kilgore assemblage are common and widespread in modern temperate freshwater environments and thus do not indicate specific information about the depositional temperature and salinity. Four of the taxa show an affinity for cool or cold water. It is probably of greater significance that six taxa are tolerant of moderate alkalinity, whereas nine taxa are said to tolerate some salinity or water of high mineral content. In contrast only three taxa are known to prefer waters of low mineral content, and only one favors an acid environment. This indicates that the climate was temperate to cool and that the water had a fairly high mineral content and perhaps was a bit saline. The lack of carbonate in the rocks may indicate either that concentrations were never great enough for carbonate deposition or that the beds were subsequently leached of carbonates. Certainly some postdepositional leaching has taken place at the fossil-plant locality. The plant-bearing bed itself is a hard siliceous shale, and the immediately overlying sediment is relatively impoverished in diatoms. Some diatom silica was leached to silicify the fossil-plant bed, but the process was only partial. The siliceous shale of unit 4 is also probably the result of postdepositional leaching and redeposition of silica.

The different beds in the stratigraphic section at the fossil-plant locality (USGS diatom localities 5833–37) show some differences in diatom assemblages which may have significance. Localities 5833–35 show great similarity as indeed they should, for they come from adjacent beds. These beds are dominated by species of the pelagic genus *Melosira.* Localities 5836 and 5837 seem to show similarities

even though they come from beds separated by a nondiatomaceous sandy silt bed. These assemblages are characterized by a lack of *Melosira granulata* and an increased abundance of *Melosira italica* and *Cymbella cistula*. The overall assemblages of these younger beds are suggestive of somewhat shallower water than the assemblages from localities 5833–35. A possible correlation of the assemblage from USGS diatom locality 5419 with that from the fossil-plant locality (about a mile distant) merits consideration. In general the isolated locality seems to show greater affinity to the lower assemblages (localities 5833–35) than to the upper assemblages (localities 5836 and 5837). The rather rich assemblage of locality 5419 seems to be closest to that of locality 5835 at the fossil-plant site, though the evidence is not conclusive enough to make a positive correlation.

In summary, the Kilgore diatom assemblage was deposited in a shallow lake with dimensions not greater than 1 or 2 miles. The climate was temperate or cool temperate, and rainfall was sufficient to maintain the lake. The waters of the lake were hard and perhaps slightly alkaline and saline, especially during dry seasons. The lake grew progressively shallower because of filling with sediments. It eventually disappeared, and the deposits were buried by sandy sediments typical of the Valentine Formation.

SYSTEMATIC DESCRIPTIONS

The classification in this report is that used by Lohman and Andrews (1968) and is based on a proposed classification by K. E. Lohman (unpub. data). It follows Moore (1954) to the rank of class and is modified from previous classifications proposed by Schutt (1896), Karsten (1928), and Hendey (1937). The treatment of nomenclature at the generic, specific, and varietal level has been conservative, and the standard nomenclature has been preserved except in instances of obvious error. This does not imply a wholehearted endorsement of previous taxonomic work, but merely an attempt to avoid further confusion. New taxa have been described as species, as it is felt that the creation of new infraspecific taxa among the diatoms should be discouraged except under most unusual circumstances. An illustration of the absurdity of some varietal names derived from modern diatom assemblages may be in order here. This late Miocene assemblage contains a form identified as *Gomphonema affine* var. *insignis*, a taxon described as a variety from living diatom assemblages. Although the type *G. affine* may have existed somewhere in late Miocene time, it need not have. Hence we have a Miocene variety of a species for which no Miocene type existed. Such absurd situations are avoided by the use of a strictly binomial system of nomenclature.

The descriptions herein recorded are for the specimens observed in the Kilgore deposit and do not necessarily reflect the total variation of each taxon. Except for the new species, they are brief and cover only salient features. For more complete descriptions the general works cited in the synonymies should be consulted. In the synonymies the first citation is that of the original author of the taxon; second, references to the genus and species as accepted in this paper are given in chronologic order; third, synonyms and misidentifications are given in chronologic order. The most common errors, those of incorrect attributions of authorship, have been placed in the third category. References that have not been examined by the writer are marked by an asterisk. The brief comments on the ecology of modern diatom taxa are adapted from Patrick and Reimer (1966), Hustedt (1927–30, 1931–59, 1961–66), and Hustedt (1930). The known geologic ranges of the species and varieties are based on the results of this study, and some will undoubtedly be extended when older diatom assemblages are investigated.

Kingdom PROTISTA Haeckel, 1866
Subkingdom PROTOCTISTA Hogg, 1860
Division CHRYSOPHTYA Pascher, 1914
Class DIATOMOPHYCEAE Rabenhorst, 1864
Order CENTRALES Schütt, 1896
Suborder DISCINEAE Kützing, 1844
Family COSCINODISCACEAE Kützing, 1844
Subfamily MELOSIROIDEAE Kützing, 1844
Genus MELOSIRA Agardh, 1824

Melosira granulata (Ehrenberg) Ralfs

Plate 1, figures 1, 2

Gallionella granulata Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 415.

Melosira granulata (Ehrenberg) Ralfs, *in* Pritchard, 1861, History of Infusoria, p. 820.

Hustedt, 1927, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 248–252, fig. 104.

Orthosira punctata W. Smith, 1856, Synopsis of the British Diatomaceae, v. 2, p. 62, pl. 53, fig. 339.

Meloseira granulata (Ehrenberg) Ralfs. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 30.

Description.—Valves cylindrical, bound in chains of frustules; diameter about 15μ, length of valve about 9μ–15μ, with valve orientation in a strewn mount more commonly the girdle view; puncta coarse, arranged in longitudinal rows, about 11 rows in 10μ; puncta about eight to 10 in 10μ; valve ends denticulate.

Remarks.—This species is common in USGS diatom localities 5419 and 5833, and it is abundant in localities 5834 and 5835.

Living representatives of this plantonic species are common in eutrophic lakes, ponds, and streams and often occur in great abundance.

Known geologic range.—Late Miocene to present.

Melosira granulata var. angustissima Müller

Plate 1, figure 3

Melosira granulata var. *angustissima* Müller, 1899, Hedwigia, v. 38, p. 315, pl. 12, fig. 28.

Hustedt, 1927, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 250–251, fig. 104d.

Description.—Valve cylindrical, similar to the type, except that the length:width ratio is much greater; diameter commonly 4μ–5μ, length often greater than 20μ.

Remarks.—The variety occurs in the same relative abundance as the type, common in localities 5419 and 5833, and is abundant in localities 5834 and 5835.

The modern ecology of the variety is similar to that of the type.

Known geologic range.—Late Miocene to present.

Melosira italica (Ehrenberg) Kützing

Plate 1, figure 4

Gaillonella italica Ehrenberg, 1836, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1836, p. 53.

Melosira italica (Ehrenberg) Kützing, 1844, Die kieselschaligen Bacillarien oder Ditaomeen, p. 55, pl. 2, fig. 6.

Hustedt, 1927, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 257–262, fig. 109.

Lohman and Andrews, 1968, U.S. Geol. Survey Prof. Paper 593–E, p. E12, pl. 1, fig. 6.

Gallionella crenulata Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 376, pl. 2, fig. I, 41; pl. 3, fig. I, 28; pl. 4, fig. I, 31.

Melosira crenulata (Ehrenberg) Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 55, pl. 2, fig. 8.

Meloseira crenulata (Ehrenberg) Kützing. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 29.

Description.—Valves cylindrical, bound in chains of frustules, often but not always greater in height than in diameter; margin denticulate; mantle finely punctate, about 14 in 10μ, arranged in longitudinal or slightly spiral rows, about 16 in 10μ. Diameter about 10μ–20μ, height about 10μ–20μ; length:width ratio widely variable, but most specimens are seen in girdle view.

Remarks.—The rows of puncta on the Kilgore specimens tend to be more longitudinal and less spiral than in some modern forms. Along with *M. italica* there occurs a very thin walled finely punctate variety, usually seen as a single valve or attached pair in girdle view. These thin-walled valves are nearly always slightly crushed on the open ends, and this gives the appearance of a slightly flattened truncated conical valve. This apparent change from a cylindrical to a truncated conical outline appears to be a mechanical deformation and without significance in differentiating the thin-walled form from *M. italica.*

The species is common in USGS diatom localities 5834 and 5835 and abundant in localities 5419, 5836, and 5837.

M. italica is a cosmopolitan species and lives today in temperate fresh-water environments throughout the world as a pelagic form in lakes and as a littoral form in smaller bodies of water.

Known geologic range.—Late Eocene to present.

Melosira distans (Ehrenberg) Kützing

Plate 1, figure 5

Gaillonella distans Ehrenberg, 1836, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1836, p. 83–84.

Melosira distans (Ehrenberg) Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 54, pl. 2, fig. 12.

Hustedt, 1927, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 262–266, fig. 110–111.

Meloseira distans (Ehrenberg) Kützing. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 30.

Description.—Valve of relatively low height compared to diameter, recognized only in valve view in strewn mounts of the Kilgore deposit; ends of valve convex, punctate, with no discernable lineation or orderly arrangement of the coarse puncta. Diameter, about 18μ.

Remarks.—This species is common in USGS diatom locality 5419 and rare in localities 5833 and 5835.

Living representatives of the species are littoral forms and show a preference for cool fresh-water environments.

Known geologic range.—Late Miocene to present.

Order PENNALES Schütt, 1896
Suborder ARAPHIDINEAE Karsten, 1928
Family FRAGILARIACEAE Kützing, 1844
Subfamily TABELLARIOIDEAE, Kützing, 1844
Genus TETRACYCLUS Ralfs, 1843

Tetracyclus lacustris Ralfs

Plate 1, figures 6, 7

Tetracyclus lacustris Ralfs, 1843, Annals and Mag. Nat. History, v. 12, p. 105, pl. 2, fig. 2.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 12–15, fig. 545a–d.

Description.—Valve elongate with a moderate transverse swelling at center; apices rounded and on some specimens subcuneate; pseudoraphe very narrow but distinct; costae three to four in 10μ, some specimens incomplete; striae very fine. Length, 20μ–34μ; width, about 13μ.

Remarks.—*T. lacustris* has frequently been confused with *T. pagesi,* and the two species have often been placed together as a single variable species. Although doubtful specimens may occur, in most instances the two species can be readily distinguished. Patrick and Reimer (1966, p. 102, pl. 1, fig. 9) unfortunately describe as *T. lacustris* a species that seems much closer to *T. pagesi,* and their illustration is that of a rather extreme form of *T. pagesi.*

This species occurs frequently in USGS diatom locality 5835; it is rare in localities 5419, 5833, and 5834.

Living representatives of the species prefer cool standing waters.

Known geologic range.—Late Miocene to present.

Tetracyclus pagesi Héribaud

Plate 1, figures 8, 9

Tetracyclus pagesi Héribaud, 1902, Les diatomées fossiles d'Auvergne, p. 17, pl. 8, fig. 10.

Tetracyclus lacustris var. *capitata* Hustedt, *in* Schmidt, 1911, Atlas der Diatomaceenkunde, pl. 269, fig. 6.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 14, fig. 545e.

Description.—Valve elongate with highly variable degree of transverse swelling at the center; apices rounded and on some specimens slightly subcuneate; ends always distinctly capitate or subcapitate; pseudoraphe very narrow but distinct; costae three to four in 10μ, prominent; striae very fine. Length, 33μ–43μ; width, about 15μ–18μ.

Remarks.—*T. pagesi* is distinguished from *T. lacustris* by its generally larger size and its distinctive capitate or subcapitate ends. Some specimens show a much more greatly expanded central swelling than *T. lacustris,* but this characteristic is not consistent enough to be in itself definitive. Some specimens of *T. pagesi* may appear similar to *T. lacustris,* but the shape of the ends, if not the central swelling, is sufficient to distinguish the two species.

The species occurs frequently in USGS diatom locality 5419, and is rare in localities 5834–36.

Living representatives of the species are apparently similar in ecology to *T. lacustris.*

Known geologic range.—Late Miocene to present, described by Héribaud from the upper Pliocene of France.

Tetracyclus tripartitus Brun and Héribaud

Plate 1, figures 10, 11

Tetracyclus tripartitus Brun and Héribaud, *in* Héribaud, 1893, Les diatomées d'Auvergne, p. 223, pl. 6, fig. 5.

Tetracyclus tripartitus var. *gracilis* Peragallo and Héribaud *in* Héribaud, 1902, Les diatomées d'Auvergne, p. 39, pl. 8, fig. 11.

Tetracyclus lacustris var. *elongata* Hustedt *in* Schmidt, 1911, Atlas der Diatomaceenkunde, pl. 269, figs. 7, 8.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 14, fig. 545h.

Description.—Valve elongate, faintly to distinctly triundulate, with central swelling slightly exceeding the terminal swellings in width; apices rounded and on some specimens subcuneate; pseudoraphe very narrow but distinct; costæ three to four in 10μ, prominent; striæ very fine. Length, 55μ–64μ; width, about 15μ.

Remarks.—Although the internal structure of this species is similar to *T. lacustris* and *T. pagesi,* its relatively great size, distinctly triundulate lateral margins, and high length:width ratio are diagnostic of the species. Peragallo and Héribaud (in Héribaud, 1902) distinguished a variety *gracilis* based on weakly triundulate specimens. There seems to be complete intergradation, however, between the type and the variety, and the distinction appears to be artificial.

Tetracyclus tripartitus is rare in USGS diatom localities 5419 and 5835.

The modern ecology is similar to that of *T. lacustris.*

Known geologic range.—Late Miocene to present, described by Héribaud (1902) from the upper Pliocene of France.

Tetracyclus rupestris (A. Braun) Grunow

Plate 1, figures 12, 13

Gomphogramma rupestre A. Braun, *in* Rabenhorst, 1853, Die Süsswasser-Diatomaceen (Bacillarien) für Freunde der Mikroscopie, p. 33, pl. 9.*

Tetracyclus rupestris (A. Braun) Grunow, *in* Van Heurck, 1881, Synopsis des diatomées de Belgique, pl. 52, figs. 13, 14.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 15–16, fig. 547.

Description.—Valve elliptical, small, with broadly rounded apices; pseudoraphe definite but very narrow; costae four to five in 10μ, some rudimentary and not reaching the center; striae very fine. Length, 13μ–20μ; width, 9μ–11μ.

Remarks.—This species may be a small relatively unornamented form of *T. lacustris*. It does not have the characteristic shape of *T. lacustris*, however, and seems to conform to the description of *T. rupestris*. It is smaller than *T. ellipticus*.

This species is rare in USGS diatom localities 5419, 5833, and 5835.

Living representatives of the species are reported from very shallow water and moist surface environments.

Known geologic range.—Late Miocene to present.

Tetracyclus cruciformis Andrews, n. sp.

Plate 1, figures 14–17

Diagnosis.—Valve cruciform, with four extensions or arms of nearly equal length set at right angles. Pseudoraphe narrow, in part indistinct, extending to the ends of some of the four arms of the valve, but indistinct in other arms. Segments of the pseudoraphe from the arms join together in an irregular manner in the central area. Costae, two to four in 10μ, irregularly spaced, normal or diagonal to the sides of the arms, terminating or looping irregularly in the central area. Striae 17–27 in 10μ, finely punctate, oriented generally parallel to the costae and hence somewhat irregularly distributed in the central area. Length and width equal and indistinguishable from each other in the structure of the valve, ranging from 41μ to 45μ in the specimens examined.

Holotype.—USGS diatom catalog 3626–4 (pl. 1, fig. 14), length and width, 45μ.

Paratypes.—USGS diatom catalog 3626–41 (pl. 1, fig. 15), length and width, 43μ. USGS diatom catalog 3626–20 (pl. 1, fig. 16), length and width, 39μ. USGS diatom catalog 3626–31, (pl. 1, fig. 17), length and width, 41μ. All from USGS diatom locality 5836.

Remarks.—This species of *Tetracyclus* is highly distinctive in that it involves the modification of a form closely related to *T. lacustris* into a species with four arms, each usually showing a pseudoraphe. This involves a basic change in structure from the normally pennate species of the genus *Tetracyclus* to a pseudocentric form. Because of the obvious affinities for *T. lacustris*, however, there seems to be no justification for creating a new genus to accommodate this form, but it can be recognized as a distinctive species of *Tetracyclus*. This species should be an excellent marker fossil if it proves to be of widespread distribution.

A similar or perhaps identical species has been reported from the Miocene of the Lake Baikal region of the U.S.S.R. by Cheremisinova (1968). Although she has named and figured her species as *Tetracyclus floriformis* sp. nov., no formal diagnosis or description has been made as far as the writer is aware. This name, unless validly published with a description or diagnosis, has no standing under the present rules of nomenclature.

Occurs frequently in USGS diatom locality 5836, also reported from the Miocene of the U.S.S.R.

Known geologic range.—Late Miocene.

Subfamily FRAGILARIOIDEAE Kützing, 1844
Genus FRAGILARIA Lyngbye, 1819

Fragilaria brevistriata Grunow

Plate 1, figures 18, 19

Fragilaria brevistriata Grunow, *in* Van Heurck, 1885, Synopsis des diatomées de Belgique, p. 157.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 168–170, fig. 676a–e.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 128–129, pl. 4, fig. 14.

Description.—Valve linear-lanceolate with subrostrate apices; striae about 16 in 10μ, short, marginal to a central hyaline area. Length as much as 48μ; width about 6μ.

Remarks.—This species is more often seen in girdle view as chains of frustules than in valve view. Specimens from Kilgore have striae of moderate length, and they more closely resemble the species as illustrated by Patrick and Reimer (1966) than as illustrated by Hustedt (1931). The hyaline central area suggests that the Kilgore forms are closer to the modern *F. brevistriata* than to *F. virescens*.

The species is abundant in USGS diatom localities 5419 and 5836; it is rare in localities 5833 and 5835.

Living representatives of the species are tolerant of a wide range of fresh-water environments.

Known geologic range.—Late Miocene to present.

Fragilaria gigantea Lauby

Plate 1, figures 20, 21

Fragilaria gigantea Lauby, 1910, France Service Carte Géol. Bull. 125, v. 20, p. 214, pl. 9, fig. 17.

Description.—Valve large, robust, elongate with rounded subcapitate apices; margins nearly straight, but with a slight tendency to be triundulate in some specimens; pseudoraphe very faint to nonexistent; transverse striae about 11 in 10μ, parallel, coarse, strongly beaded, on some specimens continuous across the center of valve where the pseudoraphe should be located, and on some slightly separated by the pseudoraphe or discontinuous on opposite sides of a tenuous pseudoraphe; length, 60μ–100μ; width, 9μ–10μ.

Remarks.—This species in the Kilgore deposit appears to be identical with Lauby's species from the Massif Central in France. The only difference, probably not significant, is that the Kilgore specimens have about 11 striae in 10μ, whereas Lauby indicated that his specimens had 15 striae in 10μ. *F. gigantea* is a distinctive species, generally larger and more robust than most Fragilarias, but showing only vestiges of a pseudoraphe. It should be an excellent marker fossil.

Lauby (1910, p. 125, 331) reported this species from one locality, the Route du Mont-Dore à Besse in the Department of Puy-de-Dôme, France. Although he indicates that the deposit is Plaisancian (early Pliocene) in age, this stage is now considered to be of middle Pliocene age (Wood and others, 1941). *F. gigantea* occurs frequently in USGS diatom locality 5419, rare in localities 5834 and 5835.

Known geologic range.—late Miocene to middle Pliocene.

Genus SYNEDRA Ehrenberg, 1830

Synedra rumpens Kützing

Plate 1, figure 22

Synedra rumpens Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 69, pl. 16, fig. 6.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 207–208, fig. 697.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 143, pl. 5, fig. 19.

Description.—Valve linear, tapering to small subcapitate apices; pseudoraphe narrow; central area extends to lateral margins and is longer than it is wide; valve margins show a suggestion of swelling along central area; striæ about 13 in 10μ. Length about 35μ; width about 4μ.

Remarks.—The species is rare in USGS diatom locality 5835.

Living representatives of the species are widely distributed in standing or slow-flowing fresh waters.

Known geologic range.—Late Miocene to present.

Synedra ulna (Nitzsch) Ehrenberg

Plate 1, figure 23

Bacillaria ulna Nitzsch, 1817, Naturf. Gesell. Halle, Neue Schr. v. 3, no. 1, p. 99–104, pl. 5.

Synedra ulna (Nitzsch) Ehrenberg, 1836, Kgl. preuss. Akad. Wiss. Berlin, Ber. 1836, p. 53.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 195–201, fig. 691A, a–c.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 148–149, pl. 7, figs. 1, 2.

Description.—Valve linear, very gradually tapering to small subrostrate apices; pseudoraphe very narrow; hyaline central area formed by lack of marginal striae; striae about 10 in 10μ, parallel. Length as much as 216μ; width about 4μ.

Remarks.—This species is frequent as fragments in USGS diatom localities 5419, 5834, and 5835, and it is rare in locality 5837.

Living representatives of the species are common and widely distributed in fresh-water environments.

Known geologic range.—Late Miocene to present.

Suborder RAPHIDIOIDINAE Karsten, 1928
Family EUNOTIACEAE Kützing, 1844
Genus EUNOTIA Ehrenberg, 1837

Eunotia parallela Ehrenberg

Plate 1, figure 24

Eunotia parallela Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 414.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 302, fig. 768.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 193, pl. 10, fig. 12.

Description.—Valve with parallel dorsal and ventral margins; slightly concave ventral margin and slightly convex dorsal margin, flexed a little in opposite direction near the rounded apices; striæ about 12 in 10μ, somewhat irregular in spacing, parallel. Length, 45μ–87μ; width, about 6μ–10μ.

Remarks.—The species is frequent in USGS diatom locality 5419 and rare in localities 5834 and 5835.

Living representatives of the species are more common in cool or cold fresh waters.

Known geologic range.—Late Miocene to present.

Eunotia pectinalis var. minor (Kützing) Rabenhorst

Plate 1, figure 25

Himatidium minus Kützing, 1844, Die kieselschaligan Bacillarien oder Diatomeen, p. 39, pl. 16, fig. 10.

Eunotia pectinalis var. *minor* (Kützing) Rabenhorst, 1864. Flora Europaea Algarum, sect. 1, p. 74.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 298, fig. 763d–f.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 207, pl. 12, figs. 12, 13.

Description.—Ventral margin slightly concave, dorsal margin somewhat more convex; dorsal margin somewhat pinched in, which narrows the valve near the rounded apices; striæ about 14 in 10μ, parallel, irregularly spaced. Length, 24μ–38μ; width, about 7μ.

Remarks.—The species occurs frequently in USGS diatom locality 5419 and is rare in localities 5835 and 5836.

Living representatives of the species occur in acid to circumneutral water, but it will tolerate some calcium carbonate.

Known geologic range.—Late Miocene to present.

Suborder MONORAPHIDINEAE Karsten, 1928
Family ACHNANTHACEAE Kützing, 1844
Subfamily ACHNANTHOIDEAE Schütt, 1896
Genus ACHNANTHES Bory, 1822

Achnanthes hungarica (Grunow) Grunow

Plate 1, figures 26, 27

Achnanthidium hungaricum Grunow, 1863, Kaiserl.-kgl. zool.-bot. Gesell. Wien Verh., v. 13, p. 146, pl. 4, fig. 8a–c.

Achnanthes hungarica (Grunow) Grunow, *in* Cleve and Grunow, 1880, Kgl. svenska vetensk. akad. Handl., v. 17, no. 2, p. 20.

Hustedt, 1933, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 383–384, fig. 829.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 259, pl. 16, figs. 27, 28.

Description.—Valves elliptical with subcuneate apices; raphe valve with narrow linear axial area widening abruptly at the central area to form a hyaline stauros extending to the margins of the valve; raphe fine, terminating in rather prominent central pores and distal ends flexed in opposite directions near the apices of the valve; striæ faint, slightly radiate. Pseudoraphe valve with narrow pseudoraphe, only slightly expanded at central area; striæ slightly radiate, somewhat more pronounced than on raphe valve; striæ about 18 in 10μ on both valves. Length, about 20μ; width, about 8μ.

Remarks.—The species as observed in the Kilgore deposit is somewhat more elliptical than specimens figured by Patrick and Reimer (1966) and more closely resembles the figures of Hustedt (1933).

Achnanthes hungarica is rare in USGS diatom locality 5835.

Living representatives of the species are rare and occur in fresh, alkaline, or slightly saline lakes or ponds.

Known geologic range.—Late Miocene to present.

Suborder BIRAPHIDINEAE Karsten, 1928
Family NAVICULACEAE Kützing, 1844
Subfamily NAVICULOIDEAE Kützing, 1844
Genus STAURONEIS Ehrenberg, 1843

Stauroneis phoenicenteron (Nitzsch) Ehrenberg

Plate 2, figure 1

Bacillaria phoenicenteron Nitzsch, 1817, Naturf. Gesell. Halle, Neue Schr. v. 3, no. 1, p. 92–97, pl. 4, figs. 12, 14.

Stauroneis phoenicenteron (Nitzsch) Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 387, pl. 2, fig. V; pl. 3, fig. I, 17.

Hustedt, 1959, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 766–770, fig. 1118a.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 359, pl. 29, figs. 1, 2.

Description.—Valve lanceolate with rounded somewhat protracted apices; striae 14–16 in 10μ, radiate, sharply punctate; puncta irregularly placed on the striæ, which terminate with a somewhat ragged margin along the axial area; stauros slightly expanding because of the radiating striae. Length, 75μ–117μ; width, 17μ–22μ.

Remarks.—The Kilgore specimens are distinctly convex on the lateral margins, and resemble *S. phoenicenteron* f. *gracilis* as figured by Patrick and Reimer (1966, pl. 29, figs. 3, 4). However, the coarser striation of the Kilgore forms place them within the limits of *S. phoenicenteron*. The only criterion for the differentiation of f. *gracilis* from the type seems to be arbitrary, with specimens having more than 17 striæ in 10μ being referred to f. *gracilis*.

Occurs frequently in USGS diatom localities 5419 and 5835.

Living representatives of this species have a broad pH tolerance and are common and widespread in many fresh-water environments.

Known geologic range.—Late Miocene to present.

Stauroneis anceps Ehrenberg

Plate 2, figure 2

Stauroneis anceps Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 422, pl. 2, fig. I, 18.

Hustedt, 1959, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 771–775, fig. 1a.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 361, pl. 30, fig. 1.

Description.—Valve elliptical-lanceolate with protracted subrostrate apices. Axial area narrow, linear, widening in the central area to the margins as a parallel-sided stauros. Striae slightly radiate, about 22 in 10μ, finely but distinctly punctate. Length, 38μ–42μ; width, about 9μ.

Remarks.—This species shows an obvious relationship to *S. phoenicenteron*, but it is generally smaller and more finely striated.

The species occurs frequently in USGS diatom locality 5419.

Living representatives of the species are widespread in fresh-water environments and tolerant of a considerable range in pH.

Known geologic range.—Late Miocene to present.

Stauroneis smithii Grunow

Plate 2, figure 3

Stauroneis smithii Grunow, 1860, Kaiserl.-kgl. zool.-bot. Gesell. Wien Verh., v. 10, p. 564–565, pl. 4, fig. 16.

Hustedt, 1959, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 810–813, fig. 1157a–c.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 365, pl. 30, fig. 12.

Description.—Valve markedly triundulate, terminating in small rostrate-apiculate ends; central undulation wider than terminal undulations; prominent pseudoseptum. Axial area linear, widening centrally into a parallel-sided stauros; striae very fine, punctate. Length, about 26μ; width about 7μ.

Remarks.—Rare in USGS diatom locality 5836.

Living representatives of this species show a preference for alkaline waters.

Known geologic range.—Late Miocene to present.

Stauroneis lauenburgiana Hustedt

Plate 2, figures 4–6

Stauroneis lauenburgiana Hustedt, 1950, Archiv für Hydrobiologie, v. 6, p. 405, pl. 37, fig. 15.

Hustedt, 1959, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 808–809, fig. 1155a, b.

Description.—Valve lanceolate to elongate with produced rostrate to subrostrate apices; short pseudoseptum; axial area varies in width because of irregular length of the striae; central area widened into a stauros with nearly parallel sides; striae about 19 in 10μ, very slightly radiate, formed by irregularly spaced puncta; punctation anomoeonoid with puncta showing a disorderly longitudinal alinement. Length, 40μ–48μ; width, about 9μ–10μ.

Remarks.—This species occurs frequently in USGS diatom locality 5836 and is rare in locality 5837.

Living representatives of the species have been reported from both standing and flowing fresh water.

Known geologic range.—Late Miocene to present.

Genus ANOMOEONEIS Pfitzer, 1871

Anomoeoneis sphaerophora (Ehrenberg) Pfitzer

Plate 2, figure 7

Navicula sphaerophora Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 419, pl. 3, fig. IV, 3.

Anomoeoneis sphaerophora (Ehrenberg) Pfitzer. Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 374–375, pl. 32, fig. 1.

Anomoeoneis sphaerophora (Kützing) Pfitzer, 1871, Untersuchungen über Bau und Entwicklung der Bacillariaceen (Diatomaceen), p. 77–78, pl. 3, fig. 10.

Hustedt, 1959, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 740–744, fig. 1108a.

Description.—Valve elliptical-lanceolate with extended rostrate apices; axial area narrow, linear, broadening into a transversely elliptical, asymmetric central area; striae about 18 in 10μ, slightly radiate; composed of irregularly spaced puncta, partly oriented in irregular longitudinal rows. Length about 42μ; width about 14μ.

Remarks.—This species, as it occurs in the Kilgore deposit, has some features differing from living forms. Although the central area tends to be asymmetrical, the areas between the raphe and the lateral margins tend to be filled with normal puncta and not hyaline as in modern specimens. These hyaline areas in modern specimens often show vestiges of puncta that no longer exist in those areas. The Kilgore forms, therefore, may be more primitive forms of *A. sphaerophora* in which the lateral puncta are fully developed.

This species is rare in USGS diatom locality 5836.

Modern representatives of this fresh-water species show some preference for alkaline water and are tolerant of some salt concentration.

Known geologic range.—Late Miocene to present.

Genus NEIDIUM Pfitzer, 1871

Neidium iridis var. ampliata (Ehrenberg) Cleve

Plate 2, figure 8

Navicula ampliata Ehrenberg, 1854, Mikrogeologie, pl. 15A, figs. 32, 35?

Neidium iridis var. *ampliata* (Ehrenberg) Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 69.

Hustedt *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 245, fig. 381.

Neidium iridis var. *ampliatum* (Ehrenberg) Cleve. Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 388, pl. 34, fig. 5.

Description.—Valve linear-elliptical with broad subrostrate apices; axial area narrow, widening abruptly to form a small rounded central area; striae about 17 in 10μ, slightly oblique, sharply punctate. Length, about 79μ–86μ; width, about 22μ.

Remarks.—This species occurs frequently in USGS diatom locality 5836.

Living representatives of this species are more common in standing than in flowing water, and they are tolerant of a wide range in pH.

Known geologic range.—Late Miocene to present.

Genus NAVICULA Bory, 1822

Navicula amphibola Cleve

Plate 2, figure 9

Navicula amphibola Cleve, 1891, Soc. pro Fauna et Flora Fennica, Acta, v. 8, no. 2, p. 33.

Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 45.

Hustedt, 1966, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 3, p. 792–795, fig. 1767.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 445, pl. 39, figs. 7, 8.

Description.—Valve elliptical-lanceolate with sharply rostrate, rounded apices; axial area narrow, widening abruptly to form a transverse central area by the irregular shortening of the adjacent striae; striae about seven to eight in 10μ, radiate, slightly irregular, widely spaced, and ornamented with distinct puncta. Length, 33μ–62μ; width, about 15μ–20μ.

Remarks.—This species is common in USGS diatom locality 5836, frequent in localities 5419 and 5834, and rare in localities 5835 and 5837.

Living representatives of the species are common in circumneutral waters.

Known geologic range.—Late Miocene to present.

Navicula niobrara Andrews, n. sp.

Plate 2, figures 10, 11

Diagnosis.—Valve lanceolate with subrostrate rounded apices; axial area about 1/5–1/6 the width of the valve, tapering toward the apices, but nearly constant in width approaching the central area, which is distinctly rounded; diameter about one-third the width of the valve; margins of the axial and central areas slightly ragged because of the uneven length of adjacent striae; raphe straight, inclined to the plane of the valves, terminating in pores slightly deflected toward one side of the central area; striae six to nine in 10μ, irregular in length and spacing, distinctly separated, divergent; puncta fine but distinct, about 15–16 in 10μ. Length, 102μ–120μ; width, 36μ–40μ.

Holotype.—USGS diatom catalog 3626–29 (pl. 2, fig. 10); length, 104μ; width, 39μ.

Paratype.—USGS diatom catalog 3626–33 (pl. 2, fig. 11); length, 110μ; width, 37μ. Both from USGS diatom locality 5836.

Remarks.—This species is similar in size and general outline to *N. maculata* (J. W. Bailey) Cleve, but differs considerably in ornamentation. These differences from *N. maculata* include: a wider axial area and rounder central area, much finer punctation and consequent wider spacing of the striae, lateral deflection of the central pores. *N. niobrara* may be included in the subgeneric group termed *Naviculae punctatae* by Cleve (1895, p. 37). The species has a large but thin valve, and it is more commonly found in the Kilgore deposit as fragments than as whole specimens. Because of its large size and distinctive punctation, *N. niobrara* should be an excellent marker fossil.

Occurs frequently in USGS diatom locality 5419 and is common in localities 5836 and 5837.

Known geologic range.—Late Miocene.

Navicula actinota Andrews, n. sp

Plate 2, figures 12, 13

Diagnosis.—Valve elliptical-lanceolate with rostrate to subapiculate apices; axial area about one-sixth or one-seventh the width of the valve, narrowing toward the apices and widening to a transversely elliptical central area. Raphe filamentous, terminating in prominent pores at the central area; striae eight to nine in 10μ, distinctly separated, divergent throughout the length of the valve; puncta eight to 12 in 10μ, dotlike near the axial area, but elongating to become rodlike or raylike parallel to the striae nearer the margins of the valve; raylike puncta appear to have sharp, rectangular corners. Length, 51μ–57μ; width, 22μ–24μ.

Holotype.—USGS diatom catalog 3626–11 (pl. 2, fig. 12); length, 51μ; width, 22μ.

Paratype.—USGS diatom catalog 3626–34 (pl. 2, fig. 13); length, 57μ; width, 24μ.

Remarks.—*N. actinota* falls within Cleve's subgeneric group *Naviculae punctatae,* and it is generally similar in external shape to several species within that group. The most distinctive characteristic of this species is the peculiar shape of the rectangular raylike puncta. These puncta are elongated in the direction of the striae, and their sharply angular corners are striking. Because of its highly distinctive punctation, *N. actinota* should be a useful marker fossil.

Rare in USGS diatom locality 5836.

Known geologic range.—Late Miocene.

Navicula cuspidata (Kützing) Kützing

Frustulia cuspidata Kützing, 1833, Linnaea, v. 8, p. 549, pl. 14, fig. 26.

Navicula cuspidata (Kützing) Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 94, pl. 3, figs. 24, 37.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 464, pl. 43, figs. 9, 10.

Navicula cuspidata forma *genuina* Hustedt, 1961, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 3, p. 59–64, fig. 1206a.

Description.—Valve lanceolate with small attenu-

ated rounded apices; axial area narrow, expanding only slightly at central area; striae fine, 13 or more in 10μ, parallel; longitudinal rows of puncta can be seen only at high magnification.

Remarks.—The valves of this species are very thin and fragile and only broken specimens were observed. The differences between *N. cuspidata* and *N. halophila* as described in the literature are not striking, and the Kilgore specimens could possibly be assigned to *N. halophila*. The coarseness of the striae has, however, suggested that they be placed in *N. cuspidata*.

This species is rare in USGS diatom localities 5836 and 5837.

Living representatives of the species are widespread in many fresh-water environments.

Known geologic range.—Late Miocene to present.

Navicula bacillum Ehrenberg

Plate 2, figure 14

Navicula bacillum Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 418, pl. 4, fig. V, 8.

Hustedt, 1961, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 3, p. 113–115, fig. 1248a–d.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 494–495, pl. 47, figs. 4, 5.

Description.—Valve linear, with rounded apices; axial area narrow, widening into a longitudinally elliptical central area; striae about 18 in 10μ at the center, finer near the apices; striae radiate and curved, convex toward the apices. Length, 28μ–47μ; width, about 7μ–10μ.

Remarks.—The species occurs frequently in USGS diatom locality 5419 and is rare in localities 5834, 5836, and 5837.

Living representatives of the species are found in fresh to slightly saline waters and are tolerant of alkalinity.

Known geologic range.—Late Miocene to present.

Navicula radiosa Kützing

Plate 2, figure 15

Navicula radiosa Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 91, pl. 4, fig. 23.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 299, fig. 513.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 509, pl. 48, fig. 15.

Description. — Valve lanceolate with sharply rounded apices; axial area narrow, widening slightly to form a rather ill-defined central area; striae about 13 in 10μ, intensely radiate at the center, but becoming slightly convergent near the apices; center striae shortened to accommodate the great divergence of the striae near the center of the valve. Length about 38μ; width about 8μ.

Remarks.—This species is rare in USGS diatom locality 5835.

Living representatives of the species are common in circumneutral fresh water and are tolerant of some salinity.

Known geologic range.—Late Miocene to present.

Navicula graciloides A. Mayer

Plate 2, figure 16

Navicula graciloides A. Mayer, 1919, Kryptogamische Forschungen, Bayerische botanische Gesellschaft, München, v. 1, no. 4, p. 203, 212, pl. 7, fig. 60*

Hustedt *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 299, fig. 515.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 516, pl. 49, figs. 9, 10.

Description. — Valve linear to lanceolate with rounded slightly subrostrate apices; axial area narrow, expanding to a transversely oval central area by shortening of the marginal striae; striae about nine to 10 in 10μ, strongly radiate, curved. Length about 41μ–43μ; width, about 10μ–11μ.

Remarks.—This species is rare in USGS diatom localities 5419 and 5835.

Living representatives of the species occur in fresh to slightly saline circumneutral waters.

Known geologic range.—Late Miocene to present.

Navicula anglica var. subsalsa (Grunow) Cleve

Plate 2, figure 17

Navicula tumida var. *subsalsa* Grunow, 1860, Kaiserl.-kgl. zool.-bot. Gesell, Wien Verh., v. 10, p. 537, pl. 2, fig. 43b, c.

Navicula anglica var. *subsalsa* (Grunow) Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 22.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 303.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 520–521, pl. 49, fig. 20.

Description.—Valve lanceolate with subrostrate, broadly rounded apices. Axial area very narrow, widening abruptly to a transversely elliptical central area. Striae about 11 in 10μ, radiate, curved convexly toward the apices. Length, about 25μ; width, about 9μ.

Remarks.—This species is rare in USGS diatom locality 5834.

Living representatives of this species prefer hard or slightly saline, circumneutral waters.

Known geologic range.—Late Miocene to present.

Navicula elginensis (Gregory) Ralfs

Plate 2, figure 18

Pinnularia elginensis Gregory, 1856, Quart. Jour. Micr. Sci., v. 4, p. 9, pl. 1, fig. 33*.

Navicula elginensis (Gregory) Ralfs, *in* Pritchard, 1861, History of Infusoria, p. 902.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 524–525, pl. 5, fig. 3.

Navicula dicephala (Ehrenberg) W. Smith. Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 302–303, fig. 526.

Description.—Valve linear to lanceolate with rostrate to subcapitate apices; axial area narrow, widening at the center to form a rounded central area; striae about 11 in 10μ, radiate, slightly curved and convex toward the apices. Length, 29μ–30μ; width, about 9μ–10μ.

Remarks.—This species occurs in all of the samples studied from Kilgore. It is common in USGS diatom locality 5836, frequent in locality 5419, and rare in localities 5833–5835 and 5837.

Living representatives of the species are widespread in slightly saline and in fresh-water environments.

Known geologic range.—Late Miocene to present.

Navicula elginensis var. rostrata (A. Mayer) Patrick

Plate 2, figure 19

Navicula dicephala var. *rostrata* A. Mayer, 1917, Kgl. Bayern botanischen Gesellschaft Denkschriften, v. 13 (N.F. 7), p. 114, pl. 1, fig. 42a, b.*

Navicula elginensis var. *rostrata* (A. Mayer) Patrick, *in* Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon 13, p. 526, pl. 50, fig. 6.

Remarks.—This variety is distinguished from the type on the basis of its subrostrate to rostrate apices. Other characteristics and modern ecology are similar to those of the type.

The variety occurs frequently in USGS diatom locality 5419.

Known geologic range.—Late Miocene to present.

Genus PINNULARIA Ehrenberg, 1840

Pinnularia subcapitata var. paucistriata (Grunow) Cleve

Plate 3, figure 1

Navicula subcapitata var. *paucistriata* Grunow, *in* Van Heurck, 1880, Synopsis des diatomées de Belgique, pl. 6, fig. 23.

Pinnularia subcapitata var. *paucistriata* (Grunow) Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 75.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 597, pl. 55, fig. 11.

Pinnularia subcapitata var. *paucistriata* Grunow. Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 317.

Description.—Valve linear with rounded apices; axial area narrow near apices, widening uniformly to central area, which is a transverse fascia because of lack of striae along the lateral margins; striae about 11 in 10μ, slightly radiate near the center, slightly convergent near the apices. Length, about 27μ; width about 8μ.

Remarks.—This variety is similar to modern forms, but the apices do not appear to be at all rostrate.

Rare in USGS diatom locality 5833.

Modern representatives of this variety prefer fresh water of low mineral content.

Known geologic range.—Late Miocene to present.

Pinnularia brevicostata Cleve

Plate 3, figure 2

Pinnularia brevicostata Cleve, 1891, Soc. pro Fauna et Flora Fennica, Acta, v. 8, no. 2, p. 25, pl. 1, fig. 5.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 329–330, fig. 609.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 623, pl. 60, fig. 1.

Description.—Valve linear with a slight expansion at the center; rounded apices; axial area about half the width of the valve; striae short, 12 in 10μ, slightly radiate, very slightly shortened at the central area. Length about 53μ; width about 11μ.

Remarks.—This species is rare in USGS diatom locality 5419.

Living representatives of the species prefer cool waters of low mineral content.

Known geologic range.—Late Miocene to present.

Pinnularia clevei Patrick

Plate 3, figure 3

Pinnularia clevei Patrick, 1945, Farlowia, v. 2, no. 2, p. 193, pl. 3, figs. 9, 10.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 628–629, pl. 61, fig. 3.

Description.—Valve elongate but slightly expanded

near the center; axial area about a third the width of the valve; costae, seven in 10μ, slightly radiate in the center but convergent near the apices; costae crossed by a longitudinal band; central area slightly asymmetrical but only vaguely differentiated from the axial area. Length about 113μ; width about 21μ.

Remarks.—This species is rare in USGS diatom locality 5835.

Living representatives of the species have widespread distribution in freshwater environments.

Known geologic range.—Late Miocene to present.

Pinnularia torta (Mann) Patrick

Plate 3, figures 4, 5

Navicula torta Mann, 1924, Washington Acad. Sci. Jour., v. 14, p. 31, pl. 4, fig. 6.

Pinnularia torta (Mann) Patrick, *in* Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 634, pl. 63, fig. 3.

Pinnularia major var. *asymmetrica* Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 89, pl. 1, fig. 22.

Description.—Valve linear with rounded ends, on some specimens slightly swollen in the center; axial area about ¼–⅓ the width of the valve, noticeably asymmetrical to the center line; raphe about centrally located in the axial area, filamentous, oblique to the plane of the valves; central area rounded, slightly expanded in direction of the deflection of the central pores of the raphe; costae about eight in 10μ, moderately radiate at the center and convergent at the ends, some specimens flexed to an attenuated S-shape, crossed by a broad longitudinal band. Length, 112μ–196μ; width, 20μ–28μ.

Remarks.—The specimens of *P. torta* observed in the Kilgore deposit appear to be somewhat less asymmetrical with regard to raphe and axial area than that figured by Patrick and Reimer (1966, pl. 63, fig. 3).

The species is rare in USGS diatom localities 5419, 5834, and 5836.

Living representatives of the species prefer standing acid waters of low mineral content.

Known geologic range.—Late Miocene to present.

Pinnularia viridis (Nitzsch) Ehrenberg

Plate 3, figure 6

Bacillaria viridis Nitzsch, 1817, Naturf. Gesell. Halle, Neue Schr. v. 3, no. 1, p. 97–98, pl. 6, figs. 1–3.

Pinnularia viridis (Nitzsch) Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 305, 385, pl. 1, fig. I, 7, fig. III, 3; fig. IV, 3; pl. 2, fig. I, 22, fig. III, 1, fig. V, 2, fig. VI, 21; pl. 3, fig. I, 1, 2.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 334–335, fig. 617a.

Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 639, pl. 64, fig. 5.

Description.—Valve linear, tapering toward rounded apices; axial area narrow, widening slightly to form a small rounded, asymmetrical central area; raphe complexly twisted; costae six to eight in 10μ, slightly radiate at center and becoming slightly divergent near the apices and crossed by a well-defined longitudinal band. Length, 86μ–121μ; width, 17μ–20μ.

Remarks.—The species occurs frequently in USGS diatom localities 5419 and 5835.

Living representatives of this species prefer circumneutral water but are tolerant of waters with a high mineral content.

Known geologic range.—Late Miocene to present.

Family CYMBELLACEAE Agardh, 1830
Genus CYMBELLA Agardh, 1830

Cymbella naviculiformis Auerswald

Plate 3, figure 7

Cymbella naviculiformis Auerswald, *in* Rabenhorst, 1861, Die Algen Europa's, no. 1065.*

Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 166.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 281.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 356–357, fig. 653.

Description. — Valve elliptical-lanceolate, slightly asymmetrical, with protracted rostrate apices; axial area narrow, widening into a rounded central area; raphe off center, slightly convex toward the dorsal side; striae, about 12 in 10μ, radiate, finely punctate. Length, 34μ–43μ; width, about 12μ.

Remarks.—This species occurs frequently in USGS diatom localities 5419 and 5837, and it is rare in locality 5835.

C. naviculiformis is a common and widespread fresh-water diatom species.

Known geologic range.—Late Miocene to present.

Cymbella ehrenbergii Kützing

Plate 3, figure 8

Cymbella ehrenbergii Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 79, pl. 6, fig. 11.

Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 165.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 275.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 356, fig. 656.

Description.—Valve lanceolate, slightly asymmetric with slightly protracted subrostrate apices; raphe slightly off center but nearly straight; axial area narrow, widening into a rounded asymmetric central area; striae nine to 11 in 10μ, irregularly spaced and formed of distinct closely spaced puncta. Length, 48μ–58μ; width, about 17μ.

Remarks.—The species is common in USGS diatom locality 5419 and rare in localities 5834 and 5835.

Modern representatives of this species are common and widespread in many fresh-water environments.

Known geologic range.—Late Miocene to present.

Cymbella cistula (Hemprich) Grunow

Plate 3, figure 9

Bacillaria cistula Hemprich, *in* Ehrenberg, 1828, Symbolae physicae (Phytozoa), pl. 2, fig. IV, 10.*

Cymbella cistula (Hemprich) Grunow, *in* Van Heurck, 1880, Synopsis des diatomées de Belgique, p. 64, pl. 2, fig. 12.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 280.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 363, fig. 676a.

Cymbella cistula Hemprich. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 173.

Description.—Valve markedly asymmetric, with a convex dorsal side and a concave ventral side that often shows a slight swelling in center; apices rounded; raphe off center; axial area narrow, expanding to a rounded central area on some specimens; striae about eight in 10μ, coarsely punctate, radial; striae on the ventral side terminate in a row of very coarse isolated puncta along the margin of the central area. Length, 92μ–150μ; width, about 25μ.

Remarks.—This species occurs in all samples studied for this report. It is abundant in USGS diatom localities 5419 and 5836, common in locality 5837, frequent in locality 5835, and rare in localities 5833 and 5834.

Modern representatives of the species are widespread and common in fresh-water environments.

Known geologic range.—Late Miocene to present.

Cymbella cistula var. maculata (Kützing) Van Heurck

Plate 3, figure 10

Frustulia maculata Kützing, 1834, Algarum aquae dulcis Germinacarum, Dec. no. 85.*

Cymbella cistula var. *maculata* (Kützing) Van Heurck, 1880, Synopsis des diatomées de Belgique, p. 64, pl. 2, figs. 16, 17.

Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 173.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 363, fig. 676b.

Cymbella cistula maculata (Kützing) A. Schmidt. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 280.

Remarks.—*C. cistula* var. *maculata* is similar to the type variety, except that the axial area does not expand to form a distinct central area and the row of conspicuous heavy puncta on the ventral side of the central area is lacking.

This variety is common in USGS diatom locality 5419 and frequent in localities 5834–5836.

Living representatives of the variety are frequently found in association with the type and are common and widespread in fresh-water environments.

Known geologic range.—Late Miocene to present.

Cymbella tumida (Brébisson) Van Heurck

Plate 3, figure 11

Cocconema tumidum Brébisson, *in* Kützing, 1849, Species Algarum, p. 60.*

Cymbella tumida (Brébisson) Van Heurck, 1880, Synopsis des diatomées de Belgique, p. 64, pl. 2, fig. 10.

Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 176.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 280.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 366, fig. 677.

Description.—Valve cymbiform, with convex dorsal side and nearly straight ventral side marked by a broad but slight central swelling; apices small, rounded, subrostrate; raphe central, but markedly curved; axial area narrow near the apices, tapering wider toward the center, and expanded to form a small central area; striae eight to 10 in 10μ, ornamented with heavy puncta; striae mostly normal to the raphe but slightly radial near the apices. A distinctive feature is the presence of a single coarse punctum on the ventral side of the central area. Length about 34μ; width about 14μ.

Remarks.—The species occurs frequently in USGS diatom locality 5837.

Living representatives of the species are widespread in fresh-water environments, but they are seldom found in abundance.

Known geologic range.—Late Miocene to present.

Family GOMPHONEMACEAE Kützing, 1844
Genus GOMPHONEMA Agardh, 1824

Gomphonema affine Kützing

Gomphonema affine Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 86, pl. 30, fig. 54.

Grunow, *in* Van Heurck, 1880, Synopsis des diatomées de Belgique, pl. 24, figs. 8, 9.

Gomphonema lanceolatum Cleve, 1894 [non Ehrenberg, 1843], Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 183.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 376, fig. 700.

Gomphonema lanceolatum Cleve, 1894 [non Kützing, 1844]. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 295.

Remarks.—It is evident from the examination of the pertinent literature that Cleve (1894, p. 183) based both his *G. lanceolatum* and his *G. gracile* var. *lanceolata* on *G. lanceolatum* Ehrenberg. As was pointed out by Andrews (1966, p. A19), only *G. gracile* var. *lanceolata* of Cleve and others conforms to Ehrenberg's original description of *G. lanceolatum*. Therefore, the *G. lanceolatum* of Cleve (1894), Boyer (1927), Hustedt (1930), and others, is an invalid name, and it should be replaced. It is here proposed that the name *Gomphonema affine* Kutzing, 1844, replace the name *Gomphonema lanceolatum* Cleve, 1894 [non Ehrenberg, 1843].

The type of *Gomphonema affine* does not occur in the Kilgore deposit, but this nomenclatural problem must be resolved before discussing a variety of the species.

Gomphonema affine var. insignis (Gregory) Andrews, n. comb.

Plate 3, figures 12–16

Gomphonema insigne Gregory, 1856, Micros. Soc. Quart. Jour., v. 4, p. 12, pl. 1, fig. 39.

Grunow, *in* Van Heurck, 1880, Synopsis des diatomées de Belgique, pl. 24, figs. 39–41.

Gomphonema lanceolatum var. *insignis* (Gregory) Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 183.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 376, fig. 701.

Gomphonema lanceolatum insigne (Gregory) Cleve. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 295.

Description.—Valve lanceolate-clavate to nearly lanceolate, rounded on the upper end but somewhat more acutely pointed on the lower end; axial area about one-fourth the width of the valve; central area asymmetrical, formed by shortening of a single stria on one side of the valve; a single stigma on opposite side of valve from the shortened central stria; raphe filamentous, with small terminal pores deflected toward the stigma; striae six to nine in 10μ, fine, sharply punctate. Length, 29μ–84μ; width, 9μ–12μ.

Remarks.—The most distinctive characteristic of *G. affine* var. *insignis* in the Kilgore deposit is its high degree of variability both in external shape and internal ornamentation. The great variation in length together with nearly constant width causes considerable variation in external form. Some of the longer specimens resemble *G. intricatum* or even *G. intricatum* var. *vibrio* in external outline. In addition there is considerable variation in the fineness of the striae, whereas the spacing of the striae remains relatively constant. These factors seem, however, to indicate only a high degree of variation within a single taxon. Because of the intergradation between individuals in the population, any attempt at differentiating the taxon into several species or varieties seems to be both arbitrary and useless.

Common in USGS diatom localities 5419 and 5836; occurs frequently in localities 5833–5835 and 5837.

Living representatives of this variety are common in a wide range of fresh-water environments.

Known geologic range.—Late Miocene to present.

Family NITZSCHIACEAE Grunow, 1860
Subfamily NITZSCHIOIDEAE Grunow, 1860
Genus HANTZSCHIA Grunow, 1880

Hantzschia elongata (Hantzsch) Grunow

Nitzschia vivax var. *elongata* Hantzsch, 1860, Hedwigia, v. 2, no. 6, p. 35–36, pl. 6, fig. 5.

Hantzschia elongata (Hantzsch) Grunow, *in* Cleve and Grunow, 1880, Kgl. svenska vetensk. akad. Handl., v. 17, no. 2, p. 104.

Hustedt, *in* Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 395, fig. 751.

Hantzschia elongata Grunow. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 528.

Description.—Valve linear, elongate, tapering somewhat abruptly to capitate apices; keel puncta about five in 10μ; transverse striae about 12 in 10μ, distinct and finely punctate. Length, more than 140μ; width about 12μ–13μ.

Remarks.—This very long, slender species is found only as fragments in the Kilgore deposit. This fragmentation, together with a rather strong twisting of the keel near the apices, causes great difficulty in the preparation of a photomicrograph of the species at high magnification.

Hantzschia elongata occurs frequently in USGS diatom locality 5836.

Living representatives of the species are widespread in fresh-water environments.

Known geologic range.—Late Miocene to present.

Genus NITZSCHIA Hassall, 1845

Nitzshia calva Andrews, n. sp.

Plate 3, figures 17–20

Diagnosis.—Valve linear-lanceolate with slight central constriction and tapering to narrowly rounded or slightly rostrate apices; keel puncta variable, averaging about eight to nine in 10μ; transverse striae fine, punctate, about 22 in 10μ; transverse striae fringe the margins of the valve only and end irregularly as scattered puncta around a hyaline area at the center of the valve; rare puncta are scattered in central hyaline area; fringing striae are longer on the keel side of the valve. Length, about 70μ–80μ; width, about 12μ, slightly less at center.

Remarks.—*N. calva* shows obvious affinities for the group Tryblionellae (Grunow, in Cleve and Grunow, 1880, p. 67), but it is much more finely striated than most modern species of this group. The species most closely resembles *N. plana* W. Smith, as figured by Hendey (1964, pl. 39, fig. 7), a brackish-water species from the coastal waters of Great Britain. *N. calva,* however, as it occurs in the Kilgore deposit, is smaller, more finely striated, and has finer keel puncta than *N. plana.* The apices of *N. calva* are also somewhat more attenuated. *N. calva* shows similarities to *N. fremontensis* Lohman and Andrews (1968) from the upper Eocene of Wyoming. It differs from the latter species, however, in the slightly greater biconstriction of the valves and in the central hyaline area. *N. fremontensis* does show some central break down of the transverse striae into individual puncta, but it shows nothing suggesting the central hyaline area which is a distinctive feature of *N. calva.*

Holotype.—USGS diatom catalog 3626–43 (pl. 3, figs. 17, 18), length, 76μ; width, 12μ.

Paratype.—USGS diatom catalog 3626–37 (pl. 3, figs. 19, 20) length, 70μ; width, 12μ. Both from USGS diatom locality 5836.

This species is rare in USGS diatom locality 5836.

Known geologic range.—Late Miocene.

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PLATES 1-3

PLATE 1

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2. USGS diatom catalog 3624–15. Diameter, 15μ.

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USGS diatom catalog 3624–4. Diameter 5μ.

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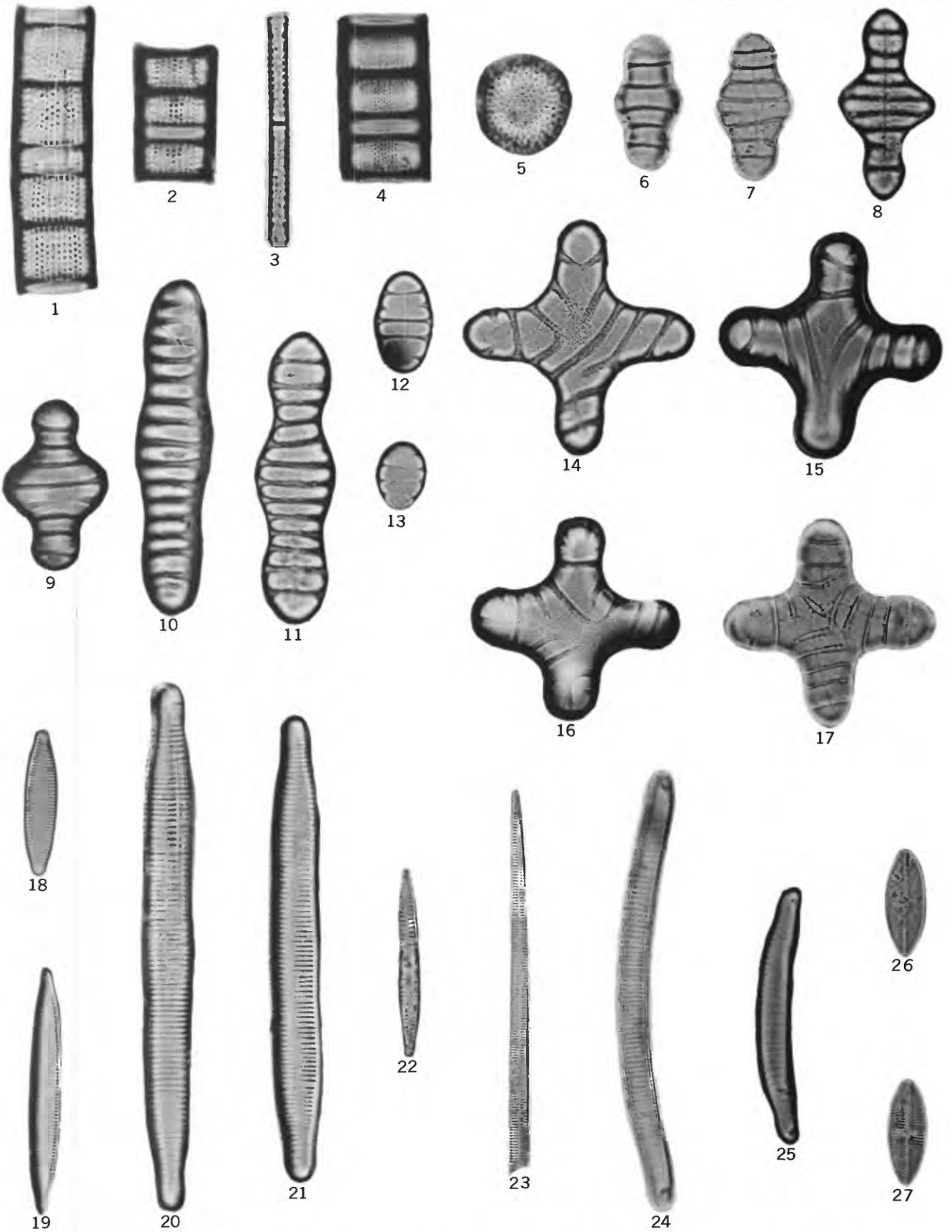
26. Raphe valve.
27. Pseudoraphe valve.



MELOSIRA, TETRACYCLUS, FRAGILARIA, SYNEDRA, EUNOTIA, AND *ACHNANTHES*

PLATE 2

[All figures × 960]

FIGURE

1. *Stauroneis phoenicenteron* (Nitzsch) Ehrenberg (p. A13).
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   10. Holotype, USGS diatom catalog 3626–29. Length, 104μ.
   11. Paratype, USGS diatom catalog 3626–33. Length, 110μ.

12, 13. *Navicula actinota Andrews*, n. sp. (p. A15).
   12. Holotype, USGS diatom catalog 3626–11. Length, 51μ.
   13. Paratype, USGS diatom catalog 3626–34. Length, 57μ.

14. *Navicula bacillum* Ehrenberg (p. A16).
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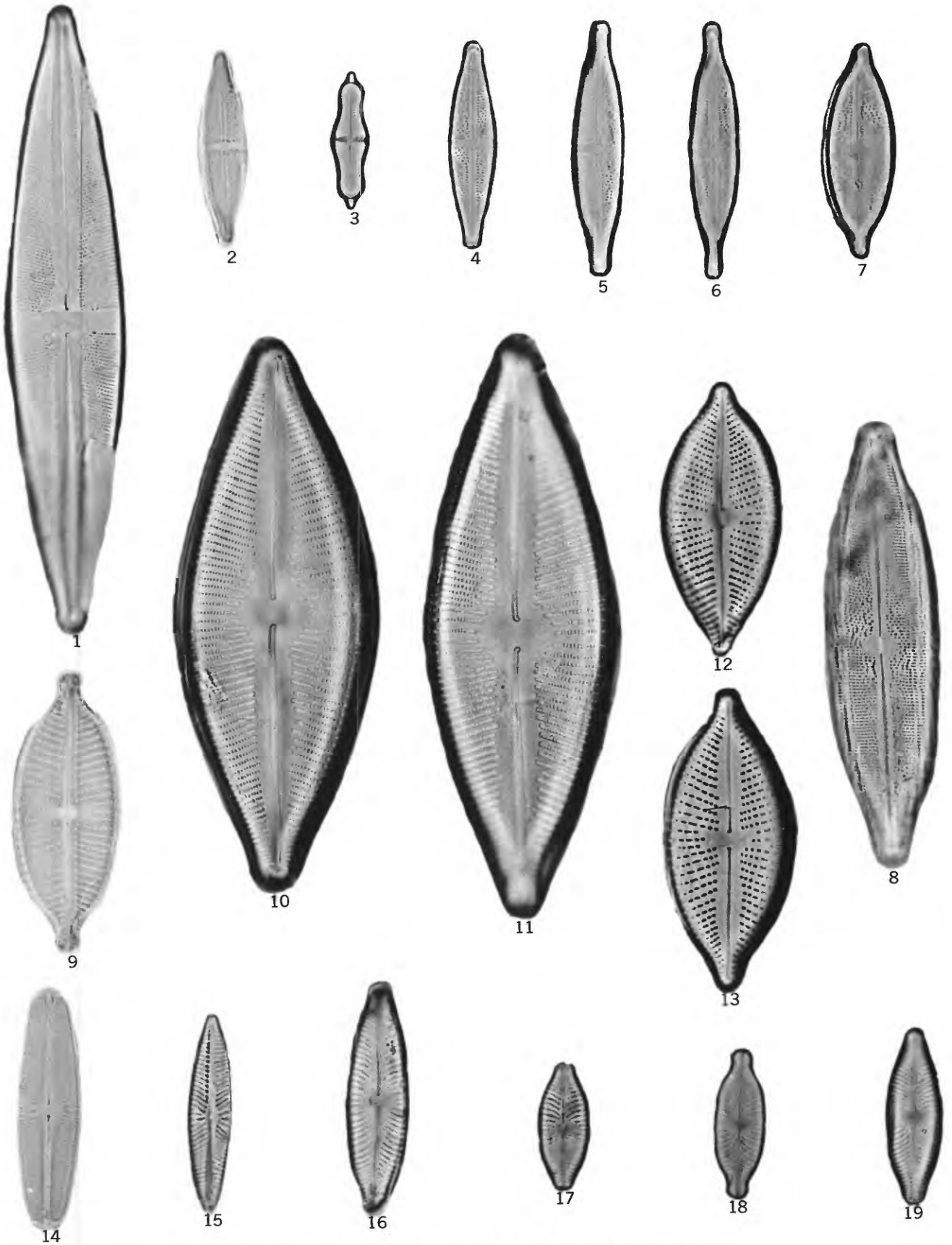
   USGS diatom catalog 3405–60. Length, 34μ.



STAURONEIS, ANOMOEONEIS, NEIDIUM, AND *NAVICULA*

PLATE 3

[All figures × 960 except figs. 4, 5, 9, 10 which are × 475]

FIGURE

1. *Pinnularia subcapitata* var. *paucistriata* (Grunow) Cleve (p. A17).
   USGS diatom catalog 3623–11. Length, 27μ.
2. *Pinnularia brevicostata* Cleve (p. A17).
   USGS diatom catalog 3405–91. Length, 53μ.
3. *Pinnularia clevei* Patrick (p. A17).
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4, 5. *Pinnularia torta* (Mann) Patrick (p. A18).
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   5. USGS diatom catalog 3626–13. Length, 184μ.

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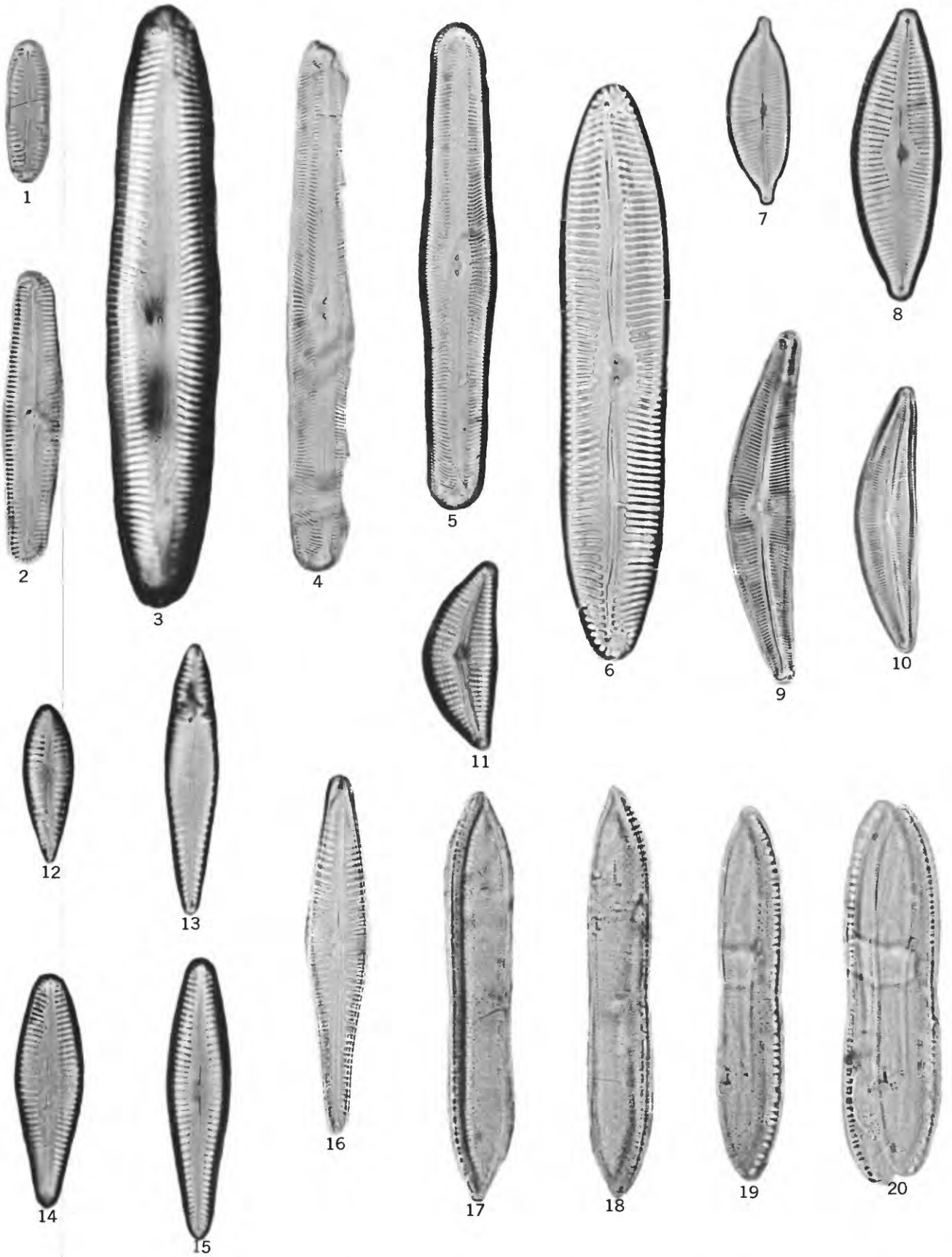

PINNULARIA, CYMBELLA, GOMPHONEMA, AND *NITZSCHIA*