Late Eocene Nonmarine Diatoms From the Beaver Divide Area Fremont County, Wyoming

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GEOLOGICAL SURVEY PROFESSIONAL PAPER 593-E

U.S. DEPARTMENT OF THE INTERIOR

Late Eocene Nonmarine Diatoms From the Beaver Divide Area Fremont County, Wyoming

By KENNETH E. LOHMAN *and* GEORGE W. ANDREWS

CONTRIBUTIONS TO PALEONTOLOGY

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A description of the earliest known
nonmarine diatom assemblage in North
America and its geologic occurrence

U.S. DEPARTMENT OF THE INTERIOR

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1968

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 40 cents (paper cover)

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LATE EOCENE NONMARINE DIATOMS FROM THE BEAVER DIVIDE AREA, FREMONT COUNTY, WYOMING

By Kenneth E. Lohman and George W. Andrews

ABSTRACT

The Beaver Divide is a high escarpment of Tertiary nonmarine strata in central Wyoming separating the Sweetwater Plateau from the relatively low-lying Wind River Basin. The Wagon Bed Formation of middle and late Eocene age and the Beaver Divide Conglomerate Member of the White River Formation—this member being of early Oligocene (Chadronian) age—are exposed near the top of the Beaver Divide in Fremont County, Wyo., about 23 miles southeast of Riverton. The upper part of the Wagon Bed Formation, dated as late Eocene (Uintan) age by Van Houten on the basis of vertebrate fossils, contains a highly silicified fresh-water limestone stratigraphically high in the section with a poorly preserved diatom assemblage. The Beaver Divide Conglomerate Member contains large blocks of similar white limestone, some of which have an assemblage of diatoms the same as that of the Wagon Bed Formation but showing excellent preservation. Both the Wagon Bed limestone and the limestone blocks from the Beaver Divide Conglomerate Member have virtually the same assemblages of nonmarine gastropods. A study of the local geology indicates that a marked erosional topography formed on the Wagon Bed strata before deposition of the Beaver Divide sediments. The Beaver Divide limestone blocks were derived from nearby exposures of the Wagon Bed Formation. The diatom assemblage under consideration was originally deposited in the Wagon Bed limestone and is, therefore, late Eocene rather than early Oligocene in age. This represents the earliest known assemblage of nonmarine diatoms from North America.

The diatom assemblage of the Wagon Bed Formation consists of 27 new species, two species known previously from the upper Miocene of France, and five species still found in living assemblages. One new genus containing two species also occurs in the deposit. The Wagon Bed diatom assemblage is strikingly distinct from later Tertiary fresh-water assemblages in that many diatom genera common to the younger deposits are totally lacking in this Eocene formation. These genera may be absent because of a highly specialized paleoecology during deposition of the Wagon Bed limestone, but the meager evidence provided by the few still-living species suggests nothing more specific than deposition in a temperate circumneutral lake.

INTRODUCTION

GENERAL STATEMENT

The Beaver Divide of central Wyoming is a conspicuous escarpment in which as much as 2,000 feet of Eocene, Oligocene, and Miocene nonmarine strata are exposed. It forms the boundary between two distinctive physiographic features, the Sweetwater Plateau and the Wind River Basin. The two rock units of concern to this report are the Wagon Bed Formation of middle and late Eocene age and the Beaver Divide Conglomerate Member of the White River Formation of early Oligocene age. These units crop out widely along the Beaver Divide; they are composed mainly of clastic debris, much of it of volcanic origin. At a few localities, however, small outcrops of cherty limestone in the upper part of the Wagon Bed contain assemblages of late Eocene fresh-water gastropods and diatoms. These limestone outcrops occur near the top of the Beaver Divide escarpment approximately 23 miles southeast of Riverton, Wyo. The locations of the Beaver Divide and some adjacent physiographic features in Wyoming are shown on the index map (fig. 1).

The fossil occurrences studied for this report are shown in figure 2.

Gastropod-bearing limestones from both the Eocene Wagon Bed Formation and the lower Oligocene Beaver Divide Conglomerate Member contain the same distinctive assemblage of fresh-water diatoms. A study of field relations set forth elsewhere in this paper strongly suggests that the limestone of the Beaver Divide Conglomerate Member has been derived as slump blocks from the older, Wagon Bed Formation. A pronounced erosional unconformity beneath the Beaver Divide Member indicates that there was enough topographic relief on the Wagon Bed terrain to permit such slumping of hard, resistant limestone blocks into the younger formation. Hence, the diatom and gastropod assemblages from both the Wagon Bed Formation and the overlying Beaver Divide Conglomerate Member are probably of late Eocene (Uintan) age, as they are thought to have been originally deposited in limestone of the Wagon Bed Formation.

These late Eocene diatoms show excellent preservation for fresh-water diatoms of so great an age and constitute the oldest known nonmarine diatom assemblage

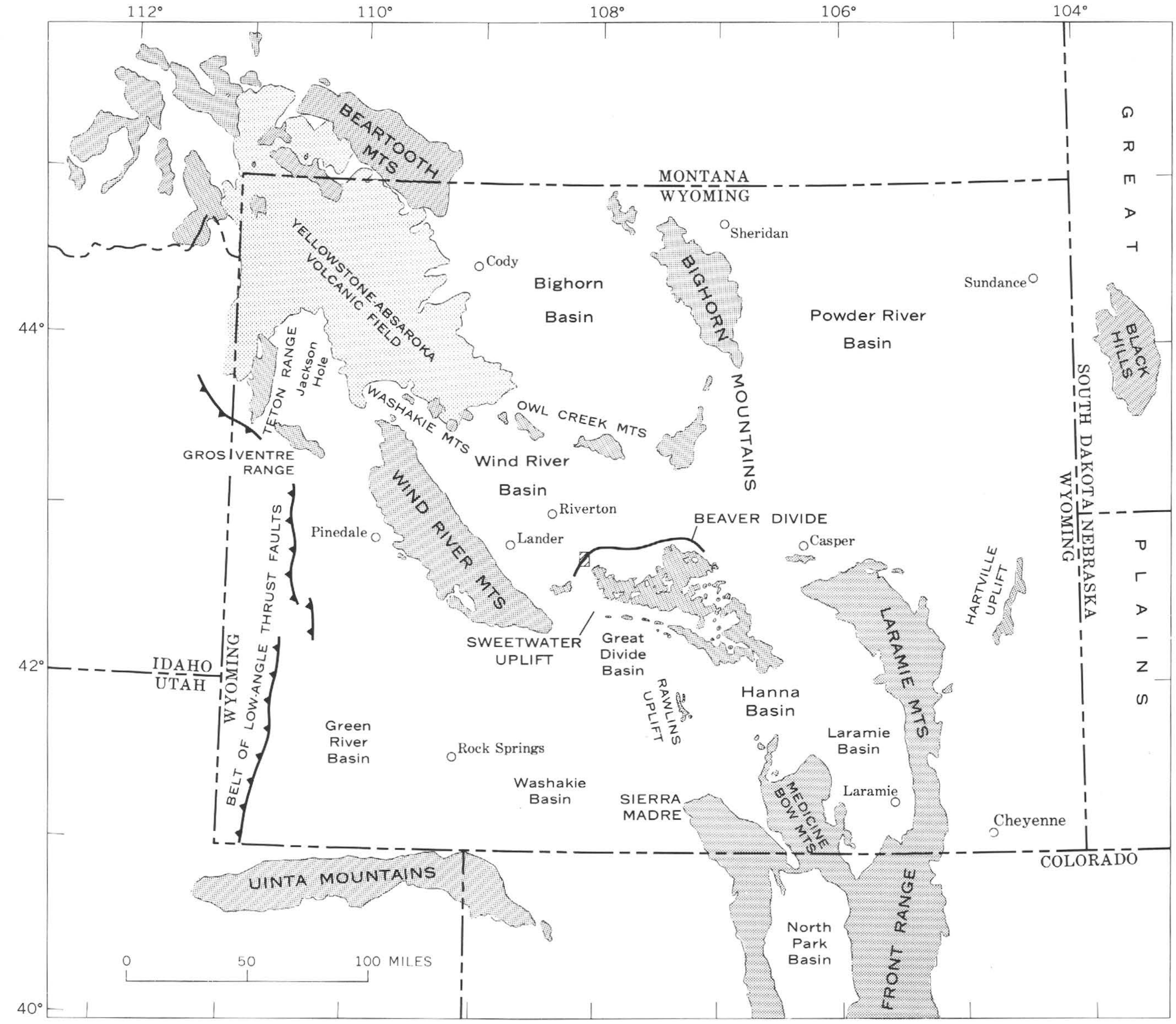
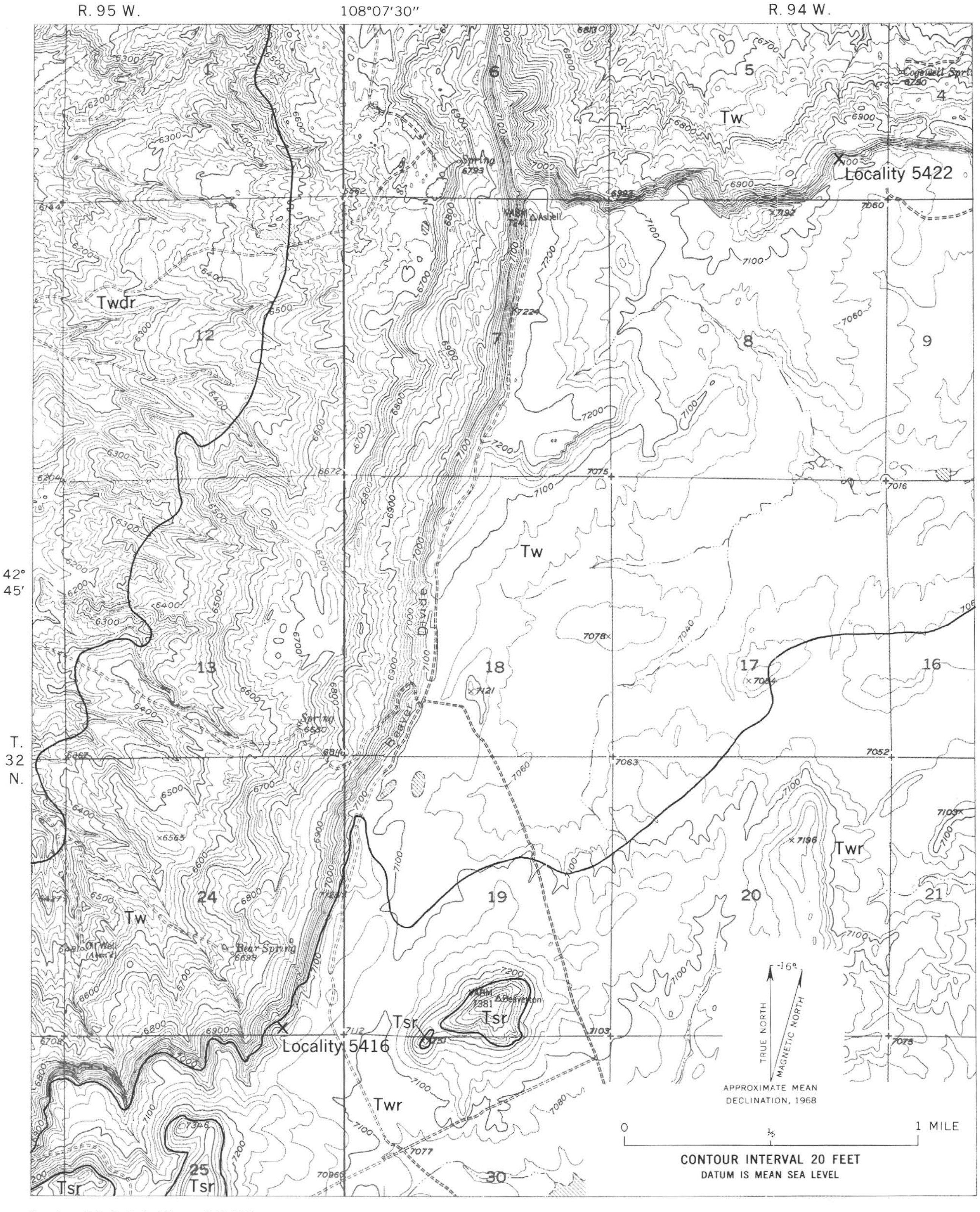


FIGURE 1.—Location of Beaver Divide and physiographic features in Wyoming and adjacent areas. The ruled rectangle on the Beaver Divide shows position of area shown in figure 2.

from North America. The next oldest diatom assemblage is from the Florissant Lake Beds of central Colorado, from which Lohman has identified more than 30 species of fresh-water diatoms. An early to middle Oligocene age has been assigned to these beds on the basis of vertebrate faunas and fossil leaves (MacGinitie, 1953, p. 73). Although the Wagon Bed Formation is only slightly older than the earliest age assigned to the Florissant Lake Beds, the diatom assemblages are strikingly different, having only one or two species in common. The Wagon Bed assemblage is a very distinctive one; it contains 10 genera, of which one is new, and 34 species, of which 27 are new. A large number of genera common to younger diatom assemblages were not found in the Wagon Bed Formation. Perhaps these genera had not yet developed by late Eocene time, or possibly their absence may only reflect some factors in the paleoecology of this particular deposit.

SUMMARY OF INVESTIGATION

The discovery of the Wagon Bed diatom assemblage came as a result of a systematic sampling of the Cenozoic nonmarine mollusk collections of the U.S. Geological Survey. The most promising assemblage thus obtained was from gastropods collected by F. B. Van Houten of Princeton University, from the Beaver Divide Conglom-



Base from U.S. Geological Survey, 1:24,000
Blue Gulch, Elkhorn Springs, and Dishpan
Butte, 1953; and Sand Draw, 1953–58

FIGURE 2.—Generalized geology of part of the Beaver Divide, Fremont County, Wyo., showing location of fossil localities. Geology modified from Van Houten (1964, pl. 2). Twdr, Wind River Formation; Tw, Wagon Bed Formation; Twr, White River Formation; Tsr, Split Rock Formation of former usage. Contacts approximately located.

erate Member of the White River Formation in the Beaver Divide area, Wyoming. A similar assemblage, but poorly preserved, was obtained from gastropods collected by Van Houten from the Wagon Bed Formation in the same area. Another similar assemblage, also poorly preserved and probably correlative with the above assemblages, was found in gastropods collected by H. A. Tourtelot, U.S. Geological Survey, from the Tepee Trail Formation in the Cedar Ridge area on the northeastern margin of the Wind River Basin.

The field relations of the Eocene Wagon Bed Formation and the lower Oligocene Beaver Divide Conglomerate Member of the White River Formation in the Beaver Divide area were examined by Andrews in September 1965, and again in August 1966. The conclusion was reached that the Beaver Divide assemblage was obtained from reworked Wagon Bed sediments and, hence, was late Eocene, not early Oligocene, in age. This assemblage has been studied in detail and is herein reported. The poorly preserved diatom assemblages of the in situ Wagon Bed Formation and the Tepee Trail Formation have also been examined for purposes of comparison.

ACKNOWLEDGMENTS

We express our thanks to Dwight W. Taylor, formerly of the U.S. Geological Survey, for his helpfulness in providing specimens for diatom study from fossil gastropod collections, for his interest in this investigation, and for critically reviewing the manuscrapt. J. D. Love, U.S. Geological Survey, kindly assisted in furnishing locality data for the Beaver Divide area and in providing helpful suggestions regarding the geology of the area. The critical review of the manuscript by Franklyn B. Van Houten, Department of Geology, Princeton University, is sincerely appreciated.

STRATIGRAPHY

PREVIOUS WORK

A detailed study of the Tertiary geology of the Beaver Divide area was recently published by Van Houten (1964). This excellent report is based partly on data gathered for U.S. Geological Survey Oil and Gas Investigations Maps OM–113 (Van Houten, 1950), OM–140 (Van Houten, 1954), and OM–180 (Van Houten and Weitz, 1956). Van Houten's 1964 report represents a synthesis and refinement of the data gathered during these earlier mapping investigations. The fossil specimens studied for this report were collected by U.S. Geological Survey field parties under the supervision of Van Houten in 1950 and 1951. An excellent summary of the earlier geologic work in the Beaver Divide area was presented by Van Houten (1964, p. 3–5).

The geology of the upper Eocene strata in the northeastern part of the Wind River Basin was described by Tourtelot (1957). This area, which is bordered by the Owl Creek and Big Horn Mountains on the north, contains upper Eocene deposits (Tepee Trail Formation) which are correlative at least in part with the Wagon Bed Formation of the Beaver Divide area. A collection of fossil gastropods made in this area by Tourtelot in 1945 contains a poorly preserved diatom assemblage similar to that of the Wagon Bed Formation.

WAGON BED FORMATION

The Wagon Bed Formation in the Beaver Divide area consists primarily of persistent beds of yellowish- and greenish-gray sandstone, siltstone, and mudstone rich in volcanic debris and bentonitic clay. Van Houten (1964, p. 36) stated, "Nodules and beds of chert and beds of silicified mudstone and sandstone are common, especially in the upper part of the formation, and there are also several layers of silicified limestone. Some of the siliceous beds are 3 to 5 feet thick and occur in persistent zones that can be traced for several miles."

One of these zones of siliceous limestone is exposed on the Beaver Divide escarpment in the W½SE¼SE¼ sec. 5, T. 32 N., R. 94 W., Fremont County, Wyo. This is fossil locality 13 in measured section 42 of Van Houten (1964, pl. 4). Fossil fresh-water gastropods were identified from this locality (USGS Cenozoic loc. 20089) by D. W. Taylor and dated as late Eocene (Uintan Age). We obtained a very poorly preserved diatom assemblage by disintegration of specimems from this collection.

The strata of the Wagon Bed Formation exposed at this locality (USGS diatom loc. 5422) consist of about 8 feet of very cherty hard white limestone. The lower contact of this limestone zone is obscured by slumping. About 2 feet above the base of this limestone is a bed of medium hard cherty limestone containing abundant fresh-water gastropods. Immediately above this hard gastropod-bearing limestone bed is a 3-inch-thick buff soft silty limestone also containing fresh-water gastropods in great abundance. The fossil snails from both of these beds are preserved as calcareous internal molds. A detailed comparison of the lithology of the fossils collected at this locality with those of the U.S. Geological Survey collection leaves little doubt that the latter collection was made at this locality.

Several samples of gastropod molds and limestone matrix from various levels in this outcrop were disintegrated and concentrated for diatom study. Many of these samples showed fragments of poorly preserved diatoms, but only a few specimens could be identified to generic or specific levels. The extensive silicification of this outcrop of Wagon Bed limestone suggests that solution and redeposition of silica was a prominent event in the postdepositional history of these rocks. The diatoms initially abundant in these beds have consequently been almost completely obliterated by silica-leaching solutions. The extensive silicification of this outcrop of the Wagon Bed Formation indicates that further search for a well-preserved diatom assemblage here would probably be futile.

The cherty limestone beds of the Wagon Bed Formation at this locality are massive and show little obvious change in thickness, whereas the thin beds of the soft matrix of the gastropod zone are very lenticular, pinching and swelling over short distances. There is no evidence for structural deformation of these beds, nor is there any noticeable brecciation or fracturing other than ordinary jointing. The cherty limestone beds, however, are probably somewhat lenticular. Another exposure in the NE¼SE¼SE¼ sec. 5, approximately 900 feet northeast of the above-mentioned locality, shows about 4–5 feet of cherty white limestone with a prominent gastropod zone near the top (fig. 3). The limestone is immediately overlain by a coarse-grained iron-stained sandstone, which weathers along joint planes into massive blocks. Van Houten (1964, p. 51) indicated that limestone beds occur in the upper of his unit 5 of the Wagon Bed Formation; consequently, these gastropod- and diatom-bearing beds are near the top of the late Eocene section exposed in the Beaver Divide area.

Van Houten (1964, p. 50–52) identified vertebrate fossils of late Eocene age from the upper part of the Wagon Bed Formation (Van Houten's unit 5), which contains the limestone considered in this report. Furthermore, he included (1964, p. 51) a report from D. W. Taylor on the gastropods found at the same locality in which an age of late Eocene (Uintan) was also assigned to them.

FIGURE 3.—Cherty white limestone of the Wagon Bed Formation exposed near USGS diatom locality 5422.

BEAVER DIVIDE CONGLOMERATE MEMBER

A very coarse conglomerate at the base of the Oligocene White River Formation, named the Beaver Divide Conglomerate Member by Nace (1939, p. 32–34), occurs generally throughout the western part of the Beaver Divide area. Van Houten (1964) recognized two conglomeratic facies, crystalline and volcanic, based on the more prominent lithologic constituent at various localities. According to Van Houten (1964, p. 57). ". . . the member lies unconformably on the Wagon Bed Formation."

The volcanic facies of the Beaver Divide Conglomerate Member is well exposed as a nearly vertical cliff near the top of the Beaver Divide escarpment in the SE¼SE¼ sec. 24, T. 32 N., R. 95 W., Fremont County, Wyo. This is fossil locality 12 in measured section 31 of Van Houten (1964, pl. 4) and USGS diatom locality 5416. Fossil fresh-water gastropods were identified from this locality (USGS Cenozoic loc. 20031) by D. W. Taylor. Of these, Van Houten (1964, p. 68) stated: "The fossil snails from locality 12 are forms that also occur in the upper part of the Wagon Bed (upper Eocene) Formation (D. W. Taylor, written communication, April, 1962)." Disintegration and concentration of the residue from several specimens in this collection yielded a well-preserved assemblage of diatoms.

The Beaver Divide Conglomerate Member in this area consists primarily of horizontally stratified pebble and cobble conglomerate composed mainly of subrounded to rounded volcanic debris. Incorporated in this conglomerate are large angular blocks of white cherty limestone. These numerous blocks show bedding that strikes in all directions and has no preferred orientation. The bedding dips in every conceivable angle from horizontal to vertical. In one large limestone block, bedding dips partly in a northerly direction and partly in a southerly direction, producing a synclinal effect. Figure 4 shows the discordant dip of a large limestone block and the nearly horizontal conglomerate cropping out in the background. The limestone blocks contain lenticular beds of soft to hard limestone, in part silty and containing root casts and rare fossil wasp burrows, vertebrate bones, and fresh-water gastropods. The blocks seem to be transected with numerous small fractures which suggest incipient brecciation, and they con-

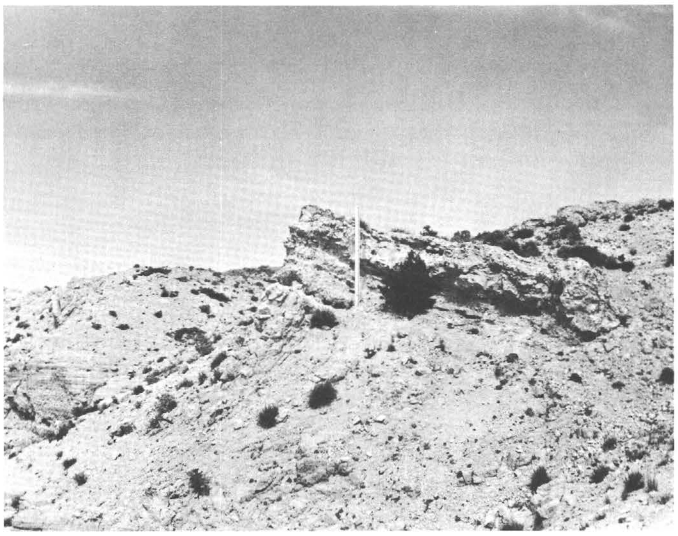


FIGURE 4.—Large discordant block of stratified limestone in the Beaver Divide Conglomerate Member. Block dips to right and into hillside; bedding in conglomerate (lower left) is nearly horizontal. Stadia rod is 7 feet long. USGS diatom locality 5416.

tain irregularly silicified zones and considerable chert. The lower and lateral contacts of the white limestone with the volcanic conglomerate are distinct and abrupt; no volcanic pebbles are incorporated into the limestone, nor is there any observable calcareous cementation of the volcanic conglomerate adjacent to the limestone bodies (fig. 5). The limestone blocks are large, some reaching a thickness of 10 feet and at least one reaching a length of about 85 feet. Figure 6 shows an irregular limestone block underlain by about one foot of volcanic conglomerate of the Beaver Divide Conglomerate Member which, in turn, rests upon clay of the Eocene Wagon Bed Formation.

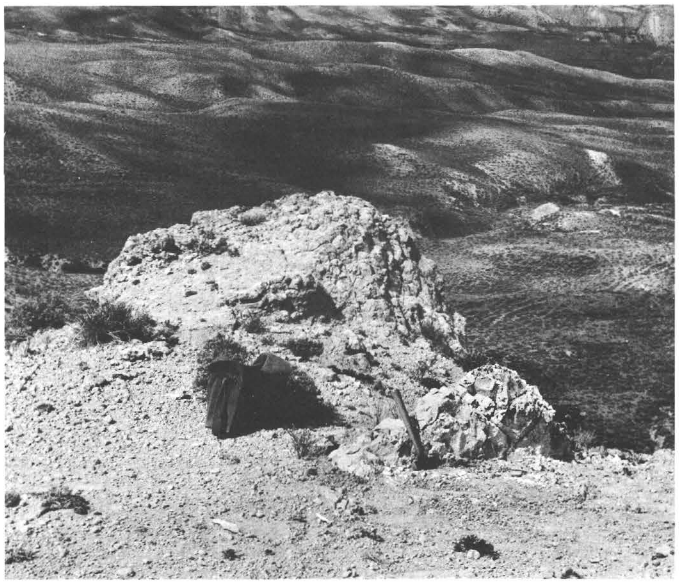


FIGURE 5.—Small block of white limestone in the Beaver Divide Conglomerate Member. USGS diatom locality 5416.

FIGURE 6.—Large limestone block in the Beaver Divide Conglomerate Member. Head of hammer is on limestone-conglomerate contact. End of hammer handle approximates Beaver Divide–Wagon Bed contact. USGS diatom locality 5416.

A panoramic view of the Beaver Divide from north to east is shown in figure 7. The outcrop area of the Beaver Divide limestone blocks of USGS diatom locality 5416 is in the center and right foreground. The strata exposed in this view show a rather low southerly regional dip. The summit of "Beaverton" butte, an outlier of the Split Rock Formation of former usage, shows over the top of the Beaver Divide to the right.

The Oligocene White River Formation unconformably overlies the Eocene Wagon Bed Formation in the Beaver Divide area. Van Houten (1964, p. 66) stated, "The basal contact [of the White River Formation] is an erosional unconformity characterized by considerable topographic relief," and he illustrated this topographic relief in stratigraphic cross sections (pls. 4 and 6). He further indicated (p. 66) that the relief in certain local areas may be as great as 500 feet per mile.

The difference in lithology, discordance of dip, and apparent lack of intergradation between the volcanic conglomerate and the enclosed limestone blocks strongly suggest that the limestone blocks are either intraformational slide blocks or blocks derived from the older Wagon Bed Formation. Van Houten (1964, p. 69) reported a gastropod assemblage (fossil loc. 17) "40 to 50 feet above the base of the White River Formation" containing forms similar to those at his fossil locality 12 (USGS diatom loc. 5416). These two localities are

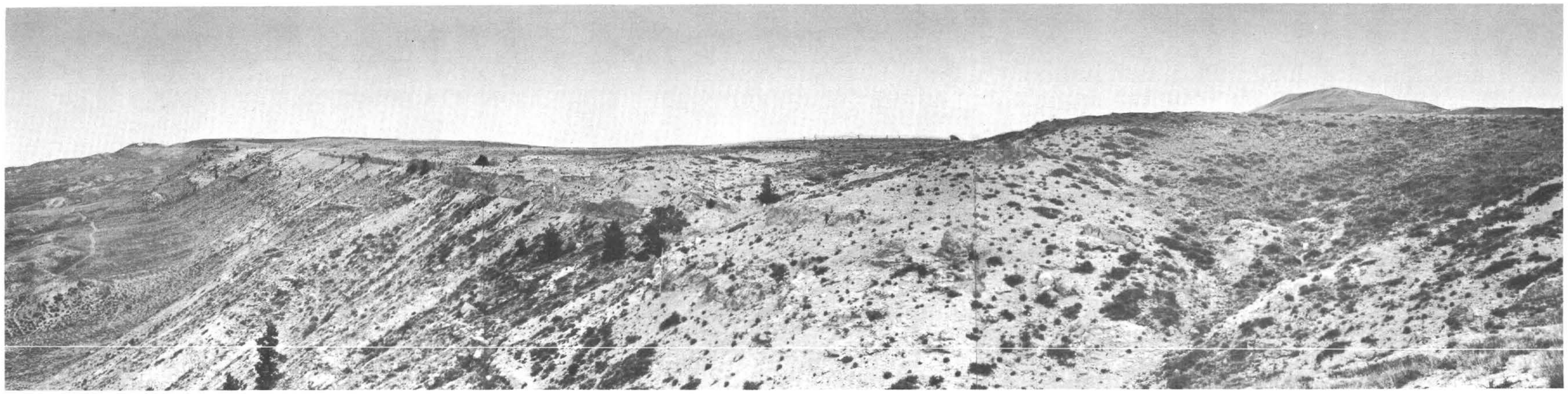


FIGURE 7.—Panoramic view of Beaver Divide from north (left) to east (right). Beaver Divide Conglomerate Member limestone blocks (USGS diatom loc. 5416) at center and right foreground. Contact of the Wagon Bed Formation and the Beaver Divide Conglomerate Member is approximately at the base of the near-vertical cliff in the middle distance and at the base of the 13-foot stadia rod at the limestone outcrop in the left middle foreground.

about 7 miles apart and on opposite sides of the Conant Creek anticline, a prominent structure in the pre-Tertiary formations of the Beaver Divide area. Unfortunately, the gastropod collection from Van Houten's fossil locality 17 has been lost, so it is not possible to compare either the lithology or the gastropods from the two localities. No further information is available regarding the limestone deposit at Van Houten's fossil locality 17; he did not state whether the limestone occurs here in place or as slump blocks. More than 25 rock collections of the White River Formation from various localities in Wyoming, Colorado, Nebraska, and South Dakota have been processed and carefully examined for diatoms. No diatoms have yet been found in any collection examined from the White River Formation.

The marked erosional topography on the top of the Wagon Bed Formation suggests that the Beaver Divide limestone blocks could well have been derived from a topographically higher outcrop of Wagon Bed limestone. Hard, cherty limestone, very similar in lithology to the limestone blocks in the Beaver Divide Conglomerate Member, is known to occur high in the upper Eocene stratigraphic section a rather short distance away. The close similarity of the gastropod assemblage in the Beaver Divide limestone blocks to that of the Wagon Bed Formation strongly suggests that the limestone blocks were derived from the Wagon Bed Formation. The diatom assemblage of the upper Eocene Wagon Bed limestone appears to be the same as the excellent diatom assemblage in the limestone blocks of the lower Oligocene Beaver Divide Member even though the Wagon Bed diatoms are poorly preserved. The balance of the available evidence indicates that the limestone blocks of the Beaver Divide Conglomerate Member were derived by slumping from outcrops of the Wagon Bed Formation that were exposed to erosion in early Oligocene time.

AGE OF THE DIATOM ASSEMBLAGE

The proposal is here made, on the basis of the evidence outlined above, that the excellently preserved diatom assemblage from limestone blocks in the Oligocene Beaver Divide Conglomerate Member of the White River Formation was deposited in late Eocene limestone of the Wagon Bed Formation. The assemblage is, therefore, of late Eocene (Uintan) age, and was transported in a limestone matrix into early Oligocene sediments. Through some fortunate accident of preservation, the Eocene diatoms incorporated into the Beaver Divide Conglomerate Member were but slightly altered by silica-leaching solutions. This may be the result of their entombment in the interiors of the calcareous mollusks before the leaching solutions operated. The diatoms so far discovered unequivocally in the Wagon Bed Formation are, regrettably, very severely altered; only the more robust individuals are preserved, in poor condition, and the more fragile individuals have been completely destroyed. The strong similarity between these assemblages and the virtual identity of the two associated gastropod faunas definitely suggest that both deposits are essentially the same age and formed under identical environmental conditions. It seems unfortunate that a complicated geologic situation necessitates a complex interpretation to determine the true age of this Eocene diatom assemblage. On the other hand, if the Wagon Bed limestone had not been incorporated into the Beaver Divide sediments, most probably the contained diatoms would have suffered the same fate as their counterparts in the undisturbed Wagon Bed deposits.

TEPEE TRAIL FORMATION

Tourtelot (1957) described the upper Eocene rocks of the Tepee Trail Formation in the northeastern part of the Wind River Basin, which is bordered by the Owl Creek and Big Horn Mountains. The "green and brown member" of the Tepee Trail Formation consists primarily of bedded sedimentary rocks rich in volcanic material and zones of conglomerate composed of volcanic rock pebbles. Concerning this "green and brown member" Tourtelot (1957, p. 7) stated, "Along Badwater Creek (southwestern part of T. 39 N., R. 88 W.) * * * light-colored siliceous fresh-water limestone is prominent in the upper part of the member." A collection of fresh-water fossil gastropods made in the SW¼SW¼ sec. 29, T. 39 N., R. 88 W., Fremont County, Wyo., and identified by T. C. Yen, formerly of the U.S. Geological Survey, was reported by Tourtelot (1957, p. 17). A sample from this collection was disintegrated and concentrated for diatom study. It contains a poorly preserved diatom assemblage, but those species that can be identified seem to be indistinguishable from forms in the upper Eocene Wagon Bed limestone of the Beaver Divide area. Van Houten (1964, p. 53) stated: "Gastropod-bearing beds of unit 5 [of the Wagon Bed Formation] probably correlate with similar limy deposits in the upper part of the 'green and brown member' and in the lower part of the Hendry Ranch Member of the Tepee Trail Formation in the northeastern part of the [Wind River] basin (Tourtelot, 1957, fig. 5)." The similarity of the Tepee Trail diatom assemblage—even though it is poorly preserved—to the Wagon Bed diatom assemblage of the Beaver Divide area, suggests confirmation of the above correlation by Van Houten.

DIATOM ASSEMBLAGE

GENERAL STATEMENT

The specimens disintegrated for diatom study consisted of calcareous internal molds of fresh-water gastropods and hard limestone matrix material. Care was exercised in collecting and cleaning the samples to prevent contamination by adventitious diatoms. In general, hard calcareous material, such as used in this study, is less susceptible to contamination than soft, unconsolidated sediments. The Eocene diatoms derived from the Oligocene Beaver Divide Conglomerate Member were contained in massive limestone blocks, and there is little likelihood of contamination by reworking during Oligocene time. The samples were disintegrated and concentrated following standard procedures of the U.S. Geological Survey diatom laboratory, and specimens were mounted for study in kollolith and hyrax. The relative abundance of each diatom in the assemblage is shown in table 1.

TABLE 1.—*Relative abundance of diatoms from the Wagon Bed Formation*

[D, dominant; A, abundant; C, common; F, frequent; R, rare]

Melosira canalifera var. *anastomosans* Héribaud	R
inordinata Lohman and Andrews, n. sp	R
interrupta Lohman and Andrews, n. sp	C
italica (Ehrenberg) Kützing	F
pella Lohman and Andrews, n. sp	C
vitrea Lohman and Andrews, n. sp	F
Anaulus ovalis Lohman and Andrews, n. sp	F
Fragilaria curvistriata Lohman and Andrews, n. sp	R
denticulata Lohman and Andrews, n. sp	C
nitida Héribaud	F
pellucida Lohman and Andrews, n. sp	C
virescens Ralfs	C
Ambistria hyalina Lohman and Andrews, n. gen. and n. sp	A
punctata Lohman and Andrews, n. sp	C
Navicula panda Lohman and Andrews, n. sp	F
perpusilla (Kützing) Grunow	F
Anomoeoneis undulata Lohman and Andrews, n. sp	F
Pinnularia barca Lohman and Andrews, n. sp	F
brebissonii (Kützing) Rabenhorst	F
elliptica Lohman and Andrews, n, sp	D
gnoma Lohman and Andrews, n sp	F
irregularis Lohman and Andrews, n. sp	R–F
obesa Lohman and Andrews, n. sp	R
runa Lohman and Andrews, n. sp	R
scapha Lohman and Andrews, n. sp	F
serpentina Lohman and Andrews, n. sp	F
spatula Lohman and Andrews, n. sp	R
subrostrata Lohman and Andrews, n. sp	F
tumida Lohman and Andrews, n. sp	R
Stauroneis fusiformis Lohman and Andrews, n. sp	F
nana Lohman and Andrews, n. sp	F
vesca Lohman and Andrews, n. sp	F
Nitzschia commutata Grunow	F
fremontensis Lohman and Andrews, n. sp	F

PALEOECOLOGIC INTERPRETATION

The diatoms and the gastropods in the upper part of the Wagon Bed Formation both indicate that limestone deposition took place in a fresh-water environment, probably in a shallow lake or in small lakes and ponds. The diatom assemblage seems to be normal, and there are practically no tautological specimens that would suggest saline or fluctuating conditions. Van Houten (1964, p. 54) stated: "Late in Eocene time, lime mud derived from limestones of Paleozoic age on the Conant Creek anticline accumulated in a local lake and was diagenetically replaced by silica derived from altered volcanic debris." Certainly, silica leached from volcanic debris was readily available for utilization by diatoms during deposition of the Wagon Bed limestone. It is much less certain whether the silification of the limestone beds is a result of diagenesis or of postdiagenetic percolating ground water. Leaching and silification could have taken place almost any time after deposition of the calcareous sediments.

Tourtelot (1957, p. 8) reported that limestone from the "green and brown member" of the Tepee Trail formation contains gastropods, pelecypods, rare vertebrate remains, and silicified prop roots of palms. He also reported (p. 12) that many fragments of fish and turtle bones are found in this member. These fossils suggest a shallow lacustrine environment and a warm-temperate to subtropical climate.

Of the seven previously known species in the Wagon Bed assemblage, two, *Melosira canalifera* var. *anastomosans* Héribaud and *Fragilaria nitida* Héribaud, were originally described from upper Miocene beds in France, and no ecologic data are available, other than the fact that they occur in a fresh-water diatomite. The five Recent species present in the assemblage—*Melosira italica*, *Fragilaria virescens*, *Navicula perpusilla*, *Pinnularia brebissonii*, and *Nitzschia commutata*—all live in temperate fresh-water lakes and ponds with pH ranging from 5.0 to 9.5. *Nitzschia commutata* also will tolerate slightly saline water, but this does not change the picture. On the basis of this meager information, a temperate circumneutral lake is suggested as the habitat of the Wagon Bed diatoms.

SYSTEMATIC DESCRIPTIONS

At various times in the past, the diatoms have been considered to be animals by some and plants by others. This ambiguity was due in large part to the fact that they possess, in varying degrees, the properties of each of the two kingdoms of organisms. As early as 1860, when three kingdoms of nature were recognized—Mineral, Animal, and Vegetable—Hogg (1860) proposed a fourth, the Primigenal Kingdom or Protoctista, to contain a great many microscopic single-celled organisms, including the diatoms. Haeckel (1866) subsequently proposed the term "Protista," as a third kingdom of organisms, which gained popularity when the journal "Protistenkunde" was established and became a publication medium for many microbiologists. Most diatom workers ignored this new kingdom, and continued to consider the diatoms as animals or plants, although since the latter part of the 19th century most have considered them as a class of algae.

Moore (1954) ably reviewed the problem and formally proposed a kingdom of organisms named Protista, following Haeckel, and gave a classification of the Protista down to the rank of class. In this classification, the Protista include all acellular or unicellular organisms in which all living functions are carried on within a single cell, without regard to animal or plant affinities.

The classification used in this paper is one proposed by Lohman (unpub. data). It follows Moore (1954) down to the rank of Class and is based upon the classifications proposed by Schütt (1896), Karsten (1928), and Hendey (1937) but is modified to include all known genera, Recent and fossil, marine and nonmarine, and to achieve what is considered to be a more orderly arrangement of genera.

No new varieties are described in this paper, as it seems wiser to retain strictly binomial nomenclature for the new taxa here considered. The use of the terms "variety" and "forma" have been greatly overextended by many students of diatoms, and the result has been a multinomial nomenclature. This has caused endless confusion, as different workers have different concepts of the terms "variety" and "forma." As many species are inherently somewhat variable, it seems wiser to indicate the limits of variation within a species rather than to set up a hierarchy of subspecific units.

Not surprisingly, a large number of new species are represented in this assemblage of the earliest known nonmarine diatoms. Of the 34 species identified from the Wagon Bed Formation, 27 are here described as new, including two species of a new genus. Descriptions and brief synonymies are given for the seven previously known species, of which five are still represented in living assemblages elsewhere. In the synonymies, the first citation is that of the original author of the species; second, references to the genus and species are given in chronologic order as accepted in this paper; third, synonyms and misidentifications are given in chronologic order.

Kingdom PROTISTA Haeckel, 1866

Subkingdom PROTOCTISTA Hogg, 1860

Phylum CHRYSOPHYTA Pascher, 1914

Class DIATOMACEAE Agardh, 1824

Order CENTRALES Schütt, 1896

Suborder DISCINEAE Kützing, 1844

Family COSCINODISCACEAE Kützing, 1844

Subfamily MELOSIROIDEAE Kützing, 1844

Genus MELOSIRA Agardh, 1824

The five species of *Melosira* occurring in the Wagon Bed Formation are characterized by fine mantle puncta; the ubiquitous *M. italica* is the most abundant. None of the coarsely punctate species, such as *M. granulata*, which is characteristic of Miocene and later deposits, were observed. Probably the genus was introduced into the nonmarine environment first as a hyaline cylinder characterized by *M. vitrea* n. sp. (p. E12) and the punctation at first was very fine, but increased in coarseness through the Eocene and Oligocene until coarse punctation became dominant in the Miocene and has continued to the present.

Melosira canalifera var. anastomosans Héribaud

Plate 1, figure 1

Melosira canalifera var. *anastomosans* Héribaud, 1903, Les diatomées fossiles d'Auvergne, 2d mem., p. 52, pl. 10 fig. 34.

Frustule cylindrical, punctate, with mantle height about half diameter of valve; valve circular, very convex, with series of roughly semicircular "canals," with closed ends extending toward center for about one-tenth diameter of valve; balance of valve finely punctate, radially arranged near margin and in random orientation in central part. Diameter, 22–35μ.

Measurement of figured specimen (USGS diatom cat. No. 3662–9), diameter, 23μ; from USGS diatom locality 5416.

Brun and Héribaud (Héribaud, 1893, p. 224, pl. 6, fig. 15) described and figured *Melosira canalifera* giving two valve views and one girdle view, obviously from three different specimens. The girdle view, almost certainly, is not of the same species as the two valve views, but appears more like *M. granulata* (Ehrenberg) Ralfs. The valve views are similar to the specimens from the Wagon Bed Formation, but the fine puncta covering the central part of the valve are not shown in one figure and are only suggested in the other. Later, Héribaud (1903) described and figured the variety *anastomosans*, giving a good valve view and a girdle view which seems to be correct. His valve view is identical with the Wagon Bed specimens, except that it shows the puncta becoming more sparse toward the center of the valve. Some of our specimens exhibit this same appearance unless focused very carefully at high magnification with an oil immersion objective. This is apparently caused by the fact that the valve is so convex that it is impossible to focus the center and margin at the same time. In some specimens, the puncta become much fainter toward the center, and this may have been partly responsible for Héribaud's failure to show them. No specimens oriented in girdle view that were satisfactory for photography were found in the Wagon Bed material, and only a few were found in valve view, but there can be little doubt that we have Héribaud's variety. Both the type and the variety were described from upper Miocene beds in the Province of Cantal, France. This variety occurs rarely in the Wagon Bed Formation.

Known geologic range: late Eocene to late Miocene.

Melosira inordinata Lohman and Andrews, n. sp.

Plate 1, figure 2

Frustule cylindrical, with thin mantle walls entirely covered with fine puncta, 12–14 in 10μ, in completely random order; distal end of valve convex, forming tangential attachment to adjacent frustule; sulcus deep and asymmetric, tapering toward girdle, without external depression; diameter, 8–10μ; height of valve, 15–20μ.

Holotype: USGS diatom cat. No. 3653–111, diameter, 9μ; valve heights, 19μ and 16μ; from USGS diatom locality 5416.

When first found in the Wagon Bed assemblage, this specimen was considered to be tautological, for in most species of *Melosira* having a pronounced sulcus, the mantle punctation does not extend beyond the sulcus. Furthermore, no other species of *Melosira* has such completely random orientation of the mantle puncta. At first sight, it seemed that the valves had been filled with finely granular material after death of the organism. Careful study at high magnification, using a 2-mm oil-immersion apochromat, however, clearly indicated that the randomly oriented puncta were confined to the mantle and were absent from the interior of the valves. Furthermore, the puncta are circular and remarkably uniform in size. It is difficult to postulate a form of uniform particulate matter of this kind that would selectively fill or coat one particular species and not be seen on any of the other species among the myriads of specimens present in the assemblage.

Melosira interrupta, n. sp. has a somewhat similar appearance but has heavier mantle walls, puncta on distal half of mantle only, and much finer puncta. Some specimens of *M. interrupta* have the mantle puncta arranged in very definite longitudinal rows; in others the longitudinal rows are less definite but never extend beyond the sulcus. The random arrangement of the puncta in *M. inordinata*, together with complete coverage of the mantle surface, is never present in *M. interrupta*. Any confusion between the two species seems to be impossible, and no gradation between the two has been found.

Rare in the Wagon Bed Formation.

Known geologic range: late Eocene.

Melosira interrupta Lohman and Andrews, n. sp.

Plate 1, figures 3, 4, 5

Frustule cylindrical with very heavy mantle wall; sulcus deep with no external depression; mantle puncta, 14–20 in 10μ, in regular or irregular rows, 18–22 in 10μ, not reaching distal end of valve, usually interrupted about halfway, with balance of mantle hyaline; distal ends of valves denticulate where joining adjacent frustule; valve circular, seldom seen in valve view. Diameter, 6–12μ; height of valve, 10–14μ.

Holotype: USGS diatom cat. No. 3660–10 (fig. 4), diameter, 11μ; valve height, 11μ. Paratype: USGS diatom cat. No. 3660–23 (fig. 3), diameter, 8μ; valve height, 12μ. Paratype: USGS diatom cat. No. 3660–17 (fig. 5), diameter, 6μ; valve height, 10μ and 11μ. All from USGS diatom locality 5416.

The manner in which the mantle puncta are interrupted along an uneven line about the middle of the mantle makes this species easy to identify at fairly high magnification; at low magnification, the entire mantle appears hyaline. The mantle puncta are usually arranged in irregular rows (pl. 1, fig. 4), but in some (pl. 1, fig. 3) the rows are regular, usually parallel to height of valve or occasionally at a slight angle to it. The height: diameter ratio varies from 1 to 1.6. The denticulate attachment between adjacent frustules is unusually strong; in the many hundreds of specimens of this species examined for this report, virtually all were in pairs consisting of valves of adjacent frustules, with the girdle ends exposed. Except for the distal, denticulate ends of the valves (in girdle view), this species resembles *M. semilaevis* Grunow (Grunow, in Van Heurck, 1882, pl. 88, fig. 18). In *M. interrupta* the ends of the frustules are flat, forming a very tight contact, aided by the denticulate margin; in *M. semilaevis*, the ends of the frustules are alternately strongly convex or strongly concave. Mills (1933–35, p. 948) considered Grunow's species to be a synonym for *M. italica* (Ehrenberg) Kützing, a wholly untenable assignment. Differences between *M. interrupta* and *M. inordinata*, n. sp., are noted above in the discussion of *M. inordinata.*

Common in the Wagon Bed Formation.

Known geologic range: late Eocene.

Melosira italica (Ehrenberg) Kützing

Plate 1, figure 6

Gaillonella italica Ehrenberg, 1838, Die Infusionsthierchen als vollkommene Organismen, pl. 10, fig. 6.

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

Schmidt, 1893, Atlas der Diatomaceenkunde, pl. 181, figs. 3–5.

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

Melosira crenulata var. *italica* (Kützing) Grunow, in Van Heurck, 1882, Synopsis des diatomées de Belgique, pl. 88, fig. 7.

Frustules cylindric, usually with height greater than diameter; margin between adjacent frustules coarsely denticulate; sulcus deep; girdle narrow; mantle finely punctate, 12–16 in 10μ in parallel or usually spiral longitudinal lines, 18–20 in 10μ; valve circular, finely punctate, with denticulate margin. Diameter, 5–28μ; height, 8–21μ.

Measurements of figured specimen (USGS diatom cat. No. 3659–60), diameter, 14μ; height of valve, 14μ; from USGS diatom locality 5416.

Boyer (1927, p. 29) erred in making this species a synonym of *M. crotonensis* (Bailey) H. S. Smith. Ehrenberg's name must stand because it has unquestioned priority by many years.

This is a truly cosmopolitan species, living today in temperate zones all over the world, as a pelagic form in large fresh-water lakes and as a littoral form in smaller ones. It is equally cosmopolitan in nonmarine diatomaceous sediments of Oligocene, Miocene, Pliocene, and Pleistocene ages. Its appearance in the upper Eocene part of the Wagon Bed Formation, where it occurs frequently, is therefore not surprising.

Known geologic range: late Eocene to Recent.

Melosira pella Lohman and Andrews, n. sp.

Plate 1, figures 7, 8

Frustule cylindrical, with thick mantle wall, without indentation at the sulcus, but greatly thickened, giving interior of valve in girdle view an oval shape; mantle covered with fine puncta, 16–20 in 10μ; in slightly oblique longitudinal rows, 24–26 in 10μ; margin between adjacent frustules denticulate; valve circular with denticulate margin; girdle very narrow. Diameter, 11–18μ; height of valve, 8–11μ.

Holotype: USGS diatom cat. No. 3659–53 (pl. 1, fig. 8), diameter, 11μ; height of valve 8μ. Paratype: USGS diatom cat. No. 3662–25 (pl. 1, fig. 7), diameter, 14μ; height of valve, 10μ. Both from USGS diatom locality 5416.

This species slightly resembles *M. distans* (Ehrenberg) Kützing, but has much finer mantle puncta, much heavier mantle walls, and a greater height: diameter ratio. Schmidt (1893, pl. 181, fig. 48) figured a form from a diatomite in Java which most nearly resembles *M. pella*. He did not assign a name to it but stated, "Grove nimmt 48 und 49 als *M. undulata* var." It is highly probably that Schmidt's figure 49, which is a valve view, is actually *M. undulata*, but his figure 48, a girdle view, is a totally different diatom and may be the species here described. Schmidt, unfortunately, gave no age or locality data other than "Essbare Erde, Java."

This distinctive species occurs commonly in the Wagon Bed Formation.

Known geologic range: late Eocene.

Melosira vitrea Lohman and Andrews, n. sp.

Plate 1, figure 10

Frustule cylindrical, with deep sulcus; mantle completely hyaline, valve ends between frustules denticulate, forming attachment between frustules; valve view circular, hyaline in center with short marginal spines. Diameter, 5–12μ; height of valve, 8–15μ.

Holotype: USGS diatom cat. No. 3653–121, diameter, 7μ; valve heights, 13μ, 14μ. USGS diatom locality 5416.

Careful examination of many specimens of this species under high magnification and under conditions of maximum resolving power available in the optical microscope revealed no trace of markings of any kind on the hyaline mantle. Its resemblance, in other respects, to *M. interrupta* (p. E11, pl. 1, figs. 3–5 of this report) suggests a strong relationship between the two. Paratype No. 3660–17 (fig. 5) of *M. interrupta*, having only a few scattered mantle puncta, is transitional between the two species. *M. vitrea*, consisting of a hyaline tube, denticulate at the distal end where it is attached to the adjacent frustule but without any form of mantle ornamentation, seems to be the most primitive of the nonmarine members of the genus *Melosira*.

Kanaya (1957, p. 76, pl. 3, figs. 1, 2) reported *Melosira sulcata* (Ehrenberg) Kützing from the marine Kellogg Shale (of Clark and Campbell, 1942) of Eocene age in California. This is a highly ornamented species of complex structure and is different from any nonmarine *Melosira*. Hanna (1927a, p. 25, pl. 3, figs. 11–14) reported *M. fausta* Schmidt from the marine Moreno Shale of Late Cretaceous and Paleocene age in California, and Long, Fuge, and Smith (1946, p. 109) described two new species—*M.* (?) *dens-serrae* and *M. patera*—from the Moreno Shale. The doubt expressed by the authors regarding the generic assignment of the first of these species seems to be justified, as neither the full description nor the inadequate illustration resemble the genus *Melosira.* The figure given for *M. patera* (Long and others, 1946, pl. 17. fig. 18 is similar to one layer of a very complex diatom described by Lohman (1948, p. 156, pl. 5, figs. 1–7) as *Melosira complexa* from the Calvert Formation of Middle Miocene age in Maryland. Heiberg (1863, p. 33) established the genus *Paralia* with *P. marina* [=*Melosira sulcata* (Ehrenberg) Kützing] as the type. Many subsequent workers have ignored Heiberg's genus, either making it a synonym of *Melosira* or a subgenus of it as Hustedt (1928, p. 276) did. Others, of which the latest is Hendey (1964, p. 73), recognized *Paralia* as a valid genus, and the pronounced differences between it and *Melosira* makes this assignment the wisest one to follow. Removing *M. sulcata* (as well as others of similar structural complexity) from *Melosira* and placing them in *Paralia* would make *M. vitrea* the earliest known member of the restricted genus. The extremely simple structure of this species, consisting of a hyaline siliceous tube, suggests, furthermore, that this primitive form may be the one from which all later Melosiras evolved. The fact that other species of *Melosira*, *M. interrupta*, *M. inordinata*, and others of increasingly complex ornamentation also occur in the Wagon Bed assemblage further suggests that *M. vitrea* may have originated in either earlier Tertiary or even Mesozoic time.

Frequent in the Wagon Bed Formation.

Known geologic range: late Eocene.

Order GONIOIDALES Lohman

Suborder BIDDULPHIINEAE Kützing, 1844

Family TERPSINÖACEAE Ralfs, 1861

Genus ANAULUS Ehrenberg, 1844

The occurrence of many specimens of *Anaulus* in the nonmarine upper Eocene part of the Wagon Bed Formation is surprising, as this genus, represented by about a dozen species ranging in age from Eocene to Recent, has been found previously only in marine sediments or living in marine waters. Apparently this isolated entry into a nonmarine environment was not a successful one, as the genus has never been recorded from any other nonmarine environment. The possibility of contamination was considered and dismissed for several reasons: (1) the Wagon Bed Formation is extremely remote from any marine Tertiary formations from which an *Anaulus* could have been reworked; (2) *Anaulus* occurs frequently in the Wagon Bed Formation, but other genera previously known only from marine environments are absent; and (3) extreme care was used to prevent contamination with other samples in the laboratory.

Anaulus ovalis Lohman and Andrews, n. sp.

Plate 1, figures 9, 14

Valve elliptical with heavy margin and deep mantle; divided into three sectors by two heavy septa, thickened at the margins; sectors hyaline except for scattered heavy puncta in random order. Length, 18–30μ; width 10–15μ.

Holotype: USGS diatom cat. No. 3659–28 (pl. 1, fig. 14), length, 30μ; width, 14μ. Paratype: USGS diatom cat. No. 3654–29 (pl. 1, fig. 9) length, 23μ; width, 12μ. Both from USGS diatom locality 5416.

The holotype (pl. 1, fig. 14) shows the scattered puncta and the septa, but it shows the margin only poorly; the paratype (pl. 1, fig. 9) shows the margin and the marginal thickening of the septa. *Anaulus mediterraneus* Grunow (Grunow, in Van Heurck, 1882, pl. 102, fig. 11) and *A. minutus* (Grunow, in Van Heurck, 1882, pl. 103, figs. 4, 5) have an elliptical outline similar to that of *A. ovalis* but they have much thinner septa and very much finer and uniformly distributed puncta. *A. ovalis* also bears a superficial resemblance to the small elliptical species of *Tetracyclus* but differs in the nature of the septa and the punctation. In *Tetracyclus*, the septa, or more properly the costae, are more numerous, and much thinner, and the puncta are much finer and are arranged to form transverse punctate striae separated by a pseudoraphe.

Found frequently in the Wagon Bed Formation.

Known geologic range: late Eocene.

Order PENNALES Schütt, 1896

Suborder ARAPHIDINEAE Karsten, 1928

Family FRAGILARIACEAE Kützing, 1844

Subfamily FRAGILARIOIDEAE Kützing, 1844

Genus FRAGILARIA Lyngbye, 1819

The genus *Fragilaria* is represented in the present assemblage by five species: the variable and cosmopolitan *F. virescens* Ralfs, widely reported from living nonmarine assemblages all over the world; *F. nitida* Héribaud, an extinct species from upper Miocene nonmarine beds in the Province of Cantal, France—this species is uncommon, having been reported from only three other localities, of which only a doubtful one is in the United States; *F. curvistriata*, *F. pellucida*, and *F. denticulata*, here described as new and known only from the upper Eocene part of the Wagon Bed Formation.

Fragilaria curvistriata Lohman and Andrews, n. sp.

Plate 1, figure 16

Valve elongate-elliptical with rounded apices; pseudoraphe very narrow, transverse striae, 20 in 10μ; divergent and arcuate throughout. Length, 15–20μ; width, 6–7μ.

Holotype: USGS diatom cat. No. 3653–122, length, 17μ; width, 6μ; USGS diatom locality 5416.

This tiny species has fine, but faint transverse striae and usually appears hyaline when viewed with dry objectives. The curved, arcuate transverse striae and simple elongate-elliptical outline are its principal distinguishing characteristics. Parallel transverse striae are virtually universal in the in the genus *Fragilaria*, and about the only other species having similar characteristics is *F. constricta* Ehrenberg, which is much larger (20–70μ long), with coarser transverse striae, fine marginal spines, and a totally different outline. Patrick and Reimer (1966 p. 122, fig. 17) gave an excellent illustration of *F. constricta*, showing the arcuate striae, such as occur in *F. curvistriata*, but no mention was made of this unusual characteristic in the specific description on page 122, where they stated: "Striae indistinctly punctate, parallel; sometimes irregularly spaced."

This species occurs frequently in the Wagon Bed assemblage.

Known geologic range: late Eocene.

Fragilaria denticulata Lohman and Andrews, n. sp.

Plate 1, figures 11, 12.

Valve short, tumid, with rounded to subrostrate apices; axial area about one-third width of valve; transverse striae, short, marginal, and robust, 10–12 in 10μ generally parallel in central half of valve, becoming slightly divergent toward apices. Frustule quadrangular in girdle view with parallel sides but slightly convex on one side and concave on opposite side. Length 12–24μ; width, 5–6μ.

Holotype: USGS diatom cat. No. 3659–49 (pl. 1, fig. 11, valve view), length, 18μ. Paratype: USGS diatom cat. No. 3659–81 (pl. 1, fig. 12, girdle view of two complete frustules), length, 19μ; width (two frustules) 9μ. Both from USGS diatom locality 5416.

This tiny species bears a superficial resemblance to *Fragilaria pinnata* Ehrenberg, but the latter has the axial area closed up to form a very narrow pseudoraphe, and is much more variable in size in shape. Some forms of the highly variable *Fragilaria construens* (Ehrenberg) Grunow also approach this species in general shape but have much finer (14–17 in 10μ) transverse striae. *Fragilaria brevistriata* Grunow, another variable species, some forms of which approach this species in outline, has much shorter and much finer (13–17 in 10μ) transverse striae.

Common in the Wagon Bed Formation.

Known geologic range: late Eocene.

Fragilaria nitida Héribaud

Plate 1, figure 17

Fragilaria nitrida Héribaud, 1903, Les diatomées fossiles D'Auvergne, 2d Mém. p. 27, pl. 11, fig. 30.

Valve narrow, elongate, with parallel margins extending nearly to apices, which are slightly narrower and truncate with flat ends; extensions of the margins form minute hornlike processes on each side of truncate ends; transverse striae very faint and irregular in length, 15–18 in 10μ; no pseudoraphe visible. Length 50–100μ; width, 5–8μ.

Length of figured specimen: USGS diatom cat. No. 3662–30, 79μ; width, 8μ; from USGS diatom locality 5416.

In his original description of this diatom, Héribaud stated that no transverse striae could be seen in a balsam mount, which is true, as they are very difficult to see with an oil immersion apochromat at × 1000 in a Hyrax mount. This is due more to their faintness than to their close spacing, as robust markings 15–16 in 10μ are not difficult to resolve under these conditions. The markings are parallel, but of varying length and distinctness. In general they follow a path down the center of the valve; no pseudoraphe could be seen.

Héribaud's material came from an upper Miocene diatomaceous deposit in the vicinity of Joursac, Cantal, France. Tempère and Peragallo (1907, p. 273) reported this species from a fresh-water diatomaceous deposit of unstated age in Thrais, Hungary, and also from one at Lugarde, Cantal, France (p. 354), of late Miocene age. They also reported it from "Mullbury Cuña, Texas" (p. 400), which is a doubtful occurrence, both as to age and locality. Tempère and Peragallo received diatomaceous material from all over the world, both fossil and Recent, from which they made slides for sale. It seems at least possible that the Texas occurrence may have been from a contaminated sample.

The frequent occurrence of *Fragilaria nitida* Héribaud in the Wagon Bed Formation not only extends the range of the species but represents the first authentic record of it in North America.

Known geologic range: late Eocene to late Miocene.

Fragilaria pellucida Lohman and Andrews, n. sp.

Plate 1, figures 19, 20

Valve very narrow, linear, with rounded, rarely subrostrate apices; pseudoraphe very narrow; transverse striae parallel, 18–21 in 10μ; no central hyaline area;

frustule quadrangular in girdle view, with narrow girdle; frequently attached to form chains of two or more frustules. Length, 45–125μ; width, 5–7μ.

Holotype: USGS diatom cat. No. 3660-5 (pl. 1, fig. 20, valve view), length, 96μ; width, 7μ. Paratype: USGS diatom cat. No. 3662-26 (pl. 1, fig. 19, two frustules in girdle view), length, 54μ; depth (two frustules), 6μ. USGS diatom locality 5416.

In valve view this species resembles *Synedra ulna* (Nitzsch) Ehrenberg but has much finer transverse striae (18-21 in 10μ). In *Synedra ulna* the transverse striae range from 8 to 12 in 10μ. Aside from this marked difference, the girdle views of our specimens frequently show two or more complete frustules attached to form chains of varying length. Although *Fragilaria* and *Synedra* are very similar in many respects, the most consistent difference between the two is the fact that in *Fragilaria* adjacent frustules usually remain attached, forming chains of varying length, whereas in *Synedra*, this form of attachment is uncommon. The distinction between the two genera, based upon a habit of growth, may be of some use when dealing with living specimens but is of doubtful value with fossil specimens, as forms that remain attached in life are often separated when the organism dies and is deposited in a sediment. Thus, many specimens of different species of *Fragilaria* that were attached in chains or ribbons during life are found in sediments as separate frustules, and even more often as separate valves. The Wagon Bed assemblage was entombed in a limestone, possibly shortly after death, which accounts for the fact that many whole frustules as well as chains of frustules of several species of *Fragilaria* (pl. 1, figs. 19, 20) and *Ambistria* (pl. 1, figs. 13, 22) were found. The assignment of most new fossil species represented by single valves to the genus *Synedra* is questionable, as the possibility that a species may have formed filaments or chains when living cannot be eliminated. The species here described has been assigned to *Fragilaria*, as the preservation was such that many chains or filaments of two or more complete frustules were found. This was purely fortuitous, however. We are inclined to agree with Patrick and Reimer (1966, p. 117), who, working with living diatoms, stated: "The genus *Fragilaria* is closely related to the genus *Synedra*. Further study may show that these two genera should be united. The main difference is that under natural conditions species of the genus *Fragilaria* form filaments, whereas this is not the case in *Synedra*."

Common in the Wagon Bed Formation.

Known geologic range: late Eocene.

Fragilaria virescens Ralfs

Plate 1, figure 18

Fragilaria virescens Ralfs, 1843, Annals and Mag. Nat. History, v. 12, p. 110, pl. 2, fig. 6.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, v. 7, pt. 2, p. 162, fig. 672A.

Valve elongate elliptical (in short forms) to elongate linear with subparallel sides and rounded or subrostrate apices; pseudoraphe very narrow; traverse striae parallel, 17–21 in 10μ; frustules quadrangular, generally in chains of two or more; girdle narrow to twice depth of mantle; length 20–80μ; width, 5–7μ.

Dimensions of figured specimen: USGS diatom cat. No. 3660–15; length, 36μ; width 6μ; transverse striae, 17 in 10μ; from USGS diatom locality 5416.

The specimens of this species are characteristically variable, and nearly all the known variations in shape have been observed in the collections from the Wagon Bed Formation. No attempt has been made to separate them into varieties as Hustedt (1931) did, as it seems wiser to consider *F. virescens* as a widely variable species. It is common in living assemblages all over the world, in springs, pools, lakes, and streams, and is also common in the assemblage from the Wagon Bed Formation.

Known geologic range: late Eocene to Recent.

Genus AMBISTRIA Lohman and Andrews, n. gen.

Valve linear, elongate, lozenge shaped, with pronounced central widening and smoothly rounded apices; margins usually concave, less commonly straight, never convex, rising gently or abruptly to wider central part, where margin is either rounded or subangular; transverse striae very short, marginal, usually 22–23 in 10μ, rarely as much as 26 in 10μ, subparallel or divergent throughout, and continuing without break along entire margin, completely around rounded apices; axial area very broad, hyaline, or with scattered coarse puncta in no regular order. Frustules rectangular in girdle view, with narrow, punctate mantle and narrow girdle, frequently attached to form chains of varying length.

Type species: *A. hyalina*, n. sp.

Aside from its distinctive shape, one of the most characteristic features of this genus is the short marginal striae that occur not only along the lateral margins of the valve but also continue without a break around the margins of the apices, remaining approximately normal to the margin at all points. These striae are so fine that ordinarily they are not visible when viewed with dry objectives at moderate magnifications unless oblique illumination is employed, but they are readily visible with oil-immersion objectives at a magnification of X 1000. The overall shape of specimens of this genus is, however, so distinctive that generic identification is easily made with relatively low magnification of about X 100. This feature and the common occurrence of the genus in the Wagon Bed Formation make it an excellent marker.

Two species, easily distinguished in valve view, have been described for this genus. In girdle view, however, it is impossible to separate the two species, as they are based upon features visible only in the valve view, as is true with many other genera. Two examples of the girdle view of complete frustules in chains of two or more are given. USGS diatom cat. No. 3662–47 (pl. 1, fig. 13), length, 25μ; depth of two frustules, 18μ. USGS diatom cat. No. 3571–60 (pl. 1, fig. 22), length, 56μ; depth of 15 frustules, 127μ. Both from USGS diatom locality 5416.

Ambistria hyalina Lohman and Andrews, n. sp.

Plate 1, figures 21, 29, 30

Diagnostic features those of the genus, except that the broad axial area between the short transverse marginal striae is always hyaline. Length, 16–85μ; width, 6–11μ.

Holotype: USGS diatom cat. No. 3662–41 (pl. 1, fig. 21), length, 62μ; width at center, 10μ. Paratype: USGS diatom cat. No. 3659–43 (pl. 1, fig. 29), length, 45μ; width at center, 6μ. Paratype: USGS diatom cat. No. 3659–85 (pl. 1, fig. 30), length, 26μ; width at center, 8μ. All from USGS diatom locality 5416.

The three figures give some idea of the range in size of this species most commonly found, although specimens as much as 85μ long occur frequently. It is easily distinguished from *A. punctata* by the absence of scattered puncta in the hyaline axial area and by the fact that it is usually much longer.

Abundant in the Wagon Bed Formation.

Known geologic range: late Eocene.

Ambistria punctata Lohman and Andrews, n. sp.

Plate 1, figures 26, 28, 31

Diagnostic features those of the genus, but confined to species having scattered puncta in no regular arrangement occupying the broad axial area between the short transverse marginal striae. Length, 16–45μ; width, 9–11μ.

Holotype: USGS diatom cat. No. 3662–39 (pl. 1, fig. 28), length, 30μ; width at center, 11μ. Paratype: USGS diatom cat. No. 3662–24 (pl. 1, fig. 26), length, 41μ; width at center, 11μ. Paratype: USGS diatom cat. No. 3659–16 (pl. 1, fig. 31), length, 32μ; width at center, 9μ. All from USGS diatom locality 5416.

The three illustrations give a fair idea of the variability of both the size and shape of this species and the random arrangement of the puncta in the axial area. No. 3659–16 (pl. 1, fig. 31) has sharply concave margins and only a few scattered puncta; No. 3662–39 (pl. 1, fig. 28) has virtually straight margins and many more scattered puncta; No. 3662–24 (pl. 1, fig. 26) has sharply concave margins, the puncta being confined to two submarginal areas near the center of the valve. All possible variations have been observed in the large number of specimens examined. The puncta can usually be seen with high-power dry objectives, but, like the marginal striae, are more easily seen with oil-immersion objectives. No specimens of this species attain the maximum length of *A. hyalina.*

Common in the Wagon Bed Formation.

Known geologic range: late Eocene.

Suborder BIRAPHIDINEAE Karsten, 1928

Family NAVICULACEAE Kützing, 1844

Subfamily NAVICULOIDEAE Kützing, 1844

Genus NAVICULA Bory, 1824

This genus, largest in number of species among the diatoms, living and fossil, marine and nonmarine, is represented in the present assemblage by only two species: *N. perpusilla* (Kützing) Grunow, still represented in living assemblages, and *N. panda*, here described as new.

Navicula panda Lohman and Andrews, n. sp.

Plate 1, figure 23

Valve linear elliptical with rounded apices; axial area narrow, widening slightly to form oval central area; raphe straight, simple; terminal nodules curved in same direction; finely punctate transverse striae, 22–23 in 10μ, divergent throughout, much coarser opposite central area. Length 12–40μ; width, 5–9μ.

Holotype: USGS diatom cat. No. 3659–7, length, 30 μ; width, 8μ. From USGS diatom locality 5416.

The coarse spacing of a few of the transverse striae in the central part of the valve makes this species easy to recognize, even though it is very small. In this respect it is somewhat similar to *N. digitulus* Hustedt, 1943, p. 162, fig. 26–30), but it is much larger and the transverse striae are much coarser; there are 30–32 in 10 μ in Hustedt's species. This abruptly coarser spacing of the transverse striae is also seen in *N. bacillum* Ehrenberg, but there is nothing else in common between the two species. N. *protracta* Grunow (Cleve and Grunow, 1880, p. 35, pl. 2, fig. 38) is somewhat similar but has rostrate, truncate apices. *N. lundstromii* Cleve (Cleve and Grunow, 1880, p. 13, pl. 2, fig. 39) is also somewhat similar but is much larger and has subrostrate apices and coarser transverse striae. Although the form illustrated is the one most often found in the Wagon Bed Formation, a somewhat longer, narrower form, identical in all other respects, also occurs rarely. As there are gradations between the two, it has not been thought advisable to separate them.

Frequent in the Wagon Bed Formation.

Known geologic range: late Eocene.

Navicula perpusilla (Kützing) Grunow

Plate 1, figure 24

Synedra perpusilla Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 63, pl. 3, fig. 31.

Navicula perpusilla (Kützing) Grunow, 1860, Kgl. zool.-bot. Gesell. Wien, Verh., v. 10, p. 552, pl. 4, fig. 7a–g.

Navicula perpusilla (Kützing) Grunow var. *perpusilla*, Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia, Mon. 13, p. 478, pl. 45, fig. 14.

Navicula perpusilla Grunow, in Van Heurck, 1880, Synopsis des diatomées de Belgique, pl. 14, fig. 22, 23.

Hustedt, 1962, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 3, p. 213, fig. 1330.

Navicula flotowii Grunow, in Van Heurck, 1880, Synopsis des diatomées de Belgique, pl. 14, fig. 41; 1885, text, p. 109.

Valve linear with tumid center and broad, rounded apices; axial area lanceolate, widened in central portion, roughly parallel with margin of valve; raphe straight, central nodules small, separated; transverse striae, radiate throughout, short, 30–36 in 10 μ, finely punctate. Length, 8–20 μ; width, 3–5 μ.

Length of figured specimen (USGS diatom cat. No. 3659–71), 15 μ; width, 4 μ. From USGS diatom locality 5416.

Kützing's (1844) original figures of this tiny species although poor, clearly show it to be a *Navicula*, as even the raphe is indicated. Grunow (1860) also recognized this feature in Kützing's figure, as he indicated by writing "*Navicula perpusilla* m. (*Synedra perpusilla* Kg?)" for the heading to his description of the species. He later (Grunow, in Van Heurck, 1880) ignored the fact that he knew Kützing was the original author of the epithet. He further confused the matter (Grunow, in Van Heurck, 1885) by giving another name, *N. flotowii*, for the same species and publishing both names on the same plate. De Toni (1892, p. 671) recognized that Kützing's species was misnamed, stating: "*Synedra perpusilla* Kuetz. est *Naviculae*." Hustedt followed Grunow in assigning the epithet to him, ignoring Kützing's definite priority.

It seems best to assign the specific name to Kützing as Patrick and Reimer (1966, p. 478) did, without, however, recognizing their nominate variety. It is regrettable that in their otherwise excellent monograph on the nonmarine living diatoms of the United States they chose, for the first time to our knowledge, to introduce a universal trinomial nomenclature into diatom literature. The term "variety" has been overworked by authors previously, but to add a nominate variety and thus make varieties of all species, even including the type, seems to add unnecessary complication to the nomenclature without contributing any useful information.

This tiny species has very fine transverse striae, and all the specimens of it in the present assemblage have very faint striae. These two factors make the striae difficult to photograph satisfactorily. In this respect, the specimens resemble Hustedt's figures more than the excellent drawing by Patrick and Reimer.

This is another one of the small group of species from the Wagon Bed Formation, where it occurs frequently, that is still represented in living assemblages elsewhere. At present it is an aerophil fresh-water species frequently growing on moss and indifferent to pH. *Pinnularia brebissonii* (p. E18) is another species in the Wagon Bed Formation which is living today in a similar environment.

Known geologic range: late Eocene to Recent.

Genus ANOMOEONEIS Pfitzer, 1871

Only one species of this genus, here described as new, occurs in the Wagon Bed Formation, but its common occurrence in the formation and its distinctive appearance make it a valuable marker for the late Eocene.

Anomoeoneis undulata Lohman and Andrews, n. sp.

Plate 1, figures 25, 27

Valve elongate with undulating margins having three nodes and rostrate apices; axial area straight and uniformly about 3μ wide; raphe straight without thickening at central area, but with hooked terminal nodules; transverse striae 17–19 in 10μ, irregularly punctate, divergent throughout length of valve, longitudinal rows not evident. Length, 30–65μ; width, 14–20μ.

Holotype: USGS diatom cat. No. 3659–45 (pl. 1, fig. 25), length, 41μ; width, 14μ. Paratype: USGS diatom cat. No. 3659–59 (pl. 1, fig. 27), length, 45μ; width, 15μ. Both from USGS diatom locality 5416.

This species generally has remarkably constant characteristics. The exceptions are a very few aberrant forms that maintain the same external shape with undulate margins but have incomplete striation, which varies from marginal striae only to striae that approach the normal linear axial area but end in a ragged fashion before reaching it. At first an attempt was made to erect a separate species for these aberrant forms, but their rarity and great variability soon indicated the futility of adequately defining such a species. The vast majority of the typically anomoeonoid forms in the present assemblage are so uniform that it was decided merely to consider them as aberrant forms of *Anomoeoneis undulata.* Boyer (1927, p. 325 described and named a form *A. serians* var. *apiculata* which had been figured by Lewis (1865, p. 8–9, pl. 2, fig. 5a) as *Navicula serians* var. a (apiculate). This species has a very slightly undulate margin, a much narrower axial area, and finer striae than the present species and should not be easily confused with it.

Frequent in the Wagon Bed Formation.

Known geologic range: late Eocene.

Genus PINNULARIA Ehrenberg, 1843

The most abundant genus, both as to number of species and number of individual specimens in the assemblage from the Wagon Bed Formation, is *Pinnularia.* One well-known species, *P. brebissonii*, which is still common in living assemblages, as well as 11 new species of this genus, of which *P. elliptica* is the most abundant species in the assemblage, are described in this report. None of the large parallel-sided members of the genus, of which *P. dactylus* might be considered typical, occurs in this assemblage, although they are commonly found in beds as old as middle Miocene. The longitudinal bands crossing the costae in many of the larger species of *Pinnularia*, such as *P. dactylus*, *P. nobilis*, and *P. viridis*, are completely absent in all members of the genus in the Wagon Bed assemblage. It seems probable that this feature developed sometime between late Eocene and middle Miocene time. Another feature that must have developed after late Eocene time is the parallel arrangement of the transverse costae normal to the raphe, characteristic of many Miocene and later Pinnularias. All the Wagon Bed species of *Pinnularia* have either divergent transverse costae throughout, as in *P. elliptica*, or divergent costae in the median part and convergent costae at the apices. The above generalizations are based upon the examination of many hundreds of individuals of the 12 species of *Pinnularia* present in the Wagon Bed Formation, and not one exception was noted.

Pinnularia barca Lohman and Andrews, n. sp.

Plate 2, figure 15

Valve linear with parallel or slightly concave margins and concave, subrostrate apices; axial area very narrow, widening abruptly to form small circular central area; raphe simple, straight except for slight curvature at central nodule; transverse costae, thick, 10 in 10μ, divergent in median half of valve, convergent at apices. Length, 40–55μ.

Holotype: USGS diatom cat. No. 3659–13, length, 47μ; width, 11μ; from USGS diatom locality 5416.

This species differs from *P. subrostrata* (p. E21) in having a very narrow axial area, a small circular central area, and bolder uniformly spaced costae. Cleve-Euler (1955, p. 49, fig. 1053a, b) described several varieties and forms of *P. obliquestriata*, one of which, var. *continua*, resembles *P. barca* but has a much wider axial area and much thinner but somewhat more distant costae.

With the exception of *Pinnularia barca* and two other species, *P. gnoma* and *P. brebissonii*, all the Pinnularias in the Wagon Bed assemblage are characterized by wide axial areas.

Frequent in the Wagon Bed Formation.

Known geologic range: late Eocene.

Pinnularia brebissonii (Kützing) Rabenhorst

Plate 1, figure 15

Navicula brebissonii Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 93, pl. 3, fig. 49; pl. 30, fig. 39. Schmidt, 1886, Atlas der Diatomaceenkunde, pl. 44, figs. 17–19.

Pinnularia brebeissonii (Kützing) Rabenhorst, 1864, Flora Europaea Algarum, Sec. I, p. 222.

Pinnularia brebissonii (Kützing) Rabenhorst var. *brebissonii*, Patrick and Reimer, 1966, Acad. Nat. Sci. Philadelphia Mon. 13, p. 614, pl. 58, fig. 6.

Pinnularia microstauron var. *brebissonii* (Kützing) Hustedt, in Pascher, Süsswasser-flora Mitteleuropas, No. 10, p. 321, fig. 584.

Valve linear-elliptical with rounded ends; axial area narrow, gradually widening in the middle to form a transverse fascia reaching the margins, but wider toward the central area; costae, 10–13 in 10μ, divergent in the middle and convergent at the ends; raphe simple, straight. Length, 40–60μ; width, 11–14μ.

Length of figured specimen (USGS diatom cat. No. 3659–12), 43μ; width, 9μ; from USGS diatom locality 5416.

Hustedt (in Pascher, 1930) considered this species to be a variety of *P. microstauron* (Ehrenberg) Cleve, which has parallel margins and rostrate broad apices. Hustedt apparently ignored external shape, an important feature by which species of this genus are differentiated, so his identification serves no useful purpose. Patrick and Reimer (1966, p. 615) examined the original type specimens and agree that *P. brebissonii* and *P. microstauron* should be kept as separate species. (For comments on the inadvisability of their introduction of a universal trinomial nomenclature, see p. E17 of this report). No specimen of *P. microstauron* or any species gradational between it and *P. brebissonii* was found in the collections from the Wagon Bed Formation.

Pinnularia brebissonii occurs frequently in the Wagon Bed Formation and also occurs in many Miocene and younger formations in both the Great Basin and the Great Plains. It is one of the few species in the Wagon Bed assemblage that it still represented in living assemblages all over the world, in cool fresh water of low mineral content.

Known geologic range: late Eocene to Recent.

Pinnularia elliptica Lohman and Andrews, n. sp.

Plate 2, figures 1, 2

Valve linear elliptical with rounded to subacute ends; axial area narrow at extreme ends, widening uniformly to half width of valve in central part, with one side slightly wider opposite central nodules; raphe simple and straight except for extreme ends, prominent central nodules deflected toward wider side of central area; transverse costae, 7–8 in 10 μ, slightly curved and divergent over nearly full length of valve but becoming subparallel at apices; costae in central part of unequal length, very short ones alternate with longer ones. Length, 90–160 μ; width, 30–40 μ.

Holotype: USGS diatom cat. No. 3653–100 (pl. 2, fig. 1), length, 154 μ; width, 37 μ. Paratype: USGS diatom cat. No. 3571–4 (pl. 2, fig. 2), length, 111 μ; width, 31 μ. Both from USGS diatom locality 5416.

Schmidt (1876, pl. 42, figs. 24, 25) figured a species which he named *Navicula dariana* which might be mistaken for *P. elliptica*. Schmidt's species, however, is larger (180–210 μ long) and has a much narrower axial area, coarser costae (5–8 in 10 μ), an indentation on both sides of the valve opposite the central nodules, straight margins rather than elliptical, and blunter apices, and does not have the alternating short and long costae in the central part. Peragallo and Héribaud (Héribaud, 1902, p. 41, pl. 7, fig. 8) described and figured a variety *miocenica* of *N. dariana* which is smaller than Schmidt's type and has coarser costae (6–7 in 10 μ) but differs in no other respect. Cleve (1895, p. 90) correctly placed Schmidt's species in *Pinnularia* but erroneously made it a variety of *P. dactylus* Ehrenberg with which it shows no discernible relation. Hustedt (in Schmidt, 1934, pl. 389, figs. 1, 2) figured a new species, *Pinnularia subflexuosa*, which bears a superficial resemblance to *P. elliptica* but is much larger (200–270 μ long) and has blunt rounded ends, a complex sinuous raphe, and a narrower axial area and is without the alternating long and short costae opposite the central nodule.

This species is known only from the Wagon Bed Formation, where it dominates the assemblage.

Known geologic range: late Eocene.

Pinnularia gnoma Lohman and Andrews, n. sp.

Plate 2, figure 14

Valve linear-elliptical with broadly rounded ends; axial area very narrow near apices, widening abruptly with two or three short costae to form oval central area nearly reaching the margin; costae bold, 9–11 in 10 μ, divergent in the middle and convergent at the apices; raphe simple, straight, with central nodules turned slightly to one side. Length, 25–35μ; width, 8–9μ.

Holotype: USGS diatom cat. No. 3653–54, length, 32 μ; width, 8 μ; from USGS diatom locality 5416.

This tiny species bears a superficial resemblance to *P. brebissonii* (p. E18) but is consistently smaller and has bolder, coarser costae and more rounded apices, and the oval central area does not form a fascia reaching the margin. *P. gnoma* always has at least two very short costae opposite the central area. Examination of many specimens indicates that this species is remarkably constant in all specifications. Its frequent occurrence in the Wagon Bed Formation and the ease with which it can be identified make it a useful marker.

Known geologic range: late Eocene.

Pinnularia irregularis Lohman and Andrews, n. sp.

Plate 2, Figure 3

Valve narrow, linear-elliptical with sharply rounded apices; axial area narrow at apices, gradually widening to circular central area; raphe straight, inclined, excentric at apices; transverse costae, 9–10 in 10μ, divergent over most of valve, slightly convergent near apices; costae of unequal length, occasionally discontinuous, giving ragged edge between costae and axial area. Length, 100–120μ; width, 18–20μ.

Holotype: USGS diatom cat. No. 3662–19, length, 113μ; width, 19μ; from USGS diatom locality 5416.

The most consistent and readily noticed feature of this species is the ragged margin between the ends of the costae and the axial area, particularly in the central half of the valve. This, coupled with the other diagnostic features, removes any confusion with other species.

Rare to frequent in the Wagon Bed Formation.

Known geologic range: late Eocene.

Pinnularia obesa Lohman and Andrews, n. sp.

Plate 2, figure 9

Valve elliptical with minor axis nearly half the major axis; apices acute; axial area lanceolate, widened on one side at middle; raphe straight with prominent central nodules curved toward widened part of axial area; transverse costae, 7–8 in 10μ, divergent every-where except at extreme ends, where they are slightly convergent. Length, 50–60μ; width, 22–23μ.

Holotype: USGS diatom cat. No. 3654–27, length, 55μ; width, 22μ; from USGS diatom locality 5416.

Although superficially similar to *Pinnularia elliptica* this species is much shorter, with a smaller length : width ratio, has costae of uniform length, and has much more acute apices. The alternating long and short costae opposite the central area in *P. elliptica* alone constitutes ample reason for separating the two, as it is one of the most constant features of *P. elliptica*. *P. alpina* Wm. Smith (1853, p. 55, pl. 18, fig. 168) has a somewhat similar shape but is much larger (100–250μ long) and, has very much coarser transverse costae (3–4 in 10 μ) and broadly rounded apices. Although striking in appearance and easily identified. *P. obesa* is much less abundant in the Wagon Bed Formation than *P. elliptica* and cannot be found in every slide made from this locality.

Known geologic range: late Eocene.

Pinnularia runa Lohman and Andrews, n. sp.

Plate 2, figure 4

Valve lanceolate, narrow, with straight margins and acute, rounded apices; axial area symmetrical, wide, more than half width of valve; raphe straight, except for very slight curve at central nodules; transverse costae short, 7–8 in 10 μ, somewhat irregular in length, with a few very short costae alternating with longer ones opposite central nodules. Length, 140–150 μ; width, 27–30 μ.

Holotype: USGS diatom cat. No. 3571–62, length, 149 μ; width, 28 μ. From USGS diatom locality 5416.

In the specimen figured, the raphe seems to be continuous across the central nodules. This seems to be an accidental crack in the specimen, as the central nodules can be seen by careful focusing. This species differs from *P. elliptica* by being much narrower, having straight margins from the center to each apex, and having a symmetrical axial area without the asymmetrical widening opposite the central nodules. It bears a superficial resemblance to *P. anguste-elliptica* Cleve-Euler (Cleve-Euler, 1955, p. 72, fig. 1097), but the latter has a sinuous raphe and a narrower axial area, widened in the middle to form a circular central area. *P. anguste-elliptica* also has blunt truncated apices.

This species is rare in the Wagon Bed Formation.

Known geologic range: late Eocene.

Pinnularia scapha Lohman and Andrews, n. sp.

Plate 2, figure 5

Valve narrow, elliptical, with blunt apices; axial area narrow, abruptly widening to form a nearly square central area oriented with one diagonal parallel to longitudinal axis; raphe simple, straight except for slight curvature at central nodules; transverse costae, 9–10 in 10 μ, divergent in median part, convergent at apices. Length, 50–60 μ; width, 15–16 μ.

Holotype: USGS diatom cat. No. 3653–64, length 66 μ; width, 16 μ. From USGS diatom locality 5416.

This species differs from *P. elliptica* by being narrower, having a narower axial area with the quadrangular central area, and having more closely spaced costae. The quadrangular central area makes this species very easy to recognize in an assemblage dominated by *P. elliptica*. An additional point of difference is that the transverse costae in *P. elliptica* are divergent throughout the valve, whereas in *P. scapha* they are divergent in the median part and convergent at the apices.

Frequent in the Wagon Bed Formation.

Known geologic range: late Eocene.

Pinnularia serpentina Lohman and Andrews, n. sp.

Plate 2, figures 6, 8

Valve lanceolate with undulating sides and subrostrate apices; axial area narrow at apices, broadening gradually to more than half width of valve, with large rounded slightly asymmetrical central area; with or without widely and irregularly spaced coarse puncta in axial and central areas; costae bold, 8–10 in 10 μ, divergent over most of the valve but sharply convergent near apices; raphe straight, simple. Length 80–95 μ; width, 18–20 μ.

Holotype: USGS diatom cat. No. 3662–13 (pl. 2, fig. 8), length, 84 μ; width 18 μ. Paratype, USGS diatom cat. No. 3654–19 (pl. 2, fig. 6), length, 94 μ; width, 19 μ. Both from USGS diatom locality 5416.

Hustedt (*in* Schmidt, 1934, pl. 392, fig. 7) figured a new variety, *Pinnularia legumen* var. *cuneata*, which might be confused with *P. serpentina*. Hustedt's form, however, has cuneate instead of subrostrate to rostrate apices, a narrower axial area, a complex sinuous raphe, and a smaller, more perfectly circular central area. *P. clevei* Patrick (Patrick, 1945, p. 193, pl. 3, figs. 9, 10 [not figs. 7, 8]) also resembles the present species somewhat but is much narrower and again has a narrower axial area, a much smaller central area, a complex sinuous raphe, and cuneate ends. Patrick's 1945 figures are somewhat confusing, but an excellent figure appears in Patrick and Reimer, 1966, plate 61, figure 3.

Cleve-Euler (1939, p. 14, fig. 22) named a diatom *Pinnularia hybrida* Peragallo and Héribaud forma *acuminata, triundulata*. This form is similar in external shape to *P. serpentina* but has much shorter and finer costae ("sehr kurzen randständigen Streifen.") and a much wider axial area without the rounded central area. Cleve-Euler later changed the name to *P. brevicostata* var. *triangulata* (A. Cleve) Cleve-Euler (Cleve-Euler, 1955, p. 38, fig. 1045e), although the varietal name is carried in the explanation for her figure 1045e (1955, p. 221) as var. *triundulata*. This is an excellent example of some of the hazards of multinominal nomenclature.

Frequent in the Wagon Bed Formation.

Known geologic range: late Eocene.

Pinnularia spatula Lohman and Andrews, n. sp.

Plate 2, figure 7

Valve linear, widened slightly in median part, with bluntly rounded apices; axial area very narrow at apices, widening gradually to a transverse broad fascia almost reaching the margins; transverse costae, 11–12 in 10μ, divergent in median part and convergent at apices; marginal costae opposite central fascia very short, but always present; raphe simple and straight except for slight curvature at central nodules. Length, 50–60μ; width, 10–11μ.

Holotype: USGS diatom cat. No. 3658–84, length, 55μ; width, 11μ; from USGS diatom locality 5416.

This species resembles *P. brebissonii* (p. E18) somewhat, but it is not elliptical, has a much wider axial area, and always has short costae at the marginal ends of the broad central fascia.

This species is rare in the Wagon Bed Formation.

Known geologic range: late Eocene.

Pinnularia subrostrata Lohman and Andrews, n. sp.

Plate 2, figure 16

Valve elongate with subparallel or slightly convex margins and concave, subrostrate apices; axial area very narrow at apices, widening to about one third width of valve toward rounded central area; raphe straight, with prominent central nodules; transverse costae, narrow, 10–11 in 10μ divergent over major part, becoming convergent at apices; costae surrounding marginal part of central area irregularly shorter and more widely spaced, but always present. Length 50–90 μ; width, 10–18μ.

Holotype: USGS diatom cat. No. 3653–15, length, 73μ; width, 16μ; from USGS diatom locality 5416.

The large orbicular central area with the short widely spaced costae along the margin opposite the central area, the concave subrostrate apices, and the thin costae characterize this species and make it very easy to separate from all others. The margins are nearly straight and subparallel or very slightly convex. It differs from *P. serpentina* by having smoothly straight or slightly convex margins and by having finer and thinner costae.

Frequent in the Wagon Bed Formation.

Known geologic range: late Eocene.

Pinnularia tumida Lohman and Andrews, n. sp.

Plate 2, figure 13

Valve lanceolate with acute apices and rounded, tumid central part; axial area narrow at apices, widening uniformly to half width of valve in central part with slight arcuate widening on one side opposite central nodule; raphe simple and straight except at extreme ends; transverse costae, 8 in 10μ, slightly curved and divergent over nearly full length of valve, but becoming convergent at apices; costae in central part of unequal length, with very short ones between groups of 1–to–4 longer ones. Length, 120–135μ; width, 32–34μ.

Holotype: USGS diatom cat. No. 3655–2, length 131μ; width, 33μ; from USGS diatom locality 5416.

This species is obviously closely related to *P. elliptica* (p. E19), as many of the diagnostic features are the same. However, its external shape, with the tumid central part and the concave tapering apices, renders it quite distinct. Those with a penchant for trinomial nomenclature might make this form a variety of *P. elliptica*, but among many hundreds of specimens examined for this report, no gradation between the two was observed; therefore, the separation seems to be warranted.

The species is rare in the Wagon Bed Formation.

Known geologic range: late Eocene.

Genus STAURONEIS Ehrenberg, 1843

Three distinct species of *Stauroneis*, here described as new, occur in the Wagon Bed Formation. They are characerized by their small size (20–50μ long) and their fine irregularly punctate transverse striae, which are anomoeonoid in appearance. Although some living species of *Stauroneis*, such as *S. nobilis* Schumann, have such irregularly punctate striae, most species of the genus have regular punctation. The fact that the three species here described, which are the earliest known members of the genus, all have irregular punctation suggests that this type is the more primitive and that the regularly punctate species may have developed from it. This change apparently occurred fairly early in the Tertiary, as the middle and upper Miocene Virgin Valley Beds of Merriam (1907) in northwestern Nevada contain both *Stauroneis nana* and *S. phoenicenteron*, a large and regularly punctate species that is still represented in living assemblages elsewhere.

Stauroneis fusiformis Lohman and Andrews, n. sp.

Plate 2, figure 10

Valve elongate-elliptical with slender, produced, subcapitate to capitate apices; raphe straight, simple, terminating at the stauros; axial area very narrow; irregularly punctate transverse striae, 18–22 in 10μ, divergent throughout; stauros about 2μ wide with parallel sides; no longitudinal rows of puncta because of irregular spacing. Length, 29–50μ, usually 45–50μ; width, 8–12μ, usually 10–12μ.

Holotype: USGS diatom cat. No. 3660–2, length, 46μ; width 11μ; from USGS diatom locality 5416.

This species differs from *Stauroneis anceps* Ehrenberg by having narrower apices and coarser, irregularly punctate transverse striae. The punctation of the transverse striae in this Eocene species is anomoeonoid in character and not uniform as in *S. anceps*. It is also remarkably uniform in size and other characteristics, for among a large number measured, the majority ranged from 45 to 50μ in length; only one had a length of 29μ. The form named *S. anceps* forma *gracilis* by Rabenhorst (1864, p. 247) and *S. anceps* var. *gracilis* by Brun (1880, p. 89, p. 9, fig. 2) has similar narrow subcapitate to capitate apices but much finer striae (26–28 in 10μ) with uniform puncta.

This species occurs frequently in the Wagon Bed Formation.

Known geologic range: late Eocene.

Stauroneis nana Lohman and Andrews, n. sp.

Plate 2, figure 11

Valve small, elongate-elliptical, with rostrate apices; axial area irregular, about 1.5μ wide; stauros narrow with parallel sides, 1.5μ; raphe straight, terminating at stauros; irregularly punctate transverse striae, 18–19 in 10μ, divergent throughout; no longitudinal rows of puncta; puncta bacilliform. Length, 20–30μ; width, 6μ.

Holotype: USGS diatom cat. No. 3660–14, length, 24μ; width, 6μ; from USGS diatom locality 5416.

The stauros in this species is not prominent, as it is narrow. It is much easier to see on the specimen than it is in the photomicrograph used for the present illustration, which was chosen from a number of similar ones as it shows the faint transverse striae adequately. *Stauroneis lauenburgiana* Hustedt (Hustedt, 1950, p. 405, pl. 37, fig. 15) has a superficial resemblance to this species but differs by being larger, having short pseudosepta at the apices, and having finer and nonbacilliform puncta. The puncta also have a suggestion of being arranged in longitudinal rows, which are totally lacking in *S. nana*.

This species occurs frequently in the Wagon Bed Formation and in the middle and upper Miocene Virgin Valley Beds of Merriam (1907) in Humboldt County, Nev. (USGS diatom locs. 3523, 3524, and 3536), and rarely in the Pliocene and Pleistocene Glenns Ferry Formation of Idaho (USGS diatom loc. 4169).

Known geologic range: late Eocene to Pleistocene.

Stauroneis vesca Lohman and Andrews, n. sp.

Plate 2, figure 12

Valve lanceolate, narrow, with rounded apices; axial area narrow; stauros wider at margin than in center, with median width about 2μ; raphe straight, terminating at stauros; irregularly punctate transverse striae, 19–20 in 10μ, divergent throughout; no longitudinal rows of puncta. Length, 35–40μ; width 7μ.

Holotype: USGS diatom cat. No. 3662–12, length 38μ; width, 7μ; from USGS diatom locality 5416.

The striation on this species is similar to that on *S. fusiformis*, but the shape of the valve is totally different. Among many specimens examined, no gradation between the two was observed. *S. vesca* occurs frequently in the Wagon Bed Formation, but less so than *S. fusiformis*.

Known geologic range: late Eocene.

Family NITZSCHIACEAE Grunow, 1860

Genus NITZSCHIA Hassall, 1845

Nitzschia commutata Grunow

Plate 2, figures 18, 19

Nitzschia commutata Grunow, in Cleve and Grunow, 1880, Kgl. svenska vetensk. akad. Handl., v. 17, no. 2, p. 79.

Grunow, in Van Heurck, 1881, Synopsis des diatomées de Belgique, pl. 59, figs. 13, 14.

Hustedt, in Pascher, 1930, Die Süsswasser-flora Mitteleuropas, no. 10, p. 405, fig. 774.

Hustedt, in Schmidt, 1922, Atlas der Diatomaceenkunde, pl. 346, figs. 17–20.

Valve elongate-lanceolate with subrostrate apices; transverse striae parallel, 20–24 in 10μ; keel puncta variable, 7–10 in 10μ; margins straight or slightly constricted in middle. Length, 50–86μ; width, 5–12μ.

Measurements of figured specimens: USGS diatom cat. No. 3659–70 (pl. 2, fig. 19, valve view), length 57μ; width at constriction, 6μ; USGS diatom cat. No. 3659–77 (pl. 2, fig. 18, girdle view of frustule), length, 54μ; width at constriction, 9μ; both from USGS diatom locality 5416.

This is one of the species in the Wagon Bed assemblage that is still represented in living assemblages from fresh and slightly saline ponds and lakes.

This species occurs frequently in the Wagon Bed Formation.

Known geologic range: late Eocene to Recent.

Nitzschia fremontensis Lohman and Andrews, n. sp.

Plate 2, figure 17

Valve linear-elliptical with narrowly rounded to subrostrate apices and slight central constriction, more obvious adjacent to keel; keel prominent, marginal, with coarse, irregular keel puncta, 6–7 in 10μ; finely punctate parallel transverse striae 25 in 10μ; longitudinal rows not evident; with or without faint longitudinal bands near margins. Length, 70–85μ; width, 17–19μ.

Holotype: USGS diatom cat. No. 3662–5, length, 84μ; width, 18μ; from USGS diatom locality 5416.

Although definitely to be included in Grunow's group *Tryblionellae* (Grunow, in Cleve and Grunow, 1880, p. 67), this species has much finer transverse striae than any other species in the group with the exception of *N. circumsuta* (Bailey) Grunow, which is broadly elliptical in outline and has strongly convex margins and could not be confused with the present species.

This species occurs frequently in the Wagon Bed Formation.

Known geologic range: late Eocene.

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U.S. GOVERNMENT PRINTING OFFICE: 1968 O—285-944

PLATES 1 and 2

PLATE 1

FIGURE

1. *Melosira canalifera* var. *anastomosans* Héribaud, × 1200 (p. E10). USGS diatom cat. No. 3662–9. Diameter, 23 μ.
2. *Melosira inordinata* Lohman and Andrews, n. sp., × 1010 (p. E11). Holotype, USGS diatom cat. No. 3653–111. Diameter, 9 μ.

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  21. Holotype, USGS diatom cat. No. 3662–41, × 1600. Length, 62μ.
  29. Paratype, USGS diatom cat. No. 3659–43, × 1550. Length, 45μ.
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23. *Navicula panda* Lohman and Andrews, n. sp., × 1570 (p. E16). Holotype, USGS diatom cat. No. 3659–7. Length, 30μ.
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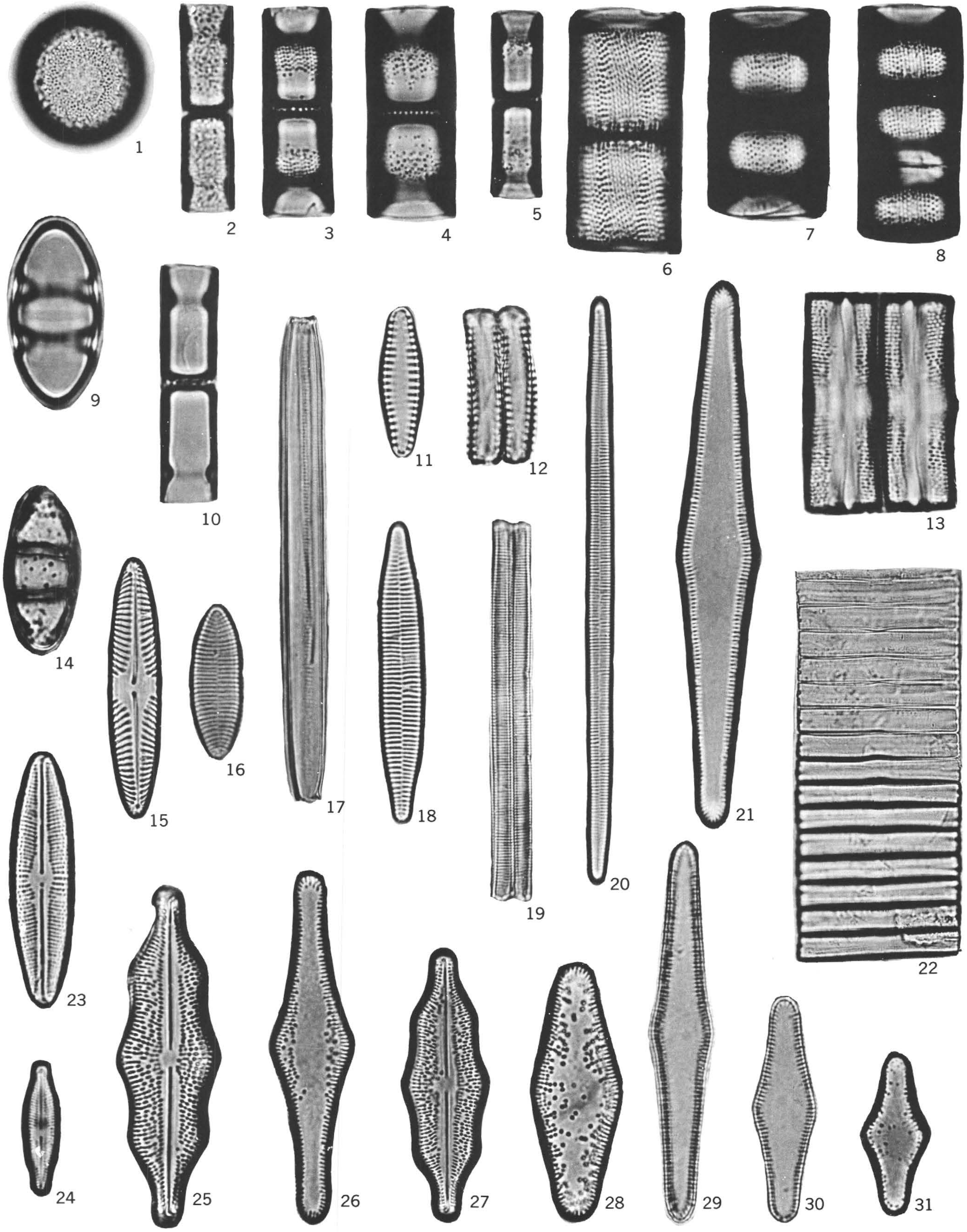
  31. Paratype, USGS diatom cat. No. 3659–16, × 940. Length, 32μ.



MELOSIRA, *ANAULUS*, *FRAGILARIA*, *AMBISTRIA*, *PINNULARIA*, *NAVICULA*, AND *ANOMOEONEIS*

PLATE 2

FIGURES 1, 2. *Pinnularia elliptica* Lohman and Andrews, n. sp., × 620 (p. E19).
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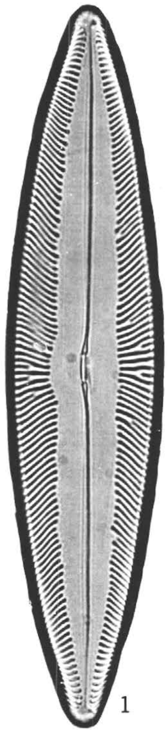
  19. USGS diatom cat. No. 3659–70, valve view. Length, 57 μ.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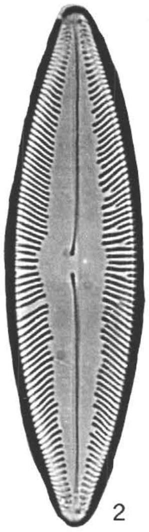
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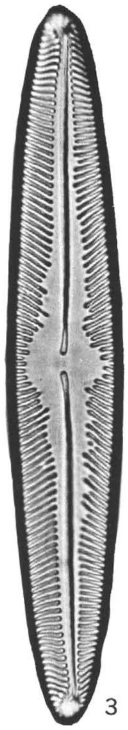
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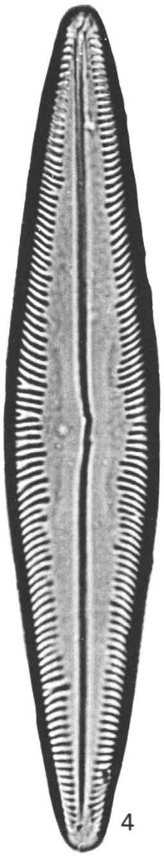
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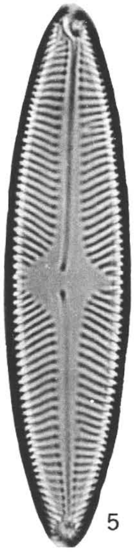
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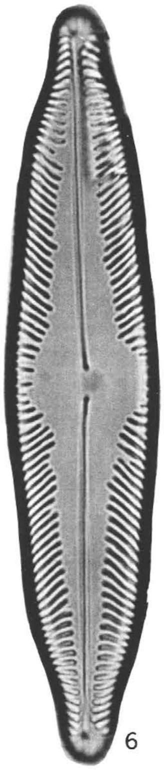
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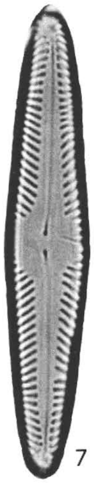
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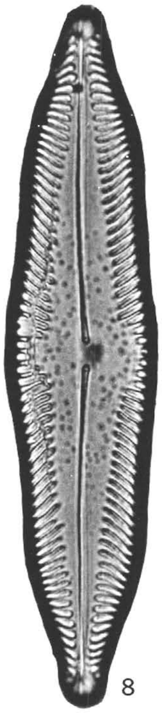
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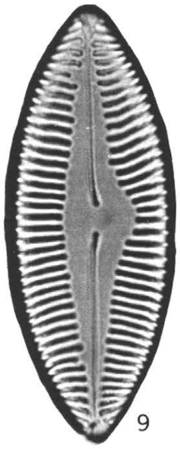
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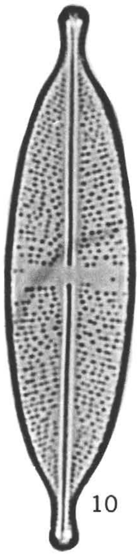
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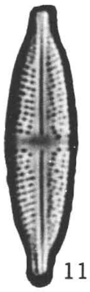
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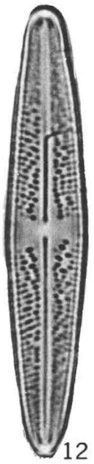
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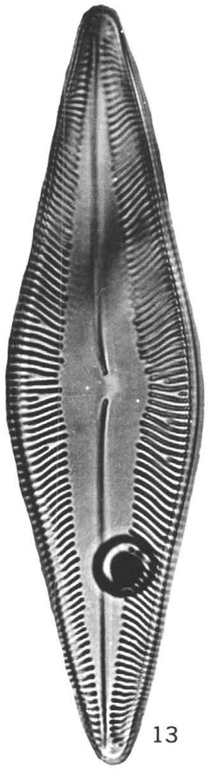
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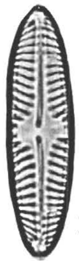
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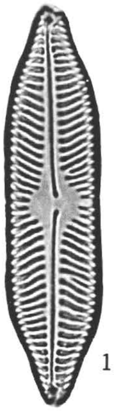
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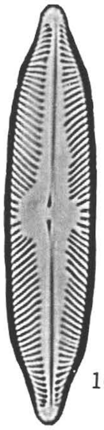
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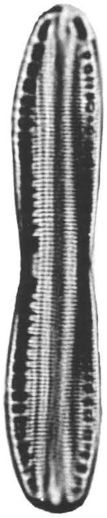
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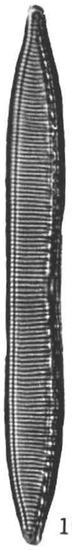
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PINNULARIA, *STAURONEIS*, AND *NITZSCHIA*