Late Pleistocene Diatoms From the Trempealeau Valley, Wisconsin

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By GEORGE W. ANDREWS

CONTRIBUTIONS TO PALEONTOLOGY

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*A late Pleistocene diatom assemblage
from west-central Wisconsin and its
paleoecologic and stratigraphic
significance*

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LATE PLEISTOCENE DIATOMS FROM THE TREMPEALEAU VALLEY, WISCONSIN

By GEORGE W. ANDREWS

ABSTRACT

The Trempealeau Valley trends in a generally southwestward direction across the Driftless Area of west-central Wisconsin between the central Wisconsin lowland and the Mississippi Valley. It contains an upper Pleistocene alluvial fill. Remnants of three terraces have been recognized in the valley: the Cortland Terrace of probable early Wisconsin (pre-Cary) age, the Arcadia Terrace of Cary age, and the Whitehall Terrace of Mankato age. The two younger terraces result from valley alluviation during the Cary and Mankato glacial maxima. Near Hixton, Wis., a 6-inch bed of diatomite occurs on the Whitehall Terrace surface. It is overlain by peat and underlain by a deposit consisting of organic debris and large fragments of spruce, which has a radiocarbon age of approximately 11,000 years B.P. This age suggests that the Hixton diatomite was deposited during the Valdres Stage of the Wisconsin Glaciation.

Seventy-three species and varieties of fresh-water diatoms have been recognized in the Hixton deposit. *Navicula rotunda* and *Epithemia irregularis* are described as new species in this report. The diatom assemblage is dominated by *Fragilaria construens* var. *venter*, a minute diatom seldom exceeding 15 microns in length. The areal distribution of the deposit, the stratigraphy, and the diatom assemblage suggest deposition in a shallow pond; the composition of the diatom assemblage suggests deposition in cool water, but the evidence is inconclusive.

INTRODUCTION

General statement.—The Trempealeau River drains part of the Driftless Area in west-central Wisconsin. Its source is near the northern margin of the Driftless Area at the edge of the glaciated Central Lowland physiographic province. Although the bedrock divide between the Driftless Area and the Central Lowland is breached in the vicinity of the headwaters of the Trempealeau River, the modern drainage is confined to the Driftless Area by a low divide on the valley alluvium. The river flows, somewhat circuitously, southwestward to join the Mississippi River a short distance downstream from Winona, Minn. The valley is nearly 60 miles long. The Trempealeau River drainage basin is bounded on the north by the drainage basin of the Buffalo River and on the south by that of the Black River. The location and regional relations of the area under consideration are shown in figures 1 and 2.

The Trempealeau Valley contains remnants of three Pleistocene terraces, which have not been previously studied. The only allusion to these deposits in the geologic literature, as far as known, is that of Chamberlin and Salisbury (1885, p. 310) who stated: "On the Trempealeau River are also fine terraces carved mainly from the finer alluvial constituents, this valley apparently not having been one of the main channels of glacial discharge."

A small deposit of diatomite on one of these terraces has been discovered recently near Hixton, Wis. This diatomite is, fortunately, associated with considerable organic debris, chiefly peat and wood, which has been dated by the radiocarbon method. The Hixton diatom assemblage is, therefore, important as a paleoecological indicator of known age in the local Quaternary sequence. The radiocarbon age of the deposit is also of value in relating the local sequence of the Trempealeau Valley to the late Quaternary history of the region.

Summary of investigation.—This study has been conducted with a two-fold emphasis. First, the diatom assemblage of the diatomite near Hixton was studied in detail to evaluate its paleoecological significance. Second, a reconnaissance survey was made of the Trempealeau Valley terraces so that the geologic setting of the Hixton diatomite might be better understood. The examination of the terraces has been primarily of a geomorphic nature, and neither the lithology nor the areal distribution of the terraces have been studied in detail. The Hixton diatomite was initially sampled in the summer of 1960. Additional samples, including those for radiocarbon dating, were taken in 1963. Observations on the geology of the deposit were made in 1960 and 1963.

Acknowledgments.—The occurrence of diatomite near Hixton, Wis., was first called to the attention of the writer by George F. Hanson, State Geologist of Wisconsin. Mr. Herman Krome of Hixton kindly assisted in collecting samples from his property on two occasions. Thanks are expressed to Kenneth E. Loh-

man, U.S. Geological Survey, for his helpful advice in the preparation of this report and for his critical review of the manuscript. The suggestions of Charles S. Denny, U.S. Geological Survey, who reviewed the manuscript, are also sincerely appreciated.

GEOLOGY

REGIONAL RELATIONSHIPS

The Trempealeau River flows through a bedrock valley cut in sandstones of Late Cambrian age. Several formations of this age are exposed in the area; all are basically fine- to medium-grained friable sandstones having only slight variations in their resistance to erosion. These poorly cemented sandstones disintegrate readily under the humid weathering conditions of the region and provide abundant sediment for transport by the stream. The Upper Cambrian rocks were formerly overlain by the resistant Oneota Dolomite of Early Ordovician age throughout the region. This dolomite was, however, completely removed by erosion from the bluffs surrounding the upper part of the Trempealeau Valley. It still caps the bluffs on either side of the valley as one approaches the Mississippi River. The Oneota Dolomite has probably contributed a small amount of chert to the Trempealeau Valley sediments, but it has not been a major source of sediment for the valley.

The Trempealeau Valley crosses the northern part of the Driftless Area, an unglaciated region in southwestern Wisconsin and smaller adjacent parts of Minnesota, Iowa, and Illinois. There is no conclusive evidence that the Driftless Area was ever covered by ice during the Pleistocene Epoch although it is surrounded by glacial drift deposits. The area was approached at different times by various ice sheets moving in different directions, but it was never completely surrounded at any time by a single ice sheet. The Driftless Area does contain drift in the sense of loess and valley findings of outwash. The loess was blown in from nearby glaciated areas, mainly those to the west, probably in large part from Mississippi Valley outwash trains. The outwash was deposited from melt water flowing from ice sheets located to the north and east.

The age of the drift shown in figure 1 on the west boundary of the Driftless Area near the Trempealeau Valley is uncertain. This scattered deposit is probably of pre-Wisconsin age, and it seems to have little bearing on the problem under discussion.

The pre-Cary drift deposits of central Wisconsin, northeast of the headwaters of the Trempealeau River, were described by Weidman (1907, p. 433-488) who attributed them to three separate glacial events. Hole (1943), on the basis of the mineralogy of these "old drifts" and a study of the soils formed upon them, con-

FIGURE 1.—Location and regional relationships of the Trempealeau Valley area (shaded).

cluded that all these deposits should be assigned to a single glacial event not older than Wisconsin in age. A radiocarbon date of more than 45,000 years for organic material subjacent to the "old drift" near Marshfield, Wis., has been published by Black (1959). The "old drift" is now considered to be pre-Cary in age but related to a single early ice advance during the Wisconsin Glaciation. The outer margin of the "old drift" passes close to Merrillan, Wis., immediately northeast of the breach in the bedrock at the head of the Trempealeau Valley. This drift is thin at the margin and does not form conspicuous topographic features.

The most recent advance into the area was made by the Cary glacier; the Chippewa lobe reached a position about 40 miles north of the head of the Trempealeau Valley. The Cary ice sheet also deposited a valley train of outwash in the Mississippi Valley, probably a factor of more importance to the history of the Trempealeau Valley. Later ice advances did not reach central Wisconsin. A valley train of outwash from the Mankato glacier was deposited in the Mississippi Valley, and the probable effects of this event are discussed later in this paper.

The entire Trempealeau Valley area is mantled by loess of Pleistocene age. These deposits have never been adequately studied, and their specific age is not known. The loess is negligible in the upper part of the Trempealeau Valley, but it abruptly increases in thickness

FIGURE 2.—The Trempealeau Valley area, west-central Wisconsin. Shaded areas indicate valleys filled by glacial outwash.

toward the Mississippi Valley. It may exceed 10 feet in thickness on parts of the upland near the western margin of the area. Hence, Pleistocene loess is an important source of sediment in the lower part of the Trempealeau watershed.

TREMPEALEAU VALLEY TERRACES

Three terrace levels are recognizable in the Trempealeau Valley, and they show varying degrees of prominence. The terraces are important keys to the Pleistocene geologic history of the valley, and a discussion of these features is fundamental to an understanding of the occurrence of the Hixton diatomite. Profiles of the terrace levels of the Trempealeau Valley are compared with a profile of the modern valley floor in figure 3.

The highest (and hence, oldest) terrace observed in the valley is herein termed the Cortland Terrace for its occurrence in the Cortland School District, Arcadia Township, Trempealeau County, Wis. This terrace is a prominent topographic feature in secs. 16, 17, and 21, T. 20 N., R. 10 W., where the terrace tread has an altitude of about 795 feet. The occurrence of the Cortland

Terrace at this locality is remarkable in that it extends nearly across the comparatively narrow valley; the modern river is confined to a narrow gap at the northwest valley wall. The river must have maintained its course at this point throughout post-Cortland time, but the reason for this is obscure. A few additional old terrace remnants that seem to correlate with the Cortland level have been noted farther up the Trempealeau Valley. A terrace level or erosion surface at an altitude of about 775 feet occurs immediately southeast of Independence, Wis. A deeply eroded probable terrace level with an altitude of about 980 feet occurs south and east of Taylor, Wis., and covers an area of several square miles at a comparatively wide part of the valley. Other probable remnants of this terrace have been noted southeast of Hixton at an altitude of about 1,020 feet and near the head of the Trempealeau Valley at an altitude of about 1,040 feet. The nature of the deposits at these localities needs confirmation in the field. Other remnants of the Cortland Terrace could probably be identified by field mapping.

The Cortland Terrace is thought to be a valley-train

FIGURE 3.—Profiles of the modern Trempealeau River valley and three Pleistocene terrace treads. Ticks on profiles show altitudes from topographic maps; profile lines dashed where inferred.

terrace related to the pre-Cary Wisconsin Glaciation of central Wisconsin. Melt water from this ice sheet probably breached the headwater divide of the Trempealeau Valley. The Cortland Terrace has no recognized counterpart in the Mississippi Valley.

The middle terrace of the Trempealeau Valley is by far the most prominent and is here named the Arcadia Terrace from the remnant which occurs at an altitude of about 775 feet immediately south of Arcadia, Trempealeau County, Wis. The Arcadia Terrace ranges in altitude from about 740 feet at the mouth of the Trempealeau Valley to about 940 feet near the head of the valley, where it merges imperceptibly with the modern flood plain. The terrace is not continuous along the valley, but its remnants are so numerous that they can be readily correlated. The terrace deposit was cut by subsequent erosion which formed a prominent escarpment. Because of the sandy nature of the deposit, this escarpment has retained its original erosional form, making the Arcadia Terrace by far the most obvious one in the valley. The Arcadia Terrace is thought to be the dissected remnant of an alluvial plain of Cary age, formed perhaps when the Trempealeau Valley was dammed by Cary outwash in the Mississippi Valley. Some of the sand in the Arcadia Terrace is probably an accumulation of locally derived debris, but much of it may also have been carried through the breached divide at the head of the valley by Cary melt water. The Arcadia Terrace is thought to correlate with the terrace remnant (alt about 725 ft) of probable Cary age in the Mississippi Valley about 1 mile east of the mouth of the Trempealeau Valley.

The lowest (and youngest) terrace observed in the Trempealeau Valley is here designated as the Whitehall

Terrace for its occurrence at an altitude of about 810 feet at Whitehall, Trempealeau County, Wis. The Whitehall Terrace is low and less prominent than the Arcadia Terrace. It ranges in altitude from about 695 feet at Dodge to about 840 feet at a point between Whitehall and Blair, where it becomes so low and forms such a weak escarpment that it cannot be easily distinguished from the modern flood plain. The Hixton diatomite was deposited in a shallow pond on the Whitehall Terrace, which was more likely an erosional than a depositional surface at Hixton. The Whitehall Terrace is apparently the dissected remnant of an alluvial plain formed by the damming of the outlet of the Trempealeau Valley by Mankato outwash in the Mississippi Valley. The terrace deposits are comparatively silty and are probably all of local origin, derived mainly from Cambrian sandstone, Pleistocene Arcadia Terrace sediments, and Pleistocene loess. A remnant of this outwash now forms a terrace at an altitude of about 680 feet near the confluence of the Trempealeau and Mississippi Rivers. This remnant in the Mississippi Valley is probably of Mankato age.

QUATERNARY GEOLOGIC HISTORY

The preglacial configuration of the Trempealeau Valley is poorly known, for the depth of the bedrock valley floor has never been determined. No bedrock crops out in the center of the valley, so it may be assumed that the preglacial valley was somewhat deeper than the modern valley. No Quaternary drainage changes are evident. The earliest event of Quaternary history recorded in the present topography was the breaching of the divides at the headwaters of the Trempealeau

River and Pigeon Creek. These divides had been formed on the relatively nonresistant Upper Cambrian sandstones of the region, and they had undoubtedly been lowered considerably by normal processes of erosion prior to their erosion by glacial melt water. These divides were probably eroded by melt water from the ice that deposited the pre-Cary drift of central Wisconsin. This ice sheet moved very close to the headwaters area (fig. 2). Perhaps the melt water from this ice sheet transported outwash debris that formed the high Cortland Terrace in the valley.

The next Pleistocene event that can be recognized in the Trempealeau Valley is the deposition of the Arcadia Terrace sediments of Cary age. The level of the terrace was controlled by the level of the Cary valley train in the Mississippi Valley, which reached an altitude of at least 725 feet. Some of the sand in the Arcadia Terrace deposits is undoubtedly of local derivation, but much of it may have been swept over the low divide at the head of the Trempealeau Valley by Cary melt water. The Arcadia surface converges toward the level of the modern flood plain at the head of the valley. The terrace is a prominent topographic feature at the site of the Hixton diatomite deposit, and it continues to the mouth of the valley. The Arcadia Terrace was largely formed by post-Cary, pre-Two Creeks erosion, and it has been modified by more recent erosion.

During the Mankato Stade the building of another outwash train in the Mississippi Valley raised the Trempealeau Valley outlet to an altitude of about 680 feet. The damming of the Trempealeau Valley resulted in the ponding of its lower reaches and perhaps in accumulation of a small amount of silty and organic debris. In the middle reaches of the valley, deposition of locally derived sand and silt produced the Whitehall Terrace deposit. At the diatomite locality near Hixton lateral erosion by a meandering stream was the dominant process during the Mankato Stade.

Post-Mankato erosion in the Mississippi Valley has reduced the outlet of the Trempealeau Valley to an altitude of about 650 feet. The outlet may have even been lower than this during late glacial and early postglacial intervals, but evidence is lacking. The pond deposits of the lower Trempealeau Valley have been almost obliterated by erosion. The more sandy deposits in the central part of the valley have been dissected to form the Whitehall Terrace. In Post-Mankato time only slight erosion and deposition appear to have taken place in the upper part of the valley, where the valley floor has remained at about the same level since the Mankato Stade. The peat and diatomite of the Hixton deposit, which occur only a few feet above the channel of the modern stream, were laid down in a depression on the

Mankato surface during the Two Creeks Interstade and the Valdres Stade.

HIXTON DIATOMITE DEPOSIT

LOCATION

The diatomite deposit studied for this report is approximately a quarter mile south of the center of the village of Hixton, Wis., a short distance southwest of State Highway 27 and northwest of the Green Bay and Western Railroad tracks. The specific location is the N $\frac{1}{2}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 17, T. 22 N., R. 5 W., Blair quadrangle, Jackson County, Wis. The location of the deposit and its relation to the nearby Arcadia Terrace and the modern Trempealeau River are shown in figure 4. The diatomite deposit is found underlying the surface of a semicircular reentrant cut by a meandering stream in the Arcadia Terrace (Cary) sediments on the south side of the Trempealeau Valley. The erosion surface beneath the deposit is thought to be related to the same cycle during which the Whitehall Terrace (Mankato) sediments were deposited further down the valley. Three meander scars occur in this immediate area, and all have diameters of approximately 450 feet. The most northeastern of these scars contains the diatomite studied for this report; the sediments underlying the other downstream meander scars have not been examined. The Hixton deposit is the only diatomite that has been reported to date from the Trempealeau Valley or from the entire Driftless Area. Other deposits probably occur in the Trempealeau Valley, and almost certainly others must remain undiscovered in a region as large as the Driftless Area.

STRATIGRAPHY

The stratigraphic section from top to bottom, as examined near the center of semicircular meander scar, is as follows:

Zone A is exposed at the surface and ranges from 6 to 18 inches in thickness; peat and peaty soil, in part sandy, and abundant fragmental organic debris.

Zone B consists of 6 to 8 inches of light- to bluish-gray friable diatomite, somewhat streaked and stained by iron oxide, containing abundant rootlets and fragmental organic debris. A half-inch layer of brownish-gray clay occurs between the diatomite and the overlying peat.

Zone C is about 6 inches of brownish-gray clay and organic matter. Partially decomposed pieces of wood are common, and coarse, matted organic debris is abundant. Noticeable odor of hydrogen sulfide.

Zone D consists of sand, fine to medium, whose thickness is undetermined, but the zone is in excess of 2 feet. Gray to black near the top, containing finely divided

organic debris and large wood fragments. Grades to clean white sand at depth.

The modern surface of the area of the diatomite deposit is somewhat irregular and hummocky, typical of a boggy area. The present vegetation consists of a rank growth of grass and weeds and some small scattered brush; small trees are growing around the edge of the Arcadia Terrace escarpment. There is physiographic evidence for a former stream channel around the outer edge of the meander bend. This channel is about 6 to 8 feet wide and 12 to 18 inches deep—comparable to the channel of the modern Trempealeau River in this part of the valley. The relation of this abandoned channel

to the diatomaceous and organic sediments is not clear. Perhaps it was eroded by a comparatively late stage of the Trempealeau River which reoccupied this area for a time.

The postdiatomite peat accumulation of zone A ranges from a thin veneer of surface soil near the base of the Arcadia Terrace escarpment (in the channel mentioned above) to a thickness of about 18 inches in the direction of the main valley. This range suggests that the top of the underlying diatomite dips slightly toward the center of the meander scar, which seems to be a reasonable assumption. The organic matter of zone A contains abundant rootlets of comparatively modern origin.

FIGURE 4.—The Hixton diatomite deposit and its relation to the older Arcadia Terrace (stippled).

The Hixton diatomite of this report (zone B) is very consistent in thickness. Cores made in the abandoned channel at the outer edge of the meander plain show that here the diatomite is completely missing in some places and is only 2 to 4 inches thick in others. Samples taken elsewhere have consistently shown a 6- to 8-inch thickness. The diatomite is contaminated with rootlets and fragmental organic debris but is nearly free from clastic sediment. It shows irregular staining by iron oxide and excellent banding at some places. The diatomite contains no calcium carbonate, and there is no suggestion that the initial deposit was a marl.

The lower organic layer (zone C) is composed of partly decomposed wood fragments and matted organic debris. It is less completely oxidized than the peat of zone A, probably because it has been somewhat protected from circulating ground water by the relatively impervious overlying diatomite. During sampling in September 1963, the water table was reached at a depth of about 3 feet. The diatomite of zone B and the organic deposit of zone C must be virtually saturated at all times, and the presence of hydrogen sulfide in zone C indicates a reducing environment at present. In the area of the abandoned channel at the outer edge of the meander plain, zone C is missing, and the diatomite, where present, rests directly on the sand of zone D. This evidence indicates that the deposit of organic material and diatomite (zones B and C) is indeed restricted to the meander-plain reentrant and is not a pre-Arcadia Terrace deposit exhumed by a later meandering stream.

Zone D grades from a mixture of sand and organic matter at the top to a clean white sand downward. Large fragments of wood, some exceeding a foot in length, were found in this zone. This wood is in a better state of preservation than the fragments in overlying zone C, and immediately after excavation it did not appear to be greatly different from modern waterlogged wood buried under similar conditions. A sample of this wood was submitted to R. A. Scott, U.S. Geological Survey, for identification. He reported "The coniferous wood is that of *Picea* sp., spruce. It has been somewhat degraded and contains numbers of fungal hyphae."

RADIOCARBON CHRONOLOGY

Three samples of organic material associated with the Hixton diatomite were submitted to the radiocarbon laboratory of the U.S. Geological Survey for age determination. The youngest of these samples consisted of peat taken from the base of zone A of the stratigraphic section at a depth of 16 to 18 inches below the surface. This sample was judged to be contaminated by modern rootlets, and it was not dated. A sample of the partially decomposed wood and matted organic debris of zone C,

immediately underlying the diatomite (USGS Radiocarbon Lab. No. W-1392), was dated at $10,990 \pm 600$ years B.P. A sample of spruce wood from the upper part of zone D (USGS Radiocarbon Lab. No. W-1391) was dated at $11,130 \pm 600$ years B.P. These two dated samples indicate that no appreciable time elapsed between the deposition of the wood of zone D and the immediately overlying organic debris of zone C. It is unlikely that the wood sample (W-1391) has been contaminated by younger radiocarbon. The close correlation in radiocarbon age between the wood sample and the sample of organic debris (W-1392) indicates that there has not been appreciable contamination of this sample. Both of the dates, therefore, may be considered as valid within the limits of the dating technique, and no problem is posed by sample contamination.

The radiocarbon age of approximately 11,000 years B.P. for the organic material underlying the Hixton diatomite suggests that this material was deposited during the Two Creeks Interstade of the Wisconsin Glaciation. Unfortunately, the peat overlying the diatomite could not be dated, for this would have provided incontrovertible evidence for the upper time limit of diatomite deposition. The available evidence, however, strongly suggests that no great amount of time elapsed between the deposition of organic debris of zone C and the overlying diatomite. This organic debris is little oxidized, and the wood fragments, in particular, at the time of excavation had the appearance of freshly buried material. This excellent preservation of the organic matter indicates that it was buried rapidly by the deposition of the relatively impervious overlying diatomite and that stagnant reducing subaqueous conditions were maintained throughout the deposition of both types of sediment. The change in deposition from organic debris to diatoms can best be accounted for on the basis of a change in environment. The Hixton diatomite was most probably laid down either during the latter part of the Two Creeks Interstade or during the following Valdres Stade.

DIATOM ASSEMBLAGE

SAMPLE PREPARATION

The samples were prepared for diatom study following standard laboratory procedure, by dissociation in distilled water. Organic matter was removed by heating in Clorox solution. A small amount of silt and fine sand was eliminated by decantation of the diatoms in suspension.

The size distribution of the diatoms in this deposit posed a special problem in sample preparation. The bulk of the sample was made up of *Fragilaria construens* var. *venter*, an elliptical diatom ranging from

15 to less than 5 microns in length. Special techniques of preparation were necessitated by the great numbers of these relatively minute specimens. The settling rates of the small diatoms in this deposit were investigated by decantation of diatom suspensions in 150-milliliter beakers after periods of 40 minutes, 1, 2, 4, and 8 hours. Pouring after the 40-minute settling time removed nearly all the fine diatoms from the sample. Pouring after the 8-hour settling time still removed some of the very fine diatoms. The other settling times were intermediate in their effect. Because all the very fine diatoms in the sample were of one variety, removing most of the minute specimens from the sample by decantation in no way prejudiced the relative abundance of the other species and varieties. It was found advantageous to study samples from which the very abundant small diatoms had been cleaned. These samples allowed a more accurate estimate of the relative abundance of the larger species and varieties and were more suitable for photography.

The prepared samples were mounted in Kollolith on strewn slides, and these were examined by traversing with a mechanical stage. Locations of individual specimens were recorded as coordinates of the mechanical stage.

PALEOECOLOGIC INTERPRETATION

The frequency of occurrence of each species and variety of diatom observed in the Hixton diatomite is shown in table 1. *Fragilaria construens* var. *venter* is listed as dominant because of its great relative abundance. The other forms are listed according to estimated relative frequency on a glass slide viewed at 250 magnification, as follows: Abundant, at least one specimen in all fields of view; common, one specimen in many (but not all) fields of view; frequent, several specimens observed on slide, but seen only in a few fields of view; rare, one or two specimens on slide. The species and varieties identified in the deposit are recognized as forms living today, except for the two new species described herein. All these living species occur in fresh water, and only a few range into saline-water environments, which suggests that the Hixton diatomite was almost certainly deposited in fresh water.

The temperature ranges of the living species and varieties are indicated in table 1 as warm, temperate, or cool. The information available on maximum and minimum temperature tolerance and optimum range of growth for most fresh-water diatoms is nearly all qualitative, and at best it is vague. The listing of "temperate" forms in table 1 may be somewhat misleading as it includes many forms that are indicated in the literature to be of common and widespread occurrence in the temperate zone of the Northern Hemisphere.

The limits of occurrence are not yet more closely defined, and these forms can be classified only on the broad spectrum of "temperate" environments.

TABLE 1.—Relative abundance, temperature, and pH range of diatoms from the Hixton diatomite

[Relative abundance: R, rare; F, frequent; C, common; A, abundant; D, dominant. Temperature: C, cool; T, temperate; W, warm]

	Relative abundance	Temperature	pH
<i>Melosira italica</i> (Ehrenberg) Kützing	C	T	6.0-9.0
<i>Cyclotella meneghiniana</i> Kützing	R	T	
<i>comta</i> (Ehrenberg) Kützing	R	T	
<i>Opephora martyi</i> Hérilaud	F	T	7.0-9.0
<i>Fragilaria capucina</i> Desmazières	R	T	
<i>leptostauron</i> (Ehrenberg) Hustedt	F	T	6.0-9.0
var. <i>rhomboides</i> Grunow	R	T	
<i>construens</i> var. <i>venter</i> (Ehrenberg) Grunow	D	T	7.3-8.0
var. <i>binodis</i> (Ehrenberg) Grunow	R	T	
var. <i>subsalina</i> Hustedt	R	T	
<i>Synedra ulna</i> (Nitzsch) Ehrenberg	C	T	6.0-11.0
<i>capitata</i> Ehrenberg	R	T	
<i>Meridion constrictum</i> Ralfs	F	T	5.0-9.5
<i>Tabellaria fenestrata</i> (Lyngbye) Kützing	R	T	
<i>Eunotia bidentata</i> W. Smith	R	C-T	
<i>praerupta</i> var. <i>inflata</i> Grunow	R	C-T	
<i>impressa</i> Ehrenberg	F	T	
<i>lunaris</i> (Ehrenberg) Grunow	R	C-T	7.3-8.1
<i>gracilis</i> (Ehrenberg) Rabenhorst	R	T	
<i>monodon</i> Ehrenberg	F	T	
<i>formica</i> Ehrenberg	R	T	
<i>Cocconeis placentula</i> Ehrenberg	R	T	
<i>pediculus</i> Ehrenberg	R	T	
<i>Diploneis ovalis</i> var. <i>oblongella</i> (Naegeli) Cleve	R	T	
<i>Stauroneis phoenicenteron</i> (Nitzsch) Ehrenberg	C	T	5.0-9.0
<i>Naricula cuspidata</i> var. <i>ambigua</i> (Ehrenberg) Cleve	F	T	8.5-11.0
<i>bacillum</i> Ehrenberg	F	T	6.5-9.0
<i>radiosa</i> Kützing	R	T	6.6-9.0
<i>reinhardtii</i> (Grunow) Grunow	R	T	
<i>dicephala</i> (Ehrenberg) Kützing	F	T	6.5-9.0
<i>oblonga</i> (Kützing) Kützing	F	T	7.0-9.0
<i>amphibola</i> Cleve	R	T	6.5-9.0
<i>rotunda</i> Andrews, n. sp.	R	T	
<i>Pinnularia interrupta</i> W. Smith	R	T	5.6-8.0
<i>mesolepta</i> var. <i>angusta</i> Cleve	R	T	
<i>lata</i> (Brébisson) W. Smith	R	T	
<i>borealis</i> Ehrenberg	R	C-T	4.0-11.0
<i>gibba</i> (Ehrenberg) W. Smith	R	T	5.9-7.0
cf. <i>P. stomatophora</i> (Grunow) Cleve	R	C-T	7.0-9.0
<i>major</i> (Kützing) W. Smith	R	T	
<i>esox</i> Ehrenberg	R	C	
<i>viridis</i> (Nitzsch) Ehrenberg	F	T	6.9-7.6
<i>streptoraphe</i> Cleve	R	C	5.9-7.6
<i>Neidium bisulcatum</i> (Lagerstedt) Cleve	R	C-T	7.1-7.5
<i>iridis</i> (Ehrenberg) Cleve	F	T	5.0-9.0
var. <i>pernalis</i> Reichelt	R		7.1
<i>Caloneis silicula</i> (Ehrenberg) Cleve	F	T	6.0-9.5
var. <i>truncatula</i> (Grunow) Cleve	R		7.0-7.6
<i>trinodis</i> (W. Smith) Boyer	F	T	
<i>Gomphonema acuminatum</i> Ehrenberg	R	T	6.5-9.0
var. <i>coronata</i> (Ehrenberg) W. Smith	R	T	
<i>augur</i> Ehrenberg	R	T	
<i>angustatum</i> var. <i>undulata</i> Grunow	R	T	
<i>intricatum</i> Kützing	F	T	7.8
<i>gracile</i> Ehrenberg	R	W-T	5.5-9.0
<i>lanceolatum</i> Ehrenberg	R	W-T	
<i>constrictum</i> Ehrenberg	F	T	
<i>capitatum</i> Ehrenberg	F	T	6.6
<i>Amphora ovalis</i> (Kützing) Kützing	F	T	6.0-9.0
<i>Cymbella ehrenbergii</i> Kützing	C	T	
<i>turgida</i> Gregory	R	W-T	5.5-9.0
<i>americana</i> Schmidt	F		
<i>cistula</i> (Hemprich) Grunow	R	T	6.5-9.0
<i>Epithemia zebra</i> (Ehrenberg) Kützing	R	T	7.0-9.0
var. <i>porcellus</i> (Kützing) Grunow	C	T	6.6
<i>turgida</i> (Ehrenberg) Kützing	A	T	5.5-9.5
var. <i>granulata</i> (Ehrenberg) Brun	F	T	
<i>irregularis</i> Andrews, n. sp.	F		
<i>Rhopalodia gibba</i> (Ehrenberg) O. Müller	F	T	6.0-11.0
<i>Hantzschia amphioxys</i> (Ehrenberg) Grunow	F	T	6.6
var. <i>capitata</i> Pantocsek	R	T	
<i>Nitzschia thermalis</i> (Ehrenberg) Grunow	R	T	
<i>Cymatopleura solea</i> (Brébisson) W. Smith	R	T	6.0-9.5

Of the 73 species and varieties recorded in the Hixton diatomite, 8 seem to favor a cool-water environment and 3, a warm-water environment. The fact that all these forms occur only rarely is hardly conclusive evidence for paleotemperature, but it does suggest a relatively cool climate. Evidence is not sufficient to justify

attempting a comparison with the present climate of west-central Wisconsin.

The pH ranges of some of the diatoms occurring in the Hixton deposit are shown in table 1. These values represent a synthesis of investigations by Sovereign (1958) on the diatoms of Crater Lake and by Patrick and Freese (1961) on the diatoms of northern Alaska. Many Hixton diatoms show a pH range in modern waters from slightly acid to somewhat alkaline environments. Available data indicate that the Hixton diatomite was deposited in a nearly neutral or perhaps slightly alkaline environment. The relative rarity of such acid-loving forms as *Eunotia* also suggests that the environment of deposition was not markedly acidic.

The ecology of *Fragilaria construens* var. *venter* is of special importance, for this variety is by far the dominant constituent of the Hixton diatom assemblage. Hustedt (1931, p. 159) stated that the species *F. construens* is one of the commonest fresh-water diatoms, found frequently in all kinds of waters and especially abundant in littoral, standing waters. Sovereign (1958, p. 107-108) reported that the type variety of the species is "widespread and abundant in the Pacific Northwest" in waters ranging in pH from 6.0 to 9.0. He did not report var. *venter* from that area. Patrick and Freese (1961, p. 148) indicated that var. *venter* is a widely distributed species, previously reported from the Arctic, and occurs commonly in their collections from northern Alaska. They give the following ecological data: "Fresh water. Lake plankton, scrapings from silt bottom of drained lake. pH, 7.3-8.0; temp, 12° C."

Although most of the diatoms of the Hixton deposit have a wide range of occurrence, many are reported to have affinities for shallow standing or flowing water. The diatoms of the Hixton assemblage probably flourished in a small, shallow pond at the south edge of the Trempealeau River flood plain. The depression containing this pond was formed by post-Cary erosion and modified during alluviation of the valley which resulted in the deposition of the Whitehall Terrace of Mankato age farther downstream. The radiocarbon age of the organic material underlying the diatomite suggests that the diatomite was deposited during the latter part of the Two Creeks Interstade or during the following Valdres Stade. The shallow pond was probably isolated from the main stream channel, and because of this the pond received little clastic debris. A relatively high water table maintained a virtually constant water level. A reducing environment of deposition for the diatomite is indicated by the excellent preservation of the underlying organic matter. The diatomite and the underlying organic debris contain a noticeable trace of hydrogen sulfide, and the bluish tint of unoxidized parts of

the diatomite suggests the presence of some ferrous iron compound. The composition of the diatom assemblage suggests that the pond waters were probably about neutral in pH during deposition of the diatomite. In summary, the site of deposition may be postulated as being a shallow fresh-water pond having stagnant reducing conditions prevalent in the bottom sediments.

The change of environment that resulted in the deposition of the diatomite in contrast to the underlying and overlying organic debris is a problem of considerable interest. The organic matter underlying the diatomite includes large fragments of spruce wood and other debris in a relatively unoxidized condition. In contrast, the overlying organic debris consists largely of finely divided black peaty material showing a considerably greater degree of oxidation. Treatment of the underlying material with Clorox solution to oxidize the organic matter produced a rather violent reaction with rapid effervescence, whereas similar treatment of the overlying material produced a slow, mild reaction.

The diatom content of both these organic deposits has been examined. In the underlying material, only three forms of extremely rare occurrence have been identified: *Tetracyclus rupestris*, *Pinnularia viridis* var. *sudetica*?, and *Epithemia turgida*. The overlying organic deposit contains a somewhat more varied but sparse assemblage of diatoms, as follows:

- Fragilaria* sp.
- Eunotia robusta* Ralfs
 - praerupta* Ehrenberg
 - var. *inflata* Grunow
 - var. *bidens* (Ehrenberg) Grunow
 - lapponica* Grunow
 - lunaris* (Ehrenberg) Grunow
 - gracilis* (Ehrenberg) Rabenhorst
 - Navicula dicephala* (Ehrenberg) Kützing
 - Pinnularia gibba* var. *linearis* Hustedt
 - viridis* var. *sudetica* (Hilse) Hustedt
 - sp.
 - Gomphonema intricatum* Kützing
 - Epithemia argus* (Ehrenberg) Kützing
 - zebra* var. *porcellus* (Kützing) Grunow
 - Hantzschia amphioxys* var. *capitata* Pantocsek

All these forms are of rare occurrence except for *Eunotia robusta* Ralfs, which is frequent. This assemblage is distinct from that of the Hixton diatomite, and it indicates deposition in a more acid, peat-bog environment.

What then was the reason for the temporary cessation in the accumulation of plant debris at Hixton and the accumulation of the diatomite? The occurrence of spruce prior to the diatomite deposition suggests a somewhat cooler climate than that which supports the modern oak-maple-pine forest of the region. Cooling of the climate related to the Valdres Stade may have

locally reduced the growth of vegetation, but allowed a relatively heavy bloom of diatoms in the pond. Temperature data on the occurrence of modern diatoms indicate that they may reproduce abundantly at temperatures too low to promote plant growth. For example, fresh-water diatoms have been reported growing in pools of melt water on icebergs. A combination of low temperature during the Valdres Stade and optimum local conditions may well account for the diatomite accumulation at Hixton.

SYSTEMATIC DESCRIPTIONS

The classification of diatoms in this paper follows Moore (1954) through the rank of class. The reasons for the inclusion of the Diatomaceae in the kingdom Protista are ably presented by Moore (1954), and Stanier (1959), and they need not be repeated here. The classification of the rank of order follows Karsten (1928). The classification from the rank of suborder to that of subfamily follows that of Hendey (1937). This classification does not differ greatly from that of Schütt (1896) and Hustedt (1927-30, 1930, 1931-59), although there are some trivial differences in the sequence of the genera.

It seems desirable to state at this point some of the principles that have been followed in this paper with regard to infrageneric classification. For most paleontologic studies it appears preferable to adopt a binomial nomenclature over trinomial or quadrinomial systems. Hence, the new taxa described herein have been classified as species rather than varieties. The previously described varietal names have been retained, although the usefulness of this rank in paleontologic work on diatoms seems questionable. The rank of *forma*, which has been used to a lesser extent by some authors, has been rejected for use in this paper. Those diatoms which have been previously classified in the *forma* have been raised or restored to either varietal or specific rank.

A synonymy is presented for each species of diatom identified in the Hixton deposit. First, the description by the founder of the species is cited; second, references to the genus and species are given, as accepted in this paper, in chronologic order; third, synonyms and misidentifications are given, also in chronologic order. The most common errors, those of incorrect attributions of authorship, have been placed in the third category. References which have not been examined by the writer are marked by an asterisk. Complete synonymies have not been given in this paper, for they may be found in one or more of the references cited. Included in the synonymies are references to descriptions in the more important and more recent and readily available works such as Boyer (1927) and either Hustedt (1927-30, 1931-59) or Hustedt (1930). To keep the length of this

paper within reason, repetitive descriptions of previously described species and varieties have not been made. Complete descriptions can be obtained by consulting the various references given in the synonymies. Most of the species and varieties are illustrated in this paper, however, except for a few rare ones for which no adequate specimens were found.

Information on the ecology and distribution of living fresh-water diatoms is sparse and is widely disseminated in the literature. Many of the earlier writers gave only sketchy data on the occurrence of the various species, and most of this information is nearly useless in determination of geographic and ecologic distribution. Fortunately, more attention is paid to these subjects by most current workers. The information presented in this paper on ecology and distribution is somewhat generalized from Hustedt (1927-30; 1931-59) and Hustedt (1930). Hustedt's reports deal with a basically temperate environment, namely that of central Europe. Certain of his environmental interpretations, for example, his mountain environments, are clearly not applicable to the Hixton deposit. On the other hand, the mountain species may be considered to occur in cool or colder waters, and a reevaluation of Hustedt's interpretations has been made in considering the local conditions in Wisconsin.

Kingdom PROTISTA

Subkingdom PROTOCTISTA

Phylum CHRYSOPHYTA

Class DIATOMACEAE

Order CENTRALES

Suborder DISCINEAE

Family COSCINODISCACEAE

Subfamily MELOSIROIDEAE

Genus MELOSIRA Agardh, 1824

Melosira italica (Ehrenberg) Kützing

Plate 1, figures 1-3

Gallionella italica Ehrenberg, 1836?, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1836, p. 53.*

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

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

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

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

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

M. italica is very common in the deposit and shows great variation in external shape. Valves range from short cylinders of relatively large diameter to elongate cylinders of relatively small diameter. Most specimens consist of two adjacent valves held together by the den-

ticulate margin; chains of frustules are rare. Hemispherical terminal valves are frequently found; frustules of two such valves occur more rarely. The rows of puncta are consistently fine and very slightly spiraled. The puncta vary slightly in size and are somewhat elongate longitudinally. The hemispherical terminal valves are somewhat more coarsely punctate.

M. italica is a common and widespread fresh-water species, occurring in littoral and shallow-water environments.

Diameters of figured specimens (USGS diatom cat. Nos. 3260–207, 3260–271, 3260–270), 22 μ , 10 μ , 7 μ .

Subfamily COSCINODISCOIDEAE

Genus CYCLOTELLA Kützing, 1834

Cyclotella meneghiniana Kützing

Plate 1, figure 4

Cyclotella meneghiniana Kützing, 1844, Die kieselalgen Bacillarien oder Diatomeen, p. 50, pl. 30, fig. 68.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 38.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 341–344, fig. 174.

C. meneghiniana is a littoral and shallow-water form, occurring predominantly in fresh water but ranging into brackish environments. It occurs very rarely in the deposit and is represented by small specimens.

Diameter of figured specimen (USGS diatom cat. No. 3261–55), 10 μ .

Cyclotella comta (Ehrenberg) Kützing

Plate 1, figure 5

Discoplea comta Ehrenberg, 1844, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1842, p. 267.

Cyclotella comta (Ehrenberg) Kützing, 1849, Species Algarum, p. 20.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 40.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 1, p. 354–356.

C. comta is a common and widespread fresh-water pelagic form, occurring in lakes and rivers. It is rarely found in this deposit. Specimens range from 16 μ to 38 μ in diameter.

Diameter of figured specimen (USGS diatom cat. No. 3410–62), 38 μ .

Order PENNALES

Suborder ARAPHIDINEAE

Family FRAGILARIACEAE

Subfamily FRAGILARIOIDEAE

Genus OPEPHORA Petit, 1888

Opephora martyi Hérivaud

Plate 1, figure 6

Opephora martyi Hérivaud, 1902, Diatomées fossiles d'Auvergne, p. 43–44, pl. 8, fig. 20.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 183.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 135, fig. 654.

O. martyi is commonly found in standing fresh waters, especially in eutrophic lakes. It is reported to occur frequently with species of *Fragilaria*. It is frequent in this deposit. Individuals range from 14 μ to 35 μ in length.

Length of figured specimen (USGS diatom cat. No. 3410–61), 35 μ .

Genus FRAGILARIA Lyngbye, 1819

Fragilaria capucina Desmazières

Fragilaria capucina Desmazières, 1825, Plantes Cryptogames de la France, éd. 1, no. 453.*

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 187.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 144, fig. 659.

F. capucina is a common fresh-water diatom in littoral environments and the plankton of fresh-water lakes. It is very rare in this deposit. Length about 32 μ .

Fragilaria leptostauron (Ehrenberg) Hustedt

Plate 1, figure 7

Biblarium leptostauron Ehrenberg, 1854, Mikrogeologie, pl. 1, fig. 35, 36.

Fragilaria leptostauron (Ehrenberg) Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 153–155, fig. 668.

Odontidium harrisionii W. Smith, 1856, Synopsis of the British Diatomaceae, v. 2, p. 18, pl. 60, fig. 373.

Fragilaria harrisionii (W. Smith) Grunow, 1862, Kaiserl.-kgl. zool.-bot. Gesell. Wien, Verh., v. 12, p. 368.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 189.

F. leptostauron is a fresh-water species common in littoral and moist soil environments, as well as in standing waters. It occurs frequently in this deposit as specimens 15 μ to 30 μ long.

Length of figured specimen (USGS diatom cat. No. 3260–36), 16 μ .

Fragilaria leptostauron var. *rhomboides* Grunow

Fragilaria harrisionii var. *rhomboides* Grunow, 1862, Kaiserl.-kgl. zool.-bot. Gesell. Wien, Verh., v. 12, p. 368.

Fragilaria leptostauron var. *rhomboides* Grunow.

Hustedt, 1928, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 154, fig. 668 g.

Occurrence of *F. leptostauron* var. *rhomboides* is similar to that of the type variety. This variety is very rare in this deposit.

Fragilaria construens var. **venter** (Ehrenberg) Grunow

Plate 1, figure 8

Fragilaria venter Ehrenberg, 1854, Mikrogeologie, pl. 8, fig. I, 12; pl. II, fig. 14; pl. 13, fig. I, 4; pl. 14, fig. 50.

Fragilaria construens var. *venter* (Ehrenberg) Grunow, in Van Heurck, 1881, Synopsis des diatomées de Belgique, p. 156, pl. 45, fig. 21B, 22, 23, 24B, 26A, B.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 158, fig. 670 h-m.

F. construens var. *venter* occurs by far most abundantly of any form in this deposit. The bulk of the deposit is made up of this one variety, which probably constitutes 80 to 90 percent of the total diatom content. This variety ranges in length from about 15μ to 3μ and perhaps even smaller. The type variety of this species has not been observed in this deposit, and two other related varieties occur only rarely.

F. construens is a very common and widespread fresh-water form. It is especially abundant in littoral or shallow standing water.

Length of figured specimen (USGS diatom cat. No. 3410-63), 13μ .

Fragilaria construens var. **binodis** (Ehrenberg) Grunow

Plate 1, figure 9

Fragilaria binodis Ehrenberg, 1854, Mikrogeologie, pl. 5, fig. II, 26.

Fragilaria construens var. *binodis* (Ehrenberg) Grunow, 1862, Kaiserl.-kgl. zool.-bot. Gesell. Wien, Verh., v. 12, p. 371.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 158, fig. 670 d-g.

Fragilaria construens binodis (Ehrenberg) Grunow. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 188.

Occurrence of *F. construens* var. *binodis* is similar to that of *F. construens* var. *venter*. A rare form in this deposit.

Length of figured specimen (USGS diatom cat. No. 3261-24), 16μ .

Fragilaria construens var. **subsalina** Hustedt

Plate 1, figure 10

Fragilaria construens var. *subsalina* Hustedt, 1925, Mitt. geogr. Gesell. und naturh. Mus. Lübeck, 2 Reihe, no. 30, p. 106, fig. 5-8.*

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 159, fig. 670 p-s.

F. construens var. *subsalina* occurs in fresh water as well as in shallow slightly brackish water. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3410-3), 35μ .

Genus SYNEDRA Ehrenberg, 1830**Synedra ulna** (Nitzsch) Ehrenberg

Plate 1, figure 11

Bacillaria ulna Nitzsch, 1817, Naturf. Gesell. Halle, Neue Schr. v. 3, p. 99.*

Synedra ulna (Nitzsch) Ehrenberg, 1838, Die Infusionsthierchen als vollkommene Organismen, p. 211, pl. 17, fig. 1.*

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 198-199.

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

S. ulna is a very common and widespread fresh-water diatom, occurring in greatest abundance in shallow, littoral waters of pools, ponds, and lakes. It occurs commonly as fragments in this deposit, but whole specimens are comparatively rare.

Length of figured specimen (USGS diatom cat. No. 3260-69), 157μ .

Synedra capitata Ehrenberg

Plate 1, figure 12

Synedra capitata Ehrenberg, 1836, Poggendorf Annalen Physik, pt. 3, fig. 3.*

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 203-204.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 201, fig. 692.

S. capitata occurs generally in shallow, littoral standing water usually in association with *S. ulna* though less abundant than that species. Rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3410-41), 197μ .

Subfamily MERIDIONOIDEAE**Genus MERIDION** Agardh, 1824**Meridion constrictum** Ralfs

Plate 1, figure 13

Meridion constrictum Ralfs, 1843, Annals and Mag. Nat. History, v. 12, p. 458-459, pl. 18, fig. 2.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 173.

Meridion (circulare var. ?) *constrictum* Ralfs. Van Heurck, 1881, Synopsis des diatomées de Belgique, pl. 51, fig. 14-15.

Meridion circulare var. *constricta* (Ralfs) Van Heurck. Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 93-94, fig. 627.

M. constrictum has gradually drifted to the rank of a variety of *M. circulare* in much of the recent literature. Following Boyer (1927), it is here returned to specific rank as designated by the original author. Obviously a close relative of *M. circulare*, it is distinguished by a constriction near the apex. *M. constrictum* is commonly found in association with *M. circulare*, but only *M. constrictum* was observed in this deposit.

This species is of common fresh-water occurrence, particularly in flowing waters. It occurs frequently in this deposit as specimens 24μ to 43μ long.

Length of figured specimen (USGS diatom cat. No. 3260-170), 39μ .

Subfamily **TABELLARIOIDEAE**Genus **TABELLARIA** Ehrenberg, 1840**Tabellaria fenestrata** (Lyngbye) Kützing

Plate 1, figure 14

Diatoma fenestratum Lyngbye, 1819, Tentamen Hydrophytologiae Daniae, p. 180, pl. 61.*

Tabellaria fenestrata (Lyngbye) Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 127, pl. 17, fig. 22; pl. 30, fig. 73.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 151-152.

Hustedt, 1931, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 26-28, fig. 554.

T. fenestrata is a fresh-water species, which ranges into slightly brackish environments. Common and widespread in standing or gently flowing waters, especially in eutrophic lakes. Rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3410-25), 72 μ .

Suborder **RAPHIDIOIDINEAE**Family **EUNOTIACEAE**Genus **EUNOTIA** Ehrenberg, 1837**Eunotia bidentula** W. Smith

Plate 1, figure 15

Eunotia bidentula W. Smith, 1856, Synopsis of the British Diatomaceae, v. 2, p. 83.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 223.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 277-278, fig. 744.

E. bidentula is a widely occurring fresh-water diatom common in cool or cold waters. It occurs rarely in this deposit. Specimens are 50 μ to 60 μ long.

Length of figured specimen (USGS diatom cat. No. 3260-256), 51 μ .

Eunotia praerupta Ehrenberg var. *inflata* Grunow

Eunotia praerupta var. *inflata* Grunow in Van Heurck, 1881, Synopsis des diatomées de Belgique, p. 143, pl. 34, fig. 17.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 280, fig. 247A, f-g.

E. praerupta var. *inflata* is a widespread fresh-water diatom occurring commonly in marsh and spring environments and more abundant in cooler waters. It is rare in this deposit.

Eunotia impressa Ehrenberg

Plate 1, figure 16

Eunotia impressa Ehrenberg, 1854, Mikrogeologie, pl. 14, fig. 66; pl. 3, fig. IV, 20.

Eunotia pectinalis var. *impressa* (Ehrenberg) O. Müller, 1896, Forsch. Biol. Stat. Plön, v. 6, p. 12.*

Eunotia pectinalis var. *minor* fo. *impressa* (Ehrenberg). Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 182, fig. 239.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 298, fig. 763 g, h.

E. impressa has been lowered in taxonomic rank to variety and finally to form. It occurs in this deposit frequently as a distinctive species, having none of the relatives imputed to it by quadrinomial nomenclature. It seems more reasonable to restore this form to the specific rank than to perpetuate an implied relationship to other taxa that cannot be conclusively demonstrated.

E. impressa is a widespread and common species occurring in standing water and small streams. It is frequent in this deposit, and specimens are very constant in length—29 μ to 32 μ .

Length of figured specimen (USGS diatom cat. No. 3410-58), 32 μ .

Eunotia lunaris (Ehrenberg) Grunow

Plate 1, figure 17

Synedra lunaris Ehrenberg, 1831, Kgl. preuss. Akad. Wiss. Berlin, Abh., p. 87.*

Eunotia lunaris (Ehrenberg) Grunow, in Van Heurck, 1881, Synopsis des diatomées de Belgique, p. 144, pl. 35, fig. 3, 4, 6A.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 225.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 302-304, fig. 769.

E. lunaris is widespread in cool, fresh-water environments, and is especially abundant in pools of bogs and marshes. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3410-65), 125 μ .

Eunotia gracilis (Ehrenberg) Rabenhorst

Plate 1, figure 18

Himatidium gracile Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 417, pl. 2, fig. I, 9; pl. 3, fig. I, 41.

Eunotia gracilis (Ehrenberg) Rabenhorst. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 217.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 305, fig. 771.

Eunotia gracilis Ehrenberg. Rabenhorst, 1864, Flora Europaea Algarum, p. 72.

E. gracilis is a common and widespread species of fresh-water diatom. It is rare in this deposit. Specimens range in length from 63 μ to 129 μ .

Length of figured specimen (USGS diatom cat. No. 3260-222), 63 μ .

Eunotia monodon Ehrenberg

Plate 1, figures 19, 20

Eunotia monodon Ehrenberg, 1854, Mikrogeologie, pl. 2, fig. II, 26.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp., p. 221.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 305-306, fig. 772 a, b.

E. monodon is a widespread and common fresh-water species, frequently occurring in springs, pools, and marshes. It is found frequently in this deposit. It shows a great variability in length, from 38μ to 100μ .

Length of figured specimens (USGS diatom cat. Nos. 3260-229 and 3260-134) 100μ , 66μ .

Eunotia formica Ehrenberg

Plate 1, figure 21

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

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 78, supp. p. 220.

Hustedt, 1932, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 308-310, fig. 775.

E. formica is a widespread fresh-water species occurring in standing waters but seldom found in abundance. The species closely resembles *E. monodon* in this deposit, but it is found only rarely.

Length of figured specimen (USGS diatom cat. No. 3260-232), 103μ .

Suborder MONORAPHIDINEAE

Family ACHNANTHACEAE

Subfamily COCCONEIOIDEAE

Genus COCCONEIS Ehrenberg, 1838

Cocconeis placentula Ehrenberg

Plate 1, figure 22

Cocconeis placentula Ehrenberg, 1838, Die Infusionsthierchen als vollkommene Organismen, p. 194.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp. p. 244.

Hustedt, 1933, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 347-350, fig. 802 a, b.

C. placentula is very common and widespread, occurring in most fresh-water environments. Rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3261-106), 34μ .

Cocconeis pediculus Ehrenberg

Plate 1, figure 23

Cocconeis pediculus Ehrenberg, 1838, Die Infusionsthierchen als vollkommene Organismen, p. 194, pl. 21, fig. 11.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp. p. 244.

Hustedt, 1933, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 350-351, fig. 804.

C. pediculus is a common and widespread fresh-water species which ranges into saline-water environments. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3260-25), 25μ .

Suborder BIRAPHIDINEAE

Family NAVICULACEAE

Subfamily NAVICULOIDEAE

Genus DIPLONEIS Ehrenberg, 1845

Diploneis ovalis var. oblongella (Naegeli) Cleve

Plate 1, figure 24

Navicula oblongella Naegeli, in Kützing, 1849, Species Algarum, p. 890.*

Diploneis ovalis var. *oblongella* (Naegeli) Cleve. Hustedt, 1937, Die Kieselalgen Deutschlands, Österreichs, und der Schweiz, pt. 2, p. 672, fig. 1065 f-k.

Diploneis ovalis var. *oblongella* Naegeli. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 93.

D. ovalis is a common and widespread species occurring in fresh- and slightly saline-water environments. It also occurs under subaerial conditions in marsh and moist soil environments. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3260-165), 29μ .

Genus STAURONEIS Ehrenberg, 1843

Stauroneis phoenicenteron (Nitzsch) Ehrenberg

Plate 1, figure 25

Bacillaria phoenicenteron Nitzsch, 1817, Naturf. Gesell. Halle Neue Schr., v. 3, pl. 3, fig. 12, 14.*

Stauroneis phoenicenteron Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, pl. 2, fig. V, I.

Stauroneis phoenicenteron (Nitzsch) Ehrenberg. Kützing, 1844, Die kieselalgenigen Bacillarien oder Diatomeen, p. 104, pl. 3, fig. 53.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp. p. 421.

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

S. phoenicenteron is very widespread and occurs commonly in littoral fresh-water environments that range from alkaline to slightly acid. It is common in this deposit and ranges from 69μ to 173μ in length.

Length of figured specimen (USGS diatom cat. No. 3260-156), 116μ .

Genus NAVICULA Bory, 1822

Navicula cuspidata var. ambigua (Ehrenberg) Cleve

Plate 2, figure 1

Navicula ambigua Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 417, pl. 2, fig. II, 9.

Navicula cuspidata var. *ambigua* (Ehrenberg) Cleve. Hustedt, 1930, in Pascher, Die Süßwasser-flora Mitteleuropas, no. 10, p. 268, fig. 434.

Navicula cuspidata var. *ambigua* Ehrenberg. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 110.

Navicula cuspidata ambigua (Ehrenberg) Cleve. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 366.

N. cuspidata is a shallow-water, littoral species of widespread and common occurrence in fresh water.

The variety is frequently found in this deposit. It ranges in length from 95μ to 130μ .

Length of figured specimen (USGS diatom cat. No. 3260-180), 113μ .

Navicula bacillum Ehrenberg

Plate 2, figure 2

- Navicula bacillum* Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 418, pl. 4, V, fig. 8.
Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 137.
Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 371-372.
Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 280-281, fig. 465.

N. bacillum occurs frequently in the deposit, and it is usually similar in appearance to the figured specimen. The valves are not markedly elliptical, and the sides are nearly parallel. The forms in this deposit resemble var. *gregoryana* in shape, but the lateral margins are not noticeably concave. Specimens range from 40μ to 55μ in length. *N. bacillum* is a common and widespread fresh-water species.

Length of figured specimen (USGS diatom cat. No. 3410-30), 51μ .

Navicula radiosa Kützing

Plate 2, figure 3

- Navicula radiosa* Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 91, pl. 4, fig. 23.
Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 17.
Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 397.
Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 299, fig. 513.

N. radiosa is a common fresh-water diatom of widespread occurrence. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3261-136), 66μ .

Navicula reinhardtii (Grunow) Grunow

Plate 2, figure 4

- Stauroneis reinhardtii* Grunow, 1860, Kaiserl.-kgl. zool.-bot. Gesell. Wien, Verh., v. 10, p. 566.
Navicula reinhardtii Grunow. Grunow, in Van Heurck, 1880, Synopsis des diatomées de Belgique, p. 86, pl. 7, fig. 5, 6.
Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 20.
Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 301, fig. 519.
Navicula reinhardtii (Grunow) Van Heurck. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 393.

N. reinhardtii is a fresh-water diatom of widespread occurrence that is seldom found in abundance. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3260-188), 45μ .

Navicula dicephala (Ehrenberg) Kützing

Plate 2, figure 5

- Pinnularia dicephala* Ehrenberg, 1838, Die Infusionsthierehen als vollkommene Organismen, p. 185.*
Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, pl. 2, fig. I, 29; pl. 2, fig. II, 5.
Navicula dicephala (Ehrenberg) Kützing, 1844, Die Kieselschaligen Bacillarien oder Diatomeen, p. 96, pl. 28, fig. 60, 62.
Navicula dicephala Kützing. W. Smith, 1853, Synopsis of the British Diatomaceae, v. 1, p. 53, pl. 17, fig. 157.
Navicula dicephala (Ehrenberg) W. Smith. Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 21.
Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 302-303, fig. 526.
Navicula dicephala W. Smith. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 386.

N. dicephala is a widespread fresh-water diatom, not usually found in great abundance. It occurs frequently in this deposit. Specimens range in length from 25μ to 42μ .

Length of figured specimen (USGS diatom cat. No. 3260-80), 39μ .

Navicula oblonga (Kützing) Kützing

Plate 2, figure 6

- Frustulia oblonga* Kützing, Dec. 8, 1833, Algarum aquae dulcis Germaniae.*
Navicula oblonga (Kützing) Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 97, pl. 4, fig. 21.
Navicula oblonga Kützing. Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 21.
Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 395.
Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 307-308, fig. 550.

N. oblonga is a widespread fresh-water species of common occurrence, which is also found in slightly saline environments. It occurs frequently in this deposit. Its length ranges from 95μ to 140μ .

Length of figured specimen (USGS diatom cat. No. 3261-127), 125μ .

Navicula amphibola Cleve

Plate 2, figure 7

- Navicula amphibola* Cleve, 1891, Soc. pro Fauna et Flora Fennica, Acta, v. 8, no. 2, p. 33.
Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 45.
Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 405.
Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 309-310, fig. 554.

It is difficult to ascertain the limits of variability intended by Cleve for *N. amphibola*. Two distinctive, but apparently related, forms occur in this deposit. *N.*

amphibola has here been restricted to the more elongate form having distinctive rostrate or subcapitate produced ends. The other related form, more rotund and having blunt subrostrate apices, is herein described as *N. rotunda*. *N. amphibola* occurs rarely in this deposit. Specimens range in length from 65μ to 77μ . It is a common and widespread fresh-water species.

Length of figured specimen (USGS diatom cat. No. 3260-116), 73μ .

Navicula rotunda Andrews, n. sp.

Plate 2, figures 8, 9

Valve of *N. rotunda* elliptical, rotund, length less than twice the width. Ends of valve subrostrate with blunt rounded apices. Axial area narrow, central area cruciform, extending laterally in the middle of the valve by shortening of the striae. Shorter striae at the middle of the valve irregular in length. Transverse striae composed of distinct puncta, slightly uneven in lineation and spacing. Striae 4.5-7 in 10μ in the center, 10 in 10μ near the apices. Puncta about 12 in 10μ , more closely spaced near the apices. Raphe has the appearance of a flattened slightly twisted thread having conspicuous central pores and hook-shaped polar terminals. Length 30μ to 40μ , width 20μ to 22μ .

Holotype: USGS diatom cat. No. 3260-196 (fig. 8), length 40μ . Figured specimen: USGS diatom cat. No. 3260-199 (fig. 9), length 32μ . USGS diatom loc. 5016.

This species shows strong affinity to *N. amphibola* Cleve, which is somewhat more frequent in the sample. It is distinguished from that species on the basis of its more rotund shape, more specifically, its high width to length ratio. The apices of *N. rotunda* are blunt, rounded, and subrostrate, whereas those of *N. amphibola* are markedly rostrate and considerably more produced. The absence of intermediate forms in the sample suggests that *N. rotunda* should be treated as a separate species rather than as a variant form of *N. amphibola*. *N. rotunda* is rare in the deposit.

Genus PINNULARIA Ehrenberg 1840

***Pinnularia interrupta* W. Smith**

Plate 2, figure 10

Pinnularia interrupta W. Smith, 1853, Synopsis of the British Diatomaceae, v. 1, p. 59, pl. 19, fig. 184.

Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 76.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 434.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 317-318, fig. 573.

P. interrupta is a common and widespread fresh-water species. It is rare in this deposit. Specimens are about 80μ long.

Length of figured specimen (USGS diatom cat. No. 3260-4), 78μ .

***Pinnularia mesolepta* var. *angusta* Cleve**

Plate 2, figure 11

Pinnularia mesolepta var. *angusta* Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 76.

Pinnularia mesolepta fo. *angusta* Cleve. Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 319, fig. 575 b.

P. mesolepta is a common fresh-water species of widespread occurrence in standing and flowing waters. It is rare in this deposit. Specimens range from 45μ to 58μ in length.

Length of figured specimen (USGS diatom cat. No. 3260-82), 58μ .

***Pinnularia lata* (Brébisson) W. Smith**

Plate 2, figure 12

Frustulia lata Brébisson, 1838, Mém. Soc. Sci. Falaise, p. 18.*

Pinnularia lata (Brébisson) W. Smith, 1853, Synopsis of the British Diatomaceae, v. 1, p. 55, pl. 18, fig. 167.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 437-438.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 324-326, fig. 595.

Pinnularia lata Brébisson. Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 81.

P. lata is common in cool, fresh waters, occurring in streams and ponds. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3260-269), about 104μ .

***Pinnularia borealis* Ehrenberg**

Plate 2, figure 13

Pinnularia borealis. Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 420, pl. 1, fig. II, 6.

Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 80-81.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 437.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 326, fig. 597.

P. borealis is a widespread fresh-water species, more common in cool waters. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3410-10), 38μ .

***Pinnularia gibba* (Ehrenberg) W. Smith**

Plate 2, figure 14

Stauroptera? gibba Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 423, pl. 1, fig. II, 3.

Pinnularia gibba (Ehrenberg) W. Smith, 1853, Synopsis of the British Diatomaceae, v. 1, p. 58, pl. 19, fig. 180.

Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 82.

Pinnularia gibba (Van Heurck) Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 440.

Pinnularia gibba Ehrenberg. Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 327, fig. 600.

P. gibba is a common and widespread fresh-water species. It occurs rarely in this deposit.

Length of figured specimen (USGS diatom cat. No. 3261-62), 77 μ .

***Pinnularia* cf. *P. stomatophora* (Grunow) Cleve**

Plate 2, figure 15

Navicula stomatophora Grunow, in Schmidt, 1876, Atlas der Diatomaceen-Kunde, pl. 44, fig. 27-29.

Pinnularia stomatophora Grunow. Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 83.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 439.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 327-328, fig. 605.

This form of *P. stomatophora* falls somewhat below the recognized size for the species but conforms in all other respects. It occurs rarely in the deposit. *P. stomatophora* is found most commonly in cool fresh waters.

Length of figured specimen (USGS diatom cat. No. 3260-129), 48 μ .

***Pinnularia major* (Kützing) W. Smith**

Plate 2, figure 16

Frustulia major Kützing, 1833, Synopsis Diatomearum, Linnaea v. 8, p. 547, fig. 25.

Pinnularia major (Kützing) W. Smith, 1853, Synopsis of the British Diatomaceae, v. 1, p. 54, pl. 18, fig. 162.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 446.

Navicula major (Kützing) Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 97, pl. 4, fig. 19.

Pinnularia major Kützing. Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 89.

Pinnularia major (Kützing) Cleve. Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 331, fig. 614.

P. major is a common and widespread fresh-water species. It occurs rarely in this deposit. Specimens range from 200 μ to 210 μ in length.

Length of figured specimen (USGS diatom cat. No. 3260-96), 200 μ .

***Pinnularia esox* Ehrenberg**

Plate 2, figure 17

Pinnularia esox Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 420-421, pl. 1, fig. II, 4.

Cleve, 1891, Soc. pro Fauna et Flora Fennica, Acta, v. 8, no. 2, p. 24, pl. 1, fig. 3.

Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 90.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 334, fig. 616.

Navicula esox (Ehrenberg) Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 94, pl. 28, fig. 53.

Pinnularia esox Cleve. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 444.

The illustrations of *P. esox* in Ehrenberg (1843) and Kützing (1844) leave much to be desired, and they raise a legitimate question concerning the placing of this species in the genus *Pinnularia*. The written descriptions of these authors, however, seem to be applicable to the *P. esox* of Cleve (1891) and later authors. This species is now well recognized and established in the literature as Cleve (1891) described it, and there seems to be no need to reject *P. esox* Ehrenberg on the basis of the questionable original figure.

P. esox is widespread in cool, fresh-water environments but rarely found elsewhere. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3410-27), 138 μ .

***Pinnularia viridis* (Nitzsch) Ehrenberg**

Plate 2, figure 18

Bacillaria viridis Nitzsch, 1817, Beiträge zur Infusorienkunde oder Naturbeschreibung der Zerkarien und Bazillarien, pl. 4, fig. 1-3.*

Pinnularia viridis (Nitzsch) Ehrenberg. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 446-447.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 334-335, fig. 617.

Pinnularia viridis Nitzsch. Ehrenberg, 1838, Die Infusionsthierchen als vollkommene Organismen, p. 182.*

Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 91-92.

P. viridis occurs frequently in this deposit. It shows considerable variation in size and shape, ranging in length from 68 μ to 170 μ . It is a common and widespread fresh-water species.

Length of figured specimen (USGS diatom cat. No. 3260-186), 98 μ .

***Pinnularia streptoraphe* Cleve**

Plate 2, figure 19

Pinnularia streptoraphe Cleve, 1891, Soc. pro Fauna et Flora Fennica, Acta, v. 8, no. 2, p. 23.

Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 93.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 448.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 337, fig. 620.

P. streptoraphe is a fresh-water species of somewhat restricted occurrence in cool waters. The species occurs rarely in this deposit.

Length of figured specimen (USGS diatom cat. No. 3260-263), 174 μ .

Genus **NEIDIUM** Pfitzer, 1871**Neidium bisulcatum** (Lagerstedt) Cleve

Plate 2, figure 20

Navicula bisulcatum Lagerstedt, 1873, Kgl. svenska vetensk. akad. Handl., Bihang, v. 1, no. 14, p. 31, pl. 1, fig. 8.

Neidium bisulcatum (Lagerstedt) Cleve. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 323.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 242, fig. 374.

Neidium bisulcatum Lagerstedt. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 68.

N. bisulcatum is a fresh-water species occurring in streams and ponds, more commonly in cool waters. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3261-88), 43 μ .

Neidium iridis (Ehrenberg) Cleve

Plate 2, figure 21

Navicula iridis Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 418, pl. 4, fig. I, 2.

Neidium iridis (Ehrenberg) Cleve. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 321.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 245, fig. 380.

Neidium iridis Ehrenberg. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 69.

N. iridis is a common fresh-water species of widespread occurrence. It is found frequently in this deposit. Specimens range in length from 69 μ to 108 μ .

Length of figured specimen (USGS diatom cat. No. 3261-82), 80 μ .

Neidium iridis var. *vernalis* Reichelt, n. comb.

Plate 2, figure 22

Neidium iridis fo. *vernalis* Reichelt, in Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 245, fig. 380.

N. iridis var. *vernalis* occurs rarely in the deposit.

Length of figured specimen (USGS diatom cat. No. 3260-43), 60 μ .

Genus **CALONEIS** Cleve, 1894**Caloneis silicula** (Ehrenberg) Cleve

Plate 3, figure 1

Navicula silicula Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 419.

Caloneis silicula (Ehrenberg) Cleve. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 308-309.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 236-239, fig. 362.

Caloneis silicula Ehrenberg. Cleve, 1894, Kgl. svenska vetensk. akad. Handl. v. 26, no. 2, p. 51-52.

C. silicula is a common and widespread fresh-water diatom. It occurs frequently in this deposit. Specimens range in length from 56 μ to 73 μ .

Length of figured specimen (USGS diatom cat. No. 3260-206), 73 μ .

Caloneis silicula var. *truncatula* (Grunow) Cleve

Plate 3, figure 2

Navicula silicula var. *truncatula* Grunow, in Van Heurck, 1880, Synopsis des diatomées de Belgique, pl. 12, fig. 25.

Caloneis silicula var. *truncatula* Grunow. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 52.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 238, fig. 363-364.

C. silicula var. *truncatula* is differentiated from the type by its more blunt ends and its straight or faintly triundulate lateral margins. It occurs rarely in this deposit. The specimens observed were about 40 μ long.

Length of figured specimen (USGS diatom cat. No. 3410-57), 43 μ .

Caloneis trinodis (W. Smith) Boyer

Plate 3, figure 3

Navicula trinodis W. Smith, 1856, Synopsis of the British Diatomaceae, v. 2, p. 94.

Lewis, 1862, Acad. Nat. Sci. Philadelphia Proc., v. 13, p. 66, pl. 2, fig. 6.

Caloneis schumanniana var. *trinodis* Lewis. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 53.

Caloneis trinodis (Lewis) Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 309-310.

The assignment of the authorship of *C. trinodis* to Lewis (1862) rather than W. Smith (1856) in many reports seems puzzling, for Lewis himself gave credit of authorship to W. Smith.

C. trinodis is a common fresh-water species, often occurring in association with *C. silicula*. It is frequent in this deposit and ranges from 31 μ to 41 μ in length.

Length of figured specimen (USGS diatom cat. No. 3260-166), 40 μ .

Family **GOMPHONEMACEAE**Subfamily **GOMPHONEMOIDEAE**Genus **GOMPHONEMA** Agardh, 1824**Gomphonema acuminatum** Ehrenberg

Plate 3, figure 4

Gomphonema acuminatum Ehrenberg, 1831?, Kgl. preuss. Akad. Wiss. Berlin, Abh., 1831, p. 86.*

Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 184-185.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 290-291.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 370-372, fig. 683.

G. acuminatum is a very common fresh-water species of widespread distribution. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3260-47), 40 μ .

Gomphonema acuminatum var. *coronata* (Ehrenberg) W. Smith

Plate 3, figure 5

Gomphonema coronatum Ehrenberg, 1840, Kgl. preuss. Akad. Wiss. Berlin, Ber., p. 211.**Gomphonema acuminatum* var. *coronata* (Ehrenberg) W. Smith. Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 370, fig. 684.*Gomphonema acuminatum* var. *coronata* Kützing. W. Smith, 1853, Synopsis of the British Diatomaceae, v. 1, p. 79.*Gomphonema acuminatum* fo. *coronata* Ehrenberg. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 184.*Gomphonema acuminatum coronatum* (Ehrenberg) Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 291.*G. acuminatum* var. *coronata* is usually found in association with the type. It is rare in this deposit. Specimens range from 49 μ to 59 μ in length.Length of figured specimen (USGS diatom cat. No. 3410-43), 49 μ .*Gomphonema augur* Ehrenberg

Plate 3, figure 6

Gomphonema augur Ehrenberg, 1840, Kgl. preuss. Akad. Wiss. Berlin, Ber., p. 211.*

Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 185.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 293.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 372, fig. 688.

G. augur is of widespread occurrence in fresh waters but is not as common as *G. acuminatum*. It is rare in this deposit.Length of figured specimen (USGS diatom cat. No. 3410-56), 42 μ .*Gomphonema angustatum* var. *undulata* Grunow

Plate 3, figure 7

Gomphonema angustatum var. *undulata* Grunow, in Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 181.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 373, fig. 694.

G. angustatum var. *undulata* is a common and widespread fresh-water form. It is rare in this deposit.Length of figured specimen (USGS diatom cat. No. 3260-19), 46 μ .*Gomphonema intricatum* Kützing

Plate 3, figure 8

Gomphonema intricatum Kützing, 1844, Die Kieselschaligen Bacillarien oder Diatomeen, p. 87, pl. 9, fig. 4.

Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 181-182.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 295.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 375-376, fig. 697.

G. intricatum is a widespread fresh-water species occurring commonly in standing water. It is frequent in this deposit. It ranges in length from 30 μ to 74 μ .Length of figured specimen (USGS diatom cat. No. 3260-26), 54 μ .*Gomphonema gracile* Ehrenberg

Plate 3, figure 9

Gomphonema gracile Ehrenberg, 1838, Die Infusionsthierchen als vollkommene Organismen, p. 217, pl. 18, fig. 3.*

Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 182-183.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 296.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 376, fig. 702.

G. gracile is widespread in standing fresh water, more abundant in warm climates, but ranges commonly into temperate environments. It is rare in this deposit.Length of figured specimen (USGS diatom cat. No. 3260-121), 60 μ .*Gomphonema lanceolatum* Ehrenberg

Plate 3, figure 10

Gomphonema lanceolatum Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, pl. 2, fig. I, 37.

Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 87, pl. 29, fig. 73; pl. 30, fig. 59.

Grunow, in Van Heurck, 1880, Synopsis des diatomées de Belgique, pl. 24, fig. 11.

Gomphonema gracile var. *lanceolata* Kützing. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 183.*Gomphonema gracile* var. *lanceolata* (Kützing) Cleve. Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 376, fig. 703.Cleve (1894, p. 183) bases both his *G. lanceolatum* and his *G. gracile* var. *lanceolata* on *G. lanceolatum* Ehrenberg. Examination of the original description and figures of Ehrenberg (1843) clearly indicates, however, that *G. lanceolatum* Ehrenberg pertains only to forms designated by Cleve (1894) and later authors as *G. gracile* var. *lanceolata*. *G. lanceolatum* of Cleve (1894), Boyer (1927), Hustedt (1930), and others is a separate and distinct species. Cleve's name is invalid and should be replaced.The distribution of this species is similar to that of *G. gracile*. It occurs rarely in this deposit.Length of figured specimen (USGS diatom cat. No. 3410-11), 61 μ .*Gomphonema constrictum* Ehrenberg

Plate 3, figure 11

Gomphonema constrictum Ehrenberg, 1830, Kgl. preuss. Akad. Wiss. Berlin, Abh., p. 63.*

Grunow, in Van Heurck, 1880, Synopsis des diatomées de Belgique, p. 123, pl. 23, fig. 6.

Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 186.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 292-293.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 377, fig. 714.

G. constrictum is widespread and common in fresh-water environments. It is frequent in this deposit. Specimens range from 32μ to 56μ in length.

Length of figured specimen (USGS diatom cat. No. 3260-100), 49μ .

Gomphonema capitatum Ehrenberg

Plate 3, figure 12

Gomphonema capitatum Ehrenberg, 1838, Die Infusionsthierchen als vollkommene Organismen, pl. 18, fig. 2.*

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 292.

Gomphonema (constrictum var.?) capitatum Ehrenberg. Grunow, in Van Heurck, 1880, Synopsis des diatomées de Belgique, p. 123, pl. 23, fig. 7.

Gomphonema constrictum var. *capitata* Ehrenberg. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 186.

Gomphonema constrictum var. *capitata* (Ehrenberg) Cleve. Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 377, fig. 715.

Although *G. capitatum* is considered by some to be a variety of *G. constrictum*, there is a notable lack of resemblance between the two forms. *G. constrictum* shows a marked constriction near the rounded apex. *G. capitatum* has lateral margins only slightly convergent toward the broad, blunt apex. *G. capitatum* is not all capitate; and although the name is inappropriate, it cannot be rejected for this reason. Following Boyer (1927), the form has been restored to specific rank, rather than retained as a variety of *G. constrictum*.

G. capitatum is a common and widespread fresh-water species. It occurs frequently in this deposit. Specimens range from 35μ to 53μ in length.

Length of figured specimen (USGS diatom cat. No. 3260-147), 49μ .

Family CYMBELLACEAE

Subfamily CYMBELLOIDEAE

Genus AMPHORA Ehrenberg, 1840

Amphora ovalis (Kützing) Kützing

Plate 3, figure 13

Frustulia ovalis Kützing, 1833, Synopsis Diatomearum, Linnaea, v. 8, p. 539, fig. 5.

Amphora ovalis Kützing, 1844, Die kieselschaligen Bacillarien oder Diatomeen, p. 107, pl. 5, fig. 35, 39.

Cleve, 1895, Kgl. svenska vetensk. akad. Handl., v. 27, no. 3, p. 104-105.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 254.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 342-343, fig. 628.

A. ovalis is a common fresh-water diatom of widespread distribution. It occurs frequently in this deposit. Specimens range in length from 32μ to 48μ .

Length of figured specimen (USGS diatom cat. No. 3260-152), 48μ .

Genus CYMBELLA Agardh, 1830

Cymbella ehrenbergii Kützing

Plate 3, figure 14

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

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

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

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

C. ehrenbergii is a common fresh-water diatom of widespread occurrence. It is common in this deposit. It ranges in length from 100μ to 153μ .

Length of figured specimen (USGS diatom cat. No. 3260-237), 147μ .

Cymbella turgida Gregory

Plate 3, figure 15

Cymbella turgida Gregory, 1856, Quart. Jour. Micros. Sci., v. 4, p. 5, pl. 1, fig. 18.*

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 283-284.

Cymbella (Encyonema) turgida Gregory. Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 168.

Cymbella turgida (Gregory) Cleve. Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 358, fig. 660.

C. turgida is found most commonly in the tropics; it is also widespread in temperate fresh-water environments but occurs mostly as small individuals. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3410-67), 45μ .

Cymbella americana Schmidt

Plate 3, figures 16, 17

Cymbella americana Schmidt, 1875, Atlas der Diatomaceen-Kunde, no. 3, pl. 9, fig. 15, 20.

Cymbella heteropleura var. *minor* Cleve, 1894, Kgl. svenska vetensk. akad. Handl., v. 26, no. 2, p. 167.

Hustedt, in Schmidt, 1931, Atlas der Diatomaceen-Kunde, no. 94, pl. 374, fig. 11, 12.

C. americana has elliptical-lanceolate valve with markedly rostrate obtuse apices. Nearly bilaterally symmetrical with ventral margin slightly convex. Axial area narrow. Transverse striae slightly convergent, shortened at the center to form a transversely elliptical central area. Striae composed of distinct puncta, slightly uneven in lineation and spacing. Striae 7-10 in 10μ near the center, slightly closer at the ends. Puncta 17-18 in 10μ , somewhat more closely spaced near the apices. Raphe nearly straight, oblique

to the plane of the valve, and having conspicuous central pores deflected toward the ventral margin. Raphe terminates in small hyaline nodules at the polar extremities. Length 55μ to 82μ , width 20μ to 23μ .

Length of figured specimens (USGS diatom cat. Nos. 3260-64 and 3261-86) 62μ , 68μ .

C. americana, as figured by Schmidt (1875, pl. 9), appears to be substantially identical with *C. heteropleura* var. *minor* as figured by Hustedt (1931, pl. 94). The apices of the specimens figured by Hustedt are perhaps a bit more rostrate and attenuate, but the difference is trivial. Cleve (1894, p. 167) states that *C. americana* seems to be intermediate between *C. cuspidata* and his *C. heteropleura* var. *minor*, and that the latter form differs from *C. cuspidata* only in the somewhat different shape of the ends and the more coarsely punctate striae. Boyer (1927, p. 275) considers *C. americana* to be a variety of *C. ehrenbergii*.

C. americana and *C. heteropleura* var. *minor* seem to be identical in all essential characteristics, and the name *C. americana* is adopted for the species in this report on the basis of its priority. Because a written diagnosis of this species was not made by Schmidt, and because Cleve's *C. heteropleura* var. *minor* was described in a perfunctory manner, a definition of the species as it occurs in the Hixton deposit is given above. *C. americana* is smaller in size than *C. heteropleura* and larger in size than *C. naviculiformis* and differs in the spacing of the transverse striae, but otherwise it resembles these species in general appearance. A close affinity is apparent between *C. americana*, *C. cuspidata*, *C. heteropleura*, and *C. naviculiformis*, but these species seem to be distinctively different from *C. ehrenbergii*. *C. americana* is frequent in this deposit.

Cymbella cistula (Hemprich) Grunow

Plate 3, figure 18

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

Cymbella cistula (Hemprich) Grunow, in Van Heurck, 1880, *Synopsis des diatomées de Belgique*, p. 64, pl. 2, fig. 12. Boyer, 1927, *Acad. Nat. Sci. Philadelphia Proc.*, v. 79, supp., p. 280.

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

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

C. cistula is a common fresh-water species of widespread distribution. It occurs rarely in this deposit.

Length of figured specimen (USGS diatom cat. No. 3410-27), 78μ .

Family EPITHEMIACEAE

Subfamily EPITHEMIOIDEAE

Genus EPITHEMIA Brébisson, 1838

Epithemia zebra (Ehrenberg) Kützing

Plate 3, figure 19

Navicula zebra Ehrenberg, 1834, *Kgl. preuss. Akad. Wiss. Berlin. Abh.*, 1834, p. 118.*

Epithemia zebra (Ehrenberg) Kützing, 1844, *Die kieselschaligen Bacillarien oder Diatomeen*, p. 34, pl. 5, fig. 12.

Boyer, 1927, *Acad. Nat. Sci. Philadelphia Proc.*, v. 79, supp., p. 490.

Hustedt, in Pascher, 1930, *Die Süßwasser-flora Mitteleuropas*, no. 10, p. 384-387, fig. 729.

E. zebra is a widespread and common fresh-water diatom. It occurs rarely in this deposit.

Length of figured specimen (USGS diatom cat. No. 3261-146), 23μ . This individual is short, not entirely typical of the species.

Epithemia zebra var. *porcellus* (Kützing) Grunow

Plate 3, figure 20

Epithemia porcellus Kützing, 1844, *Die kieselschaligen Bacillarien oder Diatomeen*, p. 34, pl. 5, fig. 18, 19.

Epithemia zebra var. *porcellus* (Kützing) Grunow, 1862, *Kaiserl.-kgl. zool.-bot. Gesell. Wien, Verh.*, v. 12, p. 328.

Hustedt, in Pascher, 1930, *Die Süßwasser-flora Mitteleuropas*, no. 10, p. 385, fig. 731.

E. zebra var. *porcellus* is of common occurrence and of widespread distribution in fresh-water environments. It is common in this deposit, and it is relatively much more common than the type. Specimens observed range in length from 38μ to 76μ .

Length of figured specimen (USGS diatom cat. No. 3260-35), 70μ .

Epithemia turgida (Ehrenberg) Kützing

Plate 3, figure 21

Navicula turgida Ehrenberg, 1830, *Kgl. preuss. Akad. Wiss. Berlin Abh.*, 1830, p. 64.*

Epithemia turgida (Ehrenberg) Kützing, 1844, *Die kieselschaligen Bacillarien oder Diatomeen*, p. 34, pl. 5, fig. 14.

Boyer, 1927, *Acad. Nat. Sci. Philadelphia Proc.*, v. 79, supp., p. 488.

Hustedt, in Pascher, 1930, *Die Süßwasser-flora Mitteleuropas*, no. 10, p. 387, fig. 733.

E. turgida is of common and widespread occurrence in fresh and slightly brackish waters. It is abundant in this deposit. Specimens range in length from 32μ to 127μ .

Length of figured specimen (USGS diatom cat. No. 3260-17), 120μ .

Epithemia turgida var. *granulata* (Ehrenberg) Brun

Eunotia granulata Ehrenberg, 1837?, *Poggendorf Annalen Physik*, 1836, p. 220, pl. 4, fig. 2.*

Epithemia turgida var. *granulata* (Ehrenberg) Brun, 1880, *Diatomées des Alpes et du Jura*, p. 44, pl. 2, fig. 13.

Epithemia granulata (Ehrenberg) Kützing, 1844, Die kiesel-schaligen Bacillarien oder Diatomeen, p. 35-36, pl. 5, fig. 20.

Epithemia turgida granulata (Ehrenberg) Brun. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 488-489.

Epithemia turgida var. *granulata* (Ehrenberg) Grunow. Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 387, fig. 734.

The occurrence of *E. turgida* var. *granulata* is the same as that of the type. This variety is distinguished from the type by its more nearly parallel ventral and dorsal margins as well as its less capitate ends. It occurs frequently in this deposit, and it ranges in length from 101 μ to 147 μ .

Epithemia irregularis Andrews, n. sp.

Plate 3, figures 22-25

Valves of *E. irregularis* arcuate, terminating in bluntly rounded or subcapitate ends. Ventral margin characterized by a broad moderately deep rounded emargination, usually occurring slightly off center, but less commonly in the center or, more rarely, near an end. Transverse costae radiate, alternating with two or three rows of puncta. Costae 4-5 in 10 μ , striae 9-10 in 10 μ , puncta 8-9 in 10 μ . Length 43 μ to 75 μ ; width 16 μ to 20 μ .

Holotype: USGS diatom cat. No. 3260-265 (fig. 22), length 49 μ . Paratypes: USGS diatom cat. Nos. 3410-8 (fig. 23), length 75 μ ; 3410-44 (fig. 24), length 60 μ ; 3260-24 (fig. 25), length 50 μ . USGS diatom loc. 5016.

This species is similar in many respects to *E. turgida*, which also occurs in the deposit. The main difference is the presence of the ventral emargination of the valve. This emargination may occur anywhere along the ventral margin, although it is most common near the center of the valve. In some specimens the indentation seems to distort or twist the valve, but only parallel to the plane of the valve. The frequent occurrence of *E. irregularis* in an assemblage of normal individuals of many genera and species appears to eliminate the possibility of it being a tautological form of *E. turgida*.

Genus *RHOPALODIA* O. Müller, 1897

Rhopalodia gibba (Ehrenberg) O. Müller

Plate 3, figure 26

Navicula gibba Ehrenberg, 1830, Kgl. preuss. Akad. Wiss. Berlin, Abh., 1830, p. 35, pl. 4, fig. 22.*

Rhopalodia gibba (Ehrenberg) O. Müller, 1897, Bot. Jahrb., v. 22, p. 65, pl. 1, fig. 15-17.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 491.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 390-391, fig. 740.

Eunotia gibba (Ehrenberg) Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, pl. 3, fig. I, 39.

Epithemia gibba (Ehrenberg) Kützing, 1844, Die kiesel-schaligen Bacillarien oder Diatomeen, p. 35, pl. 4, fig. 22.

R. gibba is a common fresh-water diatom of wide-spread occurrence. It is frequent in this deposit and shows great variation in length, ranging from 48 μ to 190 μ .

Length of figured specimen (USGS diatom cat. No. 3260-101), 58 μ .

Family **BACILLARIACEAE**

Subfamily **NITZSCHIOIDEAE**

Genus **HANTZSCHIA** Grunow, 1880

Hantzschia amphioxys (Ehrenberg) Grunow

Plate 3, figure 27

Eunotia amphioxys Ehrenberg, 1843, Kgl. preuss. Akad. Wiss. Berlin, Phys. Abh., 1841, p. 413, pl. 1, fig. I, 26; pl. 2, fig. I, 15; II, 16; pl. 3, fig. IV, 9; pl. 4, fig. V, 7.

Hantzschia amphioxys (Ehrenberg) Grunow, in Cleve and Grunow, 1880, Kgl. svenska vetensk. akad. Handl., v. 17, no. 2, p. 103.

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

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 394-395, fig. 747.

Nitzschia amphioxys (Kützing) W. Smith, 1853, Synopsis of the British Diatomaceae, v. 1, p. 41, pl. 13, fig. 105.

Hantzschia amphioxys var. *major* Grunow, in Van Heurck, 1881, Synopsis des diatomées de Belgique, 1885, p. 169, pl. 56, figs. 3, 11.

Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 529.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 394, fig. 749.

H. amphioxys has been revised in this report to include *H. amphioxys* var. *major* Grunow. Study of this assemblage and of the pertinent literature suggests that var. *major* differs from the type only in size, and that the forms have been separated arbitrarily at the length of 100 μ . It seems more useful for one to treat these forms as a single taxon, recognizing a considerable variation in size and in coarseness of the transverse striations.

H. amphioxys is of widespread occurrence, and it is found commonly in nearly all fresh-water environments. It is frequent in this deposit, and specimens range in length from 53 μ to 129 μ .

Length of figured specimen (USGS diatom cat. No. 3260-107), 72 μ .

Hantzschia amphioxys var. *capitata* Pantocsek

Plate 3, figure 28

Hantzschia amphioxys var. *capitata* Pantocsek, 1901, Die Kieselalgen oder Bacillarien des Balaton, p. 83, pl. 9, fig. 243.

Hantzschia amphioxys forma *capitata* O. Müller. Hustedt, in Schmidt's, 1921, Atlas der Diatomaceen-Kunde, pl. 329, figs. 13, 14.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 394, fig. 748.

Hantzschia amphioxys var. *major* fo. *capitata* Hustedt, in Schmidt's, 1921, Atlas der Diatomaceen-Kunde, pl. 329, fig. 3.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 394.

H. amphioxys var. *capitata* is here restored to the rank of variety, and it is considered to include the capitata individuals of *H. amphioxys* in the broad sense in which that species is defined in this report. Although the original designation of var. *capitata* has been imputed to O. Müller, reference has never been made to the publication, and it has not been located. Authorship is here attributed to Pantocsek (1901), who established var. *capitata* as a new variety of the species.

This variety is of widespread occurrence in fresh-water environments and is often found in association with the type. It is rare in this deposit.

Length of figured specimen (USGS diatom cat. No. 3260-244), 117 μ .

Genus NITZSCHIA Hassall, 1845

Nitzschia thermalis (Ehrenberg) Grunow

Pinnularia thermalis Ehrenberg, 1841?, Kgl. preuss. Akad. Wiss. Berlin, Ber., 1841, p. 21.*

Nitzschia thermalis (Ehrenberg) Grunow, 1862, Kaiserl.-kgl. zool.-bot. Gesell. Wein, Verh., v. 12, p. 568-569, pl. 12, fig. 22.

Surirella thermalis (Ehrenberg) Kützing, 1844, Die kieselalgen Bacillarien oder Diatomeen, p. 60, pl. 3, fig. 46.

Nitzschia thermalis Kützing. Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 403, 405, fig. 771.

N. thermalis is a widespread fresh-water species of frequent occurrence. It is rare in this deposit.

Suborder SURIRELLINEAE

Family SURIRELLACEAE

Subfamily SURIRELLOIDEAE

Genus CYMATOPLEURA W. Smith, 1851

Cymatopleura solea (Brébisson) W. Smith

Surirella solea Brébisson, 1838, Considérations sur les diatomées, p. 17.*

Cymatopleura solea (Brébisson) W. Smith. Boyer, 1927, Acad. Nat. Sci. Philadelphia Proc., v. 79, supp., p. 532.

Hustedt, in Pascher, 1930, Die Süßwasser-flora Mitteleuropas, no. 10, p. 425-426, fig. 823a.

Cymatopleura solea (Kützing) W. Smith, 1851, Annals and Mag. Nat. History, ser. 2, v. 7, p. 12-13, pl. 3, fig. 10-11.

C. solea is a common fresh-water species having a widespread distribution. It is rare in this deposit.

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PLATES 1-3

PLATE 1

- FIGURES 1-3. *Melosira italica* (Ehrenberg) Kützing, $\times 960$ (p. A10).
 1. USGS diatom cat. No. 3260-207. Diameter, 22μ .
 2. USGS diatom cat. No. 3260-271. Diameter, 10μ .
 3. USGS diatom cat. No. 3260-270. Diameter, 7μ .
 4. *Cyclotella meneghiniana* Kützing, $\times 960$ (p. A11).
 USGS diatom cat. No. 3261-55. Diameter, 10μ .
 5. *Cyclotella comta* (Ehrenberg) Kützing, $\times 960$ (p. A11).
 USGS diatom cat. No. 3410-62. Diameter, 38μ .
 6. *Opephora martyi* Héribaud, $\times 960$ (p. A11).
 USGS diatom cat. No. 3410-61. Length, 35μ .
 7. *Fragilaria leptostauron* (Ehrenberg) Hustedt, $\times 960$ (p. A11).
 USGS diatom cat. No. 3260-36. Length, 16μ .
 8. *Fragilaria construens* var. *venter* (Ehrenberg) Grunow, $\times 1870$ (p. A12).
 USGS diatom cat. No. 3410-63. Length, 13μ .
 9. *Fragilaria construens* var. *binodis* (Ehrenberg) Grunow, $\times 1870$ (p. A12).
 USGS diatom cat. No. 3261-24. Length, 16μ .
 10. *Fragilaria construens* var. *subsalina* Hustedt, $\times 960$ (p. A12).
 USGS diatom cat. No. 3410-3. Length, 35μ .
 11. *Synedra ulna* (Nitzsch) Ehrenberg, $\times 475$ (p. A12).
 USGS diatom cat. No. 3260-69. Length, 157μ .
 12. *Synedra capitata* Ehrenberg, $\times 475$ (p. A12).
 USGS diatom cat. No. 3410-41. Length, 197μ .
 13. *Meridion constrictum* Ralfs, $\times 960$ (p. A12).
 USGS diatom cat. No. 3260-170. Length, 39μ .
 14. *Tabellaria fenestrata* (Lyngbye) Kützing, $\times 960$ (p. A13).
 USGS diatom cat. No. 3410-25. Length, 72μ .
 15. *Eunotia bidentula* W. Smith, $\times 960$ (p. A13).
 USGS diatom cat. No. 3260-256. Length, 51μ .
 16. *Eunotia impressa* Ehrenberg, $\times 960$ (p. A13).
 USGS diatom cat. No. 3410-58. Length, 32μ .
 17. *Eunotia lunaris* (Ehrenberg) Grunow, $\times 610$ (p. A13).
 USGS diatom cat. No. 3410-65. Length, 125μ .
 18. *Eunotia gracilis* (Ehrenberg) Rabenhorst, $\times 960$ (p. A13).
 USGS diatom cat. No. 3260-222. Length, 63μ .
 19-20. *Eunotia monodon* Ehrenberg, $\times 475$ (p. A13).
 19. USGS diatom cat. No. 3260-229. Length, 100μ .
 20. USGS diatom cat. No. 3260-134. Length, 66μ .
 21. *Eunotia formica* Ehrenberg, $\times 475$ (p. A14).
 USGS diatom cat. No. 3260-232. Length, 103μ .
 22. *Cocconeis placentula* Ehrenberg, $\times 960$ (p. A14).
 USGS diatom cat. No. 3261-106. Length, 34μ .
 23. *Cocconeis pediculus* Ehrenberg, $\times 960$ (p. A14).
 USGS diatom cat. No. 3260-25. Length, 25μ .
 24. *Diploneis ovalis* var. *oblongella* (Naegeli) Cleve, $\times 1870$ (p. A14).
 USGS diatom cat. No. 3260-165. Length, 29μ .
 25. *Stauroneis phoenicenteron* (Nitzsch) Ehrenberg, $\times 960$ (p. A14).
 USGS diatom cat. No. 3260-156. Length, 116μ .

DIATOMS FROM HIXTON DEPOSIT, TREMPÉALEAU VALLEY

PLATE 2

- FIGURE
1. *Navicula cuspidata* var. *ambigua* (Ehrenberg) Cleve, $\times$ 960 (p. A14).
USGS diatom cat. No. 3260-180. Length, 113 μ .
 2. *Navicula bacillum* Ehrenberg, $\times$ 960 (p. A15).
USGS diatom cat. No. 3410-30. Length, 51 μ .
 3. *Navicula radiosa* Kützing, $\times$ 960 (p. A15).
USGS diatom cat. No. 3261-136. Length, 66 μ .
 4. *Navicula reinhardtii* (Grunow) Grunow, $\times$ 960 (p. A15).
USGS diatom cat. No. 3260-188. Length, 45 μ .
 5. *Navicula dicephala* (Ehrenberg) Kützing, $\times$ 960 (p. A15).
USGS diatom cat. No. 3260-80. Length, 39 μ .
 6. *Navicula oblonga* (Kützing) Kützing, $\times$ 475 (p. A15).
USGS diatom cat. No. 3261-127. Length, 125 μ .
 7. *Navicula amphibola* Cleve, $\times$ 960 (p. A15).
USGS diatom cat. No. 3260-116. Length, 73 μ .
 - 8-9. *Navicula rotunda* Andrews, n. sp., $\times$ 960 (p. A16).
8. Holotype. USGS diatom cat. No. 3260-196. Length, 40 μ .
9. USGS diatom cat. No. 3260-199. Length, 32 μ .
 10. *Pinnularia interrupta* W. Smith, $\times$ 960 (p. A16).
USGS diatom cat. No. 3260-4. Length, 78 μ .
 11. *Pinnularia mesolepta* var. *angusta* Cleve, $\times$ 960 (p. A16).
USGS diatom cat. No. 3260-82. Length, 58 μ .
 12. *Pinnularia lata* (Brébisson) W. Smith, $\times$ 475 (p. A16).
USGS diatom cat. No. 3260-269. Length, about 104 μ .
 13. *Pinnularia borealis* Ehrenberg, $\times$ 960 (p. A16).
USGS diatom cat. No. 3410-10. Length, 38 μ .
 14. *Pinnularia gibba* (Ehrenberg) W. Smith, $\times$ 960 (p. A16).
USGS diatom cat. No. 3261-62. Length, 77 μ .
 15. *Pinnularia* cf. *P. stomatophora* (Grunow) Cleve, $\times$ 960 (p. A17).
USGS diatom cat. No. 3260-129. Length, 48 μ .
 16. *Pinnularia major* (Kützing) W. Smith, $\times$ 475 (p. A17).
USGS diatom cat. No. 3260-96. Length, 200 μ .
 17. *Pinnularia esox* Ehrenberg, $\times$ 475 (p. A17).
USGS diatom cat. No. 3410-27. Length, 138 μ .
 18. *Pinnularia viridis* (Nitzsch) Ehrenberg, $\times$ 475 (p. A17).
USGS diatom cat. No. 3260-186. Length, 98 μ .
 19. *Pinnularia streptoraphe* Cleve, $\times$ 475 (p. A17).
USGS diatom cat. No. 3260-263. Length, 174 μ .
 20. *Neidium bisulcatum* (Lagerstedt) Cleve, $\times$ 960 (p. A18).
USGS diatom cat. No. 3261-88. Length, 43 μ .
 21. *Neidium iridis* (Ehrenberg) Cleve, $\times$ 960 (p. A18).
USGS diatom cat. No. 3261-82. Length, 80 μ .
 22. *Neidium iridis* var. *vernalis* Reichelt, $\times$ 960 (p. A18).
USGS diatom cat. No. 3260-43. Length, 60 μ .

DIATOMS FROM HIXTON DEPOSIT, TREMPÉALEAU VALLEY

PLATE 3

- FIGURE 1. *Caloneis silicula* (Ehrenberg) Cleve, $\times 960$ (p. A18).
 USGS diatom cat. No. 3260-206. Length, 73μ .
2. *Caloneis silicula* var. *truncatula* (Grunow) Cleve, $\times 960$ (p. A18).
 USGS diatom cat. No. 3410-57. Length, 43μ .
3. *Caloneis trinodis* (W. Smith) Boyer, $\times 960$ (p. A18).
 USGS diatom cat. No. 3260-166. Length, 40μ .
4. *Gomphonema acuminatum* Ehrenberg, $\times 960$ (p. A18).
 USGS diatom cat. No. 3260-47. Length, 40μ .
5. *Gomphonema acuminatum* var. *coronata* (Ehrenberg) W. Smith, $\times 960$ (p. A19).
 USGS diatom cat. No. 3410-43. Length, 49μ .
6. *Gomphonema augur* Ehrenberg, $\times 960$ (p. A19).
 USGS diatom cat. No. 3410-56. Length, 42μ .
7. *Gomphonema angustatum* var. *undulata* Grunow, $\times 960$ (p. A19).
 USGS diatom cat. No. 3260-19. Length, 46μ .
8. *Gomphonema intricatum* Kützing, $\times 960$ (p. A19).
 USGS diatom cat. No. 3260-26. Length, 54μ .
9. *Gomphonema gracile* Ehrenberg, $\times 960$ (p. A19).
 USGS diatom cat. No. 3260-121. Length, 60μ .
10. *Gomphonema lanceolatum* Ehrenberg, $\times 960$ (p. A19).
 USGS diatom cat. No. 3410-11. Length, 61μ .
11. *Gomphonema constrictum* Ehrenberg, $\times 960$ (p. A19).
 USGS diatom cat. No. 3260-100. Length, 49μ .
12. *Gomphonema capitatum* Ehrenberg, $\times 960$ (p. A20).
 USGS diatom cat. No. 3260-147. Length, 49μ .
13. *Amphora ovalis* (Kützing) Kützing, $\times 960$ (p. A20).
 USGS diatom cat. No. 3260-152. Length, 48μ .
14. *Cymbella ehrenbergii* Kützing, $\times 475$ (p. A20).
 USGS diatom cat. No. 3260-237. Length, 147μ .
15. *Cymbella turgida* Gregory, $\times 960$ (p. A20).
 USGS diatom cat. No. 3410-67. Length, 45μ .
- 16-17. *Cymbella americana* Schmidt, $\times 960$ (p. A20).
 16. USGS diatom cat. No. 3260-64. Length, 62μ .
 17. USGS diatom cat. No. 3261-86. Length, 68μ .
18. *Cymbella cistula* (Hemprich) Grunow, $\times 960$ (p. A21).
 USGS diatom cat. No. 3410-27. Length, 78μ .
19. *Epithemia zebra* (Ehrenberg) Kützing, $\times 960$ (p. A21).
 USGS diatom cat. No. 3261-146. Length, 23μ .
20. *Epithemia zebra* var. *porcellus* (Kützing) Grunow, $\times 960$ (p. A21).
 USGS diatom cat. No. 3260-35. Length, 70μ .
21. *Epithemia turgida* (Ehrenberg) Kützing, $\times 475$ (p. A21).
 USGS diatom cat. No. 3260-17. Length, 120μ .
- 22-25. *Epithemia irregularis* Andrews, n. sp., $\times 960$ (p. A22).
 22. Holotype, USGS diatom cat. No. 3260-265. Length, 49μ .
 23. Paratype, USGS diatom cat. No. 3410-8. Length, 75μ .
 24. Paratype, USGS diatom cat. No. 3410-44. Length, 75μ .
 25. Paratype, USGS diatom cat. No. 3260-24. Length, 50μ .
26. *Rhopalodia gibba* (Ehrenberg) O. Müller, $\times 960$ (p. A22).
 USGS diatom cat. No. 3260-101. Length, 58μ .
27. *Hantzschia amphioxys* (Ehrenberg) Grunow, $\times 960$ (p. A22).
 USGS diatom cat. No. 3260-107. Length, 72μ .
28. *Hantzschia amphioxys* var. *capitata* Pantocsek, $\times 960$ (p. A22).
 USGS diatom cat. No. 3260-244. Length, 117μ .

DIATOMS FROM HIXTON DEPOSIT, TREMPÉALEAU VALLEY