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POSTGLACIAL SEDIMENTS FROM TWO SITES  
IN NORTHERN IOWA.

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IMPLICATIONS OF DIATOM SUCCESSION IN POSTGLACIAL  
SEDIMENTS FROM TWO SITES IN NORTHERN IOWA

by

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## INTRODUCTION

This investigation is an attempt to evaluate the diatom record left in postglacial sediments in relation to climatic changes during deposition. Although the accumulated paleoclimatic information has come from many sources, palynologists have been the predominant reporters from the North American midwest. One of the recognized weaknesses of pollen counts in interpretations of the postglacial climatic records is that they do not truly represent the actual population densities of vegetation in the vicinity of the deposit (Davis, 1963). Under-representation and over-representation both occur due to variations in dispersal rates, quantities produced, and differential preservation capabilities of the various pollens encountered (Sangster and Dale, 1961). An equally significant problem is that most pollen identifications can be made only to the generic level; frequently, as with most grasses, only to the family level.

Diatoms grow in place and can be identified to species from fossil deposits. In the case of Lake West Okoboji, at least several hundred species (Stoermer, 1963) are known to occur in contrast to the few dozen different pollen. For certain of these diatom species, some notion of their habitat requirements are known (Cholnoky, 1960; Foged, 1947a, 1947b, 1948a, 1948b; Hustedt, 1930, 1935, 1938, 1942, 1957; Sovereign, 1958; Patrick and Reimer, 1966). Despite the lack of experimental data on exact conditions for optimum growth, it is possible to interpret the aquatic habitat and its pattern of change during postglacial time by utilizing this information on the range of environmental conditions which given taxa tolerate.

An association of species at a given level in the sediments should yield evidence concerning the nature of the aquatic environment at the time of their formation. This may, in turn, imply the existence of certain conditions in the associated terrestrial environment. The assumption must be made that the taxa involved responded to the environment then as they do today.

A major development affecting all studies of the recent Pleistocene is the technique of radiocarbon analysis to determine the age of organic remains (Libby, 1961). Ruhe and Scholtes (1955) and Ruhe et al. (1957) have presented many radiocarbon dates from Iowa, and discussed their significance, especially in relation to the development of soils. Walker (1966) and Walker and Brush (1963) have utilized this information and added much more in establishing a chronology of sediments from bogs on the Cary drift in Iowa, in which they recognized a stratigraphy of alternating organic and mineral sediment zones. These zones are considered to be the result of environmental changes and are identified as the lower silt zone (LS), lower muck (LM), upper silt (US), and upper muck zone (UM). Walker (1966) reports the following approximate dates for transitions between these layers from several bog profiles on the Des Moines Lobe:

|                          |                    |
|--------------------------|--------------------|
| Transition UM/US         | 3,000 years B. P.  |
| Transition US/LM         | 8,000 years B. P.  |
| Transition LM/LS         | 10,500 years B. P. |
| Transition LS/Cary drift | 13,000 years B. P. |

These zones are based mainly on sedimentary accumulation rates which Walker found correlated with rates of hillside erosion. By associating the erosion data with pollen profiles Walker (1966) was able to propose the following chronology for the postglacial environmental sequence:

1. The LS zone represents the post-Cary interval. Conifer pollen is present but sparse. Cool temperatures probably prevailed and vegetation was meager. Erosion rates were high due to the lack of vegetation on the new drift and the abundance of glacial melt water.
2. The LS/LM transition represents a change in erosional conditions.
3. The LM represents a more stabilized condition of forest vegetation in which the trend for conifers to disappear and be replaced by deciduous trees probably indicates warming conditions.
4. The LM/US transition probably represents a rather abrupt climatic change, exposing the soil surface and leading to higher erosion rates and unstable conditions.
5. The upper silt represents a period of high erosion. The forests disappeared and the prairie became established.
6. The US/UM transition represents a return to more stable conditions with lower erosion rates.
7. The UM has continued to accumulate with minor variations to the present time.

Concepts, terminology, and principles of research on the Pleistocene were organized by Deevey (1949). This work has provided a unifying base for research in Europe and in North America. By far the greatest part of this research is related to studies of fossil pollen and spores, although studies of mollusks and other invertebrates have provided useful information. One concept, the climatic optimum (Deevey, 1949), described a period with average temperatures warmer than the present beginning shortly after the last advance of Wisconsin glacial ice and ending about 2,500 years B. P. Deevey and Flint (1957) later proposed the term

"hypsihermal" for this interval. An attempt to identify the hypsihermal period using information other than from pollen is one of the objectives of this investigation.

Recent studies of pollen profiles from states adjacent to Iowa (Wilson and Cross, 1943; West, 1961; Watts and Wright, 1966; Fries, 1962) present a basic picture of the post-glacial sequence. Conger (1939) reported on the diatoms in the material studied by Wilson and Cross (1943) in one of the few cases where both pollen and diatoms were utilized from the same core. The picture, although modified by local conditions and proximity to the glacial front, is consistent. Only the most recent cores have been dated by the radiocarbon method (Watts and Wright, 1962; Fries, 1966). However, it is possible to infer approximate dates in undated profiles by comparison of the pollen curves. In general there seems to have been a rapid amelioration of the postglacial climate beginning about 12,000 years B. P. The warming trend continued, and by approximately 8,000 years B. P. the hypsihermal began. This warmer period lasted with minor fluctuations (Deevey and Flint, 1957) until 2,500 years B. P. The termination of this period is not clearly shown by pollen profiles, but Fries (1962) suggests there is evidence of some changes in material from northeastern Minnesota. The wetter and perhaps slightly cooler conditions that developed have continued with minor changes up to the present. Lamb (1965), using historical and meteorological data, and botanical records, has synthesized a rather detailed report on world climate from the years 2,768 B. P. (800 B. C.) to 168 years B. P. (1800 A. D.). He discusses in detail the minor variations that have occurred with special emphasis on the "warm period" 1,000-1,200 A. D. and the "Little Ice Age" 1,500-1,700

A. D. The average world temperature change during these fluctuations was about 2°F. The evidence of these known minor changes makes the minor variations indicated by diatom populations more acceptable as real reflections of environmental conditions.

Evidence from other sources support this general picture. Cullen (1967), utilizing geomorphic and radiometric dates from the coast of New Zealand, reported an abrupt rise in sea level approximately 11,000 years B. P. The average rate of rise was 30 m/1,000 years between 11,000 and 9,000 years B. P. He feels this very rapid change in sea level does not necessarily indicate an abrupt temperature change because world temperatures may have risen several degrees before polar temperatures were affected enough to permit rapid en masse melting of the ice caps.

Graham and Heimsch (1960), in an investigation of pollen from an east central Texas bog, reported that spruce pollen disappears at a level dated 12,500 years B. P. by radiocarbon analysis. Evidence of changes begin deeper in the sediments at an approximate date of 15,000 years B. P. They interpret the persistence of arboreal species pollen in the sediments for 2,500 years as evidence of isolated stands of these species persisting in locations more favorable for their growth. The pollen record is relatively stable from 8,000 years B. P. to the present in their material. Lake sediments from central Arizona (Whiteside, 1965) show major changes at 14,400 years B. P. Frequencies of Pinus pollen increase while Picea, Abies and Pseudotsuga pollen frequencies decrease. He interpreted the dominance of Picea, Abies and Pseudotsuga in the period prior to 14,400 years B. P. as evidence of a pluvial period which can be assumed to correlate with a glacial period farther north. It is conceivable that

these dates, approximately 15,000 years B. P. in Texas and approximately 14,500 years B. P. in Arizona, are an early expression of the changes reported in more northern areas at approximately 12,000 years B. P. Evidence of moderating world temperature would be expected to show up sooner in areas farther from glaciated regions.

Heusser (1964) obtained bog sediments from the Olympic peninsula of Washington the deepest part of which seem to be pre-Wisconsin. The radiocarbon date he gives for the material is more than 30,000 years B. P. which probably places it in the Sangamon interglacial. In an attempt to estimate mean July temperatures for the time interval 30,000 years B. P. to the present, he utilized modern weather records from different latitudes that have a present pollen spectrum comparable to the various levels of the sediments. The estimated maximum depression during the Wisconsin was 11°F with 9-10°F, 8-9°F and 3-4°F being indicated for fluctuations toward the end of the period.

Fluorescence microscopy has been used in attempts to correlate distantly separated profiles that pre-date the effective range, approximately 50,000 years of the radiocarbon technique (Van Gijzel, 1967). Pollen and spore walls fluoresce blue, orange-red and reddish brown with increasing age. This technique is not fully developed but it seems to hold many possibilities. One of the more significant of these would be use of fluorescence phenomena to determine the occurrence and extent of mixing of old material with recent sediments.

Brief mention must be made of the now extinct lakes that existed in the western and southwestern part of the United States. The best known of these is Lake Bonneville, which has been extensively studied. It covered

most of western Utah and parts of Nevada and Idaho when at its highest stage. Bradley (1963) states that it was in existence for essentially the whole Pleistocene epoch and has been drastically influenced by the great climatic changes that have occurred during the last million years. The sediments can reasonably be expected to reflect these changes, and of the numerous investigations, that of Eardley and Gvosdelsky (1960) on a 650 foot core of the sediments is directly related to the present work. They interpret the core to include sediments deposited from the present to the Kansan glacial period and part of the Aftonian interglacial stages. The last fresh-water phase of this lake existed from approximately 23,000 to 13,500 B. P. which represents the Wisconsin glacial period. Patrick (1935) reported on some fresh-water diatoms of the upper sediments.

A similar very deep core, 645 feet in length, of ancient Lake Austin, Texas, was obtained by Clisby and Sears (1956) The pollen profile of the upper 300 feet has been studied and the next 150 feet scanned. The pollen story is not easily interpretable but in broad terms the Sangamon interglacial and Wisconsin glacial periods seem to be reflected in the upper 19 feet. Work is in progress on the pollen present in the deeper levels of this core. The authors do not mention the possibility of studying diatoms. Flint and Gale (1958) mention that the sediments of Searls Lake, California, are devoid of diatom frustules, probably due to the alkaline nature of the sediments.

The significance of diatom productivity has been discussed by Conger (1951). Tasch (1967) elaborates on this and enlarges the scope of his discussion to include the evolution of diatoms and their significance to primary production in the sea through geologic time. He discusses the

significance and implications of the growing body of evidence that diatoms became the primary producers in marine environments in the late Mesozoic about 70 million years ago. The earliest reported well developed fresh-water flora is of middle Oligocene age; however, the range of diversity in this flora suggests this environment was colonized much earlier.

Lohman (1960) presents a concise description of the geologic range of diatoms, a review of the use of diatoms in geological stratigraphy, some techniques, and some of the problems involved. Many floras have been studied and described, most of them being Miocene or younger. Pleistocene floras have received most attention since they as a rule, are more accessible. Some of the work is of little value as a basis on which to orient present investigations. Tindale's (1953) study of Australian fossil diatoms is based on the taxonomic scheme of Van Heurck (1880-1881) and as a consequence many genera are lumped. Gill (1953) attempted a paleoecological interpretation of the above floras based on such broad differences as "predominately fresh-water" and "primarily marine." Such investigations leave much to be desired. Barber (1961) has described a flora of fossil fresh-water diatoms from North Island, New Zealand but no attempt was made to interpret it.

Hustedt (1935) has described fossil diatom floras from Sumatra. He based the interpretation of these floras on his very extensive background and on published descriptions of the ecology of the various taxa. However, no attempt was made to quantitatively define populations from different levels.

Several papers have been published dealing with the significance of peat deposits in Florida. Hanna (1933) and Patrick (Cocke, Lewis and

Patrick, 1934) utilized the diatom floras of the peat in an attempt to explain its presence in Florida. Hanna reported the diatoms of the peat are presently found in subarctic regions and that the diatoms beneath the peat made up a brackish water flora. He concluded that the Florida peat accumulated in a climate that must have been much like that in the northern tier of states or southern Canada at present.

A brief list of diatom genera collected from a deposit in northwest central Nebraska is presented by Bates and Biemesderfer (1960). Based on other information, primarily the occurrence of certain snails, they suggest that the deposit formed under a small lake that did not dry out during the summer. Although they did not state it, one suspects that this situation reflects the cooler, wetter period associated with the Wisconsin glaciation.

Round (1957, 1961, 1964), in a series of investigations of fossil diatoms in English lake sediments, discussed the paleoecological use of fossil diatoms and the associated problems. Certain assumptions must be made, the most basic being that sediments represent a true sequence, the deepest being oldest, and each higher level being younger than that just below it (concept of superposition). Basins, such as I have studied, are disturbed to varying degrees by reworking of the sediments (Round, 1957). Serious effects from this probably only occur during periods of extreme fluctuations in water level. Changes of water level will not alter the sedimentary sequence unless the change lowers the water level sufficiently to allow vertical mixing of the sediments from the effect of wind and waves (Round, 1964). The uppermost sediments may be mixed in this manner resulting in a blurring of the differences in diatom populations that

result from the changed conditions. If such a low water period persists, the trends in diatom floras would be present but not as clear and easily identifiable as when no mixing occurs.

Certain forces active within sediments may influence the reliability of their diatom records. When sand forms a major part of the sediments, as in the deeper part of many reported cores, usually few diatoms are found (Collins, 1964; Round, 1961, 1964). There is growing evidence for physical destruction in such situations. Round (1964) points out that certain taxa, mostly the long slim forms, are easily broken. Usually shorter pieces of these taxa are found if conditions otherwise allow preservation of diatoms but the long forms tend to be under-represented in population surveys based on intact valves. Actual dissolution of frustules seems to be an important factor only in very alkaline sediments and Round (1964) estimates this to be a minor factor in the interpretation of sediments. Round (1964) has provided a most concise explanation of the use of diatoms in paleoecological investigations.

The siliceous frustules of diatom cells are relatively insoluble and therefore are preserved in lake sediments in a sequence from late-glacial times to the present day and also in interglacial and preglacial deposits. Theoretically it should therefore be possible to trace the history of any species, or taxonomic, or ecological group, from the first appearance of a diatom flora in a basin, and in addition it should be feasible to relate changes in the diatom flora to variation in ecological conditions during the period.

The most significant investigations of postglacial diatom succession in North America have not been based on quantitative population counts but on more or less subjective determinations in which taxa were assigned to broad frequency categories (Conger, 1939; Hutchinson et al.,

1956, Patrick, 1935, 1943, 1946, 1954; Weaver, 1948; Andrews, 1966).

Patrick (1946) describes a rather elaborate technique for slide preparation designed to eliminate errors in relative frequency of taxa but does not then utilize the slides for population studies. Round (1957) described a technique of slide preparation based on a given weight of sediment per sample which has been previously criticized (Collins, 1964; Stoermer, 1963).

A few recent investigations (Collins, 1964; Colingsworth, 1965; Colingsworth et al., 1967; Stoermer, 1963) have been based on population counts, but the gathered data were not treated in any statistical manner. No paleoecological diatom investigations have utilized radiocarbon analyses to establish a precise chronology of the sediments.

The goal of this investigation was to use radiocarbon dates of sediments and appropriate statistical analyses of diatom populations in order to compare and evaluate the effectiveness of diatoms for this type of study with previous investigations, specifically those on the physical nature of sediments and pollen analyses.

## METHODS

## Description of Study Sites

Since diatom floras from different habitats are quite distinctive, two sites having major differences in size, drainage basin and surrounding topography were selected for study. It was expected that fluctuating climatic conditions would have affected each differently and that changes observable in the two different diatom floras should allow broader interpretations than would be possible from a single site.

The first site was Little Miller's Bay of Lake West Okoboji (Figure 1). A detailed description of the lake was given by Stoermer (1963). This site is referred to as L. M. B. in tables and figures, and as the "Lake site" in the text of this thesis.

The second site, commonly called the "Kettle Hole," (Figure 2) is located on the Henry O. Arends' farm (section 33, R37W, T99N, Dickinson County, Iowa). The area of the ephemeral pond is about 0.1 hectare (0.26 acre) and the drainage basin about 29.6 hectares (73.1 acres). The basin probably resulted from a detached, partially buried, ice block of the last advance (Algona) of glacial ice over the region. The ridge surrounding the present pond is nearly 50 feet high on the east, south, and part of the west sides. The lowest part of the rim is at the north end of the western ridge and conceivably served as an overflow during an earlier period of its existence. Water depth in the pond varies from at least 6 feet in some years to complete absence of water in others, but has never been high enough to overflow in the memory of local residents, according to Mr. Arends (personal communication).

Figure 1. Map of Little Miller's Bay showing its relation to Miller's Bay and to Lake West Okoboji (inset). Bearings to prominent landmarks from the coring site (x) are given. A is the northeast corner of the building laboratory of Iowa Lakeside Laboratory. B is the south dormer peak of the Iowa Lakeside Laboratory messhall. C is the watertower of the New Inn resort on the east shore of Lake West Okoboji.

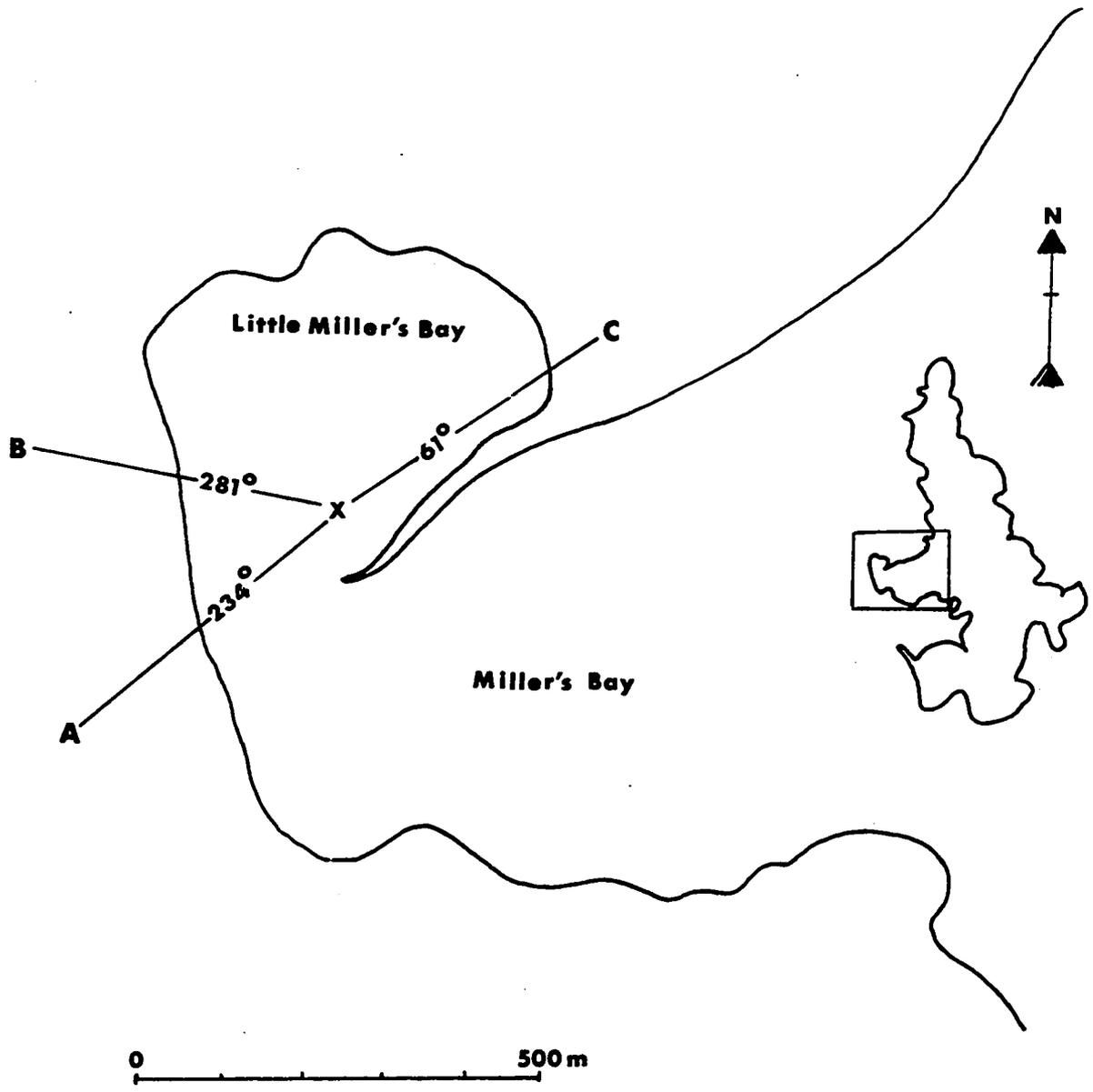
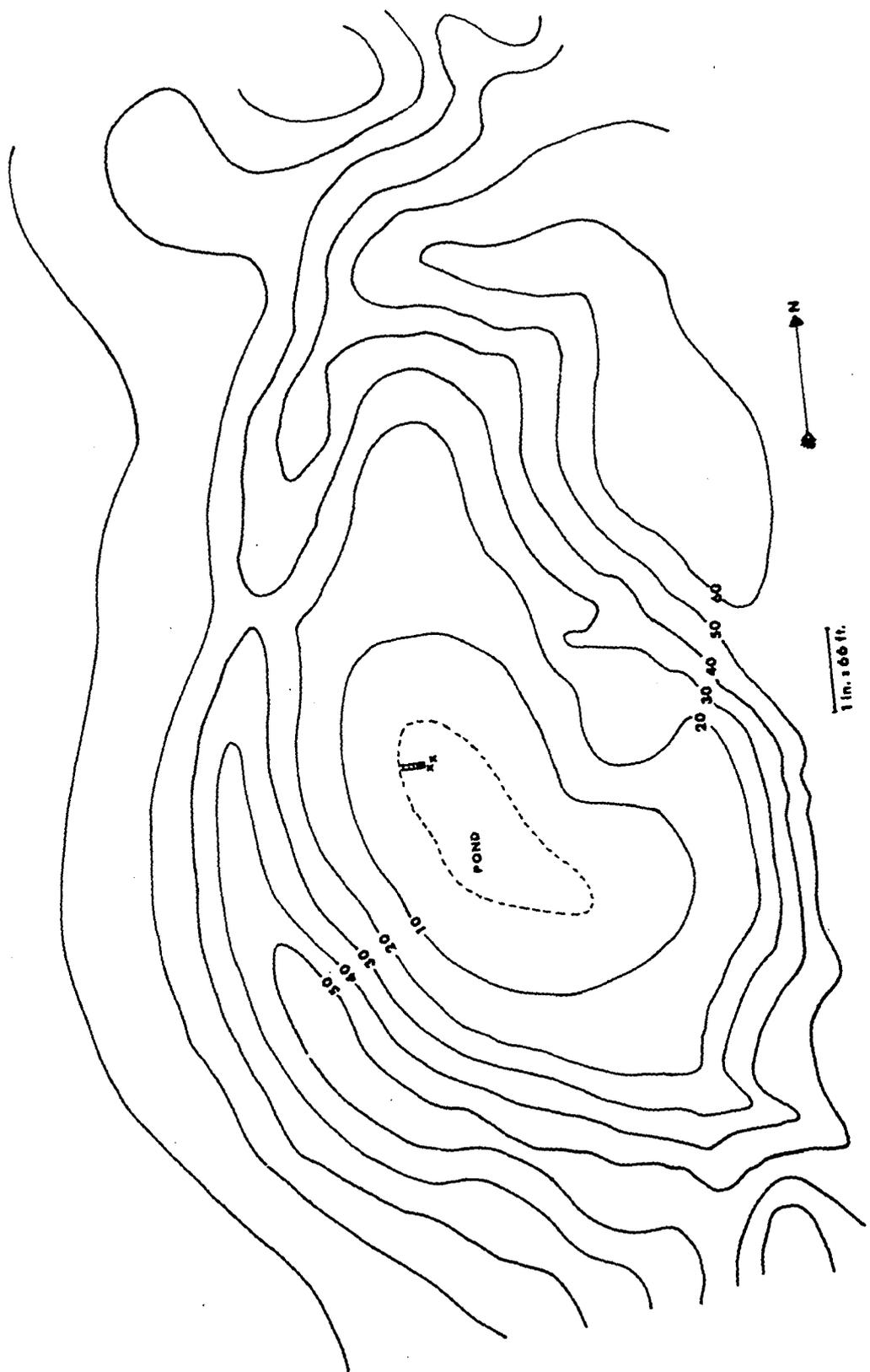


Figure 2. Topographic map of Arends' Kettle Hole adapted from an unpublished map by Gerhardt and Chase, 1938. Contour interval is 10 feet. The dock and the sampling locations (x) are indicated.



### Sampling Techniques

Because of the difficulties encountered by Stoermer (1963) in sampling the sediments of the deep hole of Lake West Okoboji, this work was shifted to a shallow bay of the lake. Work was begun in the summer of 1965 by Mr. Larry Wehr who was interested in determining the chemical composition of the sediments. A Davis peat sampler which obtains a core approximately 6 inches long and 1 inch in diameter was used for all sampling in 1965. Attempts to use it for sampling lake sediments from a floating platform met with problems related to the flexibility of the sampler rods. To overcome them, a 2½ inch pipe 12 feet in length was driven into the sediments. The sampler was then operated through the pipe. This prevented bending and permitted considerable force to be applied to the sampler. One inconvenience of this technique was that the rod connecting joints frequently caught on the bottom end of the pipe during withdrawal. Beveling the connecting joints so that they tended to slip off the edge of the pipe while being pulled up reduced this difficulty.

After sampling in several shallow areas of the lake and never obtaining cores more than 6 m in length because of a sandy layer, it was decided to undertake a series of probes across Little Miller's Bay in an attempt to obtain a deeper core. A location was eventually found (Figure 1) where it was possible to penetrate the 6 m deep sandy layer and sample the deeper sediments. The water depth at this location in June, 1965, was 1.5 m. A 6-inch sample at every foot level was obtained to a depth of 35 feet in this location, except for the 2-foot level, where the

sediments were very soft and would not exert sufficient friction on the sampler to open it (Figure 3). The Davis sampler is calibrated in feet and all measurements were originally recorded in the English system and later converted to the metric system.

The samples were carefully removed from the sampler, both ends trimmed to reduce the possibility of contamination, split lengthwise into three equal parts, and stored in plastic bags. One part was used for chemical analyses of the sediments, the second part was for pollen studies, and the third portion was processed for diatoms for use in the present investigation (Dodd, Webster, Collins and Wehr, In press).

Sampling at the Kettle Hole site was accomplished by means of a Heller Corer. This corer is more satisfactory than the Davis sampler since it is much more rigid and can be forced through more compacted or sandy sediments.

A satisfactory floating platform from which the first cores from this site were taken in June, 1966, was made from two canoes with two 4 x 8 foot sheets of 3/4 inch plywood fastened to their gunwales. The water depth at the sampling point was 61 cm. The water level was about half that in June, 1967 (29 cm), and at that time a dock was built into the pond, ending at a point approximately 2.8 m west-southwest of the original sampling site (Figure 2). At the time when samples for radiocarbon analysis were obtained in May, 1968, the pond was almost dry. Most of the bottom was exposed, except for small puddles left in cattle tracks and the pond remained essentially dry during the summer of 1968.

Consecutive samples, 5 cm in length from 25 cm to 550 cm, were taken

| Depth<br>in cm      | Collins<br>and<br>Wehr <sup>a</sup><br>1965 | C14<br>dates<br>years | Description<br>of<br>sediments |                        |
|---------------------|---|-----------------------|--------------------------------|------------------------|
| 30.5                | <br>missing<br>                             |                       | Watery<br>brown<br>muck        |                        |
| 61.0 <sup>b</sup>   |   |                       |                                |                        |
| 91.5                |   |                       |                                |                        |
| 122.0               |   |                       |                                |                        |
| 152.5               |   |                       |                                | Solid<br>brown<br>muck |
| 183.0               |   |                       |                                |                        |
| 213.5               |   |                       |                                |                        |
| 244.0               |   |                       |                                |                        |
| 274.5               |   |                       | 270-<br>280 cm                 | 2,460 ± 100 B. P.      |
| 305.0               |   |                       |                                |                        |
| 335.5               |   |                       |                                |                        |
| 427.0               |   |                       |                                |                        |
| 457.5               |   |                       |                                |                        |
| 488.0               |   |                       |                                |                        |
| 518.5               |   |                       |                                |                        |
| 549.0               |   |                       |                                |                        |
| 579.5               |   |                       | 575-<br>585 cm                 | 5,800 ± 130 B. P.      |
| 610.0               |   |                       |                                | Snail shells           |
| 640.5 <sup>b</sup>  |   |                       |                                |                        |
| 671.0               |   |                       | 665-<br>675 cm                 | 8,670 ± 130 B. P.      |
| 701.5               |   |                       | Soft and<br>sandy              |                        |
| 732.0               |   |                       | Snails                         |                        |
| 762.5               |   |                       |                                |                        |
| 793.0               |   |                       | Becoming<br>gray               |                        |
| 823.5               |   |                       |                                |                        |
| 854.0 <sup>b</sup>  |   |                       |                                |                        |
| 884.5               |   |                       |                                |                        |
| 915.0 <sup>b</sup>  |   |                       |                                |                        |
| 945.5 <sup>b</sup>  |   |                       |                                |                        |
| 976.0               |   |                       |                                |                        |
| 1006.5              |   |                       |                                |                        |
| 1037.0 <sup>b</sup> |   | 1035-<br>1040 cm      | 12,700 ± 200 B. P.             |                        |
| 1067.5 <sup>b</sup> |   |                       | Blue-gray<br>clay-like         |                        |

<sup>a</sup> 6 inches (15.25 cm) of every foot (30.5 cm) was sampled

<sup>b</sup> Levels not studied

Figure 3. Core from Little Miller's Bay

in June, 1966 (Figure 4). Since the corer could not be forced deeper it was assumed it was hitting stones in the glacial till. Later attempts reached depths of 800 cm, and it now seems that the first core may have been stopped by a buried log. Samples taken in August, 1967, extended from 250 cm to 800 cm in 10 cm segments. The samples were stored in plastic bags.

I am confident the 2.8 m horizontal distance between core sites has no effect on the stratigraphy of the core material because the depth to certain sharply defined levels in the sediments was almost identical in both core locations. This site is called the Kettle Hole in this thesis and abbreviated K. H. in some tables and figures.

When coring was in progress in Lake West Okoboji in 1965 samples were obtained for radiocarbon age determination at the 679.5 cm and the 1037.0 cm depths. In the spring of 1968 additional funds for radiocarbon dating were made available by Dr. Roger Bachman, from the Department of Zoology and Entomology, Iowa State University. Samples were then obtained from the 260 cm and 670 cm depths in the sediments of Little Miller's Bay (Figure 3). Kettle Hole sediments obtained at that time from depths of 275 cm, 335 cm, 495 cm and 675 cm were also dated (Figure 4). The radiocarbon ages of these samples were determined by Isotopes Inc., Westwood, New Jersey.

Several techniques were used to prepare the sediments for diatom study. The samples from the Lake core were all cleaned with 30% hydrogen peroxide and potassium dichromate (Van der Werff, 1958) while several methods were used for the Kettle Hole samples. One technique was that developed by Dr. John D. Dodd (unpublished) in which sediment samples are

| Depth<br>in cm | Wehr <sup>a</sup><br>1966<br>25-500<br>cm | Collins <sup>a</sup><br>1967<br>250-800<br>cm | C <sup>14</sup><br>dates<br>years | Description<br>of<br>sediments            | Levels<br>studied<br>cm               |                |
|----------------|---|---|-----------------------------------|---|---------------------------------------|----------------|
| 0              |   |   |                                   |   |                                       |                |
| 25             |   |   |                                   |   | 25                                    |                |
| 50             |   |   |                                   |   | 50                                    |                |
| 75             |   |   |                                   |   |                                       |                |
| 100            |   |   |                                   |   | 100                                   |                |
| 125            |   |   |                                   |   | Black<br>muck                         |                |
| 150            |   |   |                                   |   |                                       |                |
| 175            |   |   |                                   |   |                                       |                |
| 200            |   |   |                                   |   |                                       |                |
| 225            |   |   |                                   |   |                                       |                |
| 250            |   |   |                                   | 270-<br>280 cm                            | 4,880 ±<br>110 B. P.                  | Sandy          |
| 275            |   |   |                                   |   | Trans. to brown<br>organic            | 315<br>335     |
| 300            |   |   |                                   |   |                                       |                |
| 325            |   |   |                                   | 340-<br>350 cm                            | 9,100 ±<br>150 B. P.                  |                |
| 350            |   |   |                                   |   |                                       |                |
| 375            |   |   |                                   |   |                                       |                |
| 400            |   |   |                                   |   | Brown<br>organic<br>(wood<br>present) | 410            |
| 425            |   |   |                                   |   |                                       |                |
| 450            |   |   |                                   |   |                                       |                |
| 475            |   |   |                                   | 490-<br>500 cm                            | 10,310 ±<br>180 B. P.                 | Watery<br>gray |
| 500            |   |   |                                   |   |                                       |                |
| 525            |   |   |                                   |   |                                       |                |
| 550            |   |   |                                   |   |                                       |                |
| 575            |   |   |                                   |   |                                       |                |
| 600            |   |   |                                   | Gray-brown<br>(wood fragments<br>present) | 630                                   |                |
| 625            |   |   |                                   |   |                                       |                |
| 650            |   |   |                                   |   |                                       |                |
| 675            |   |   | 690-<br>700 cm                    | 12,400 ±<br>170 B. P.                     | Gray<br>sandy                         |                |
| 700            |   |   |                                   |   |                                       |                |
| 725            |   |   |                                   |   |                                       |                |
| 750            |   |   |                                   |   |                                       |                |
| 775            |   |   |                                   |   |                                       |                |
| 800            |   |   |                                   |   |                                       |                |

<sup>a</sup>Continuous core

Figure 4. Cores from Arends' Kettle Hole

treated with a macerating agent followed by ammonium hydroxide and then separated into two parts. One part is used for diatom studies; the other is further treated for the study of pollen. Certain samples treated in this manner required additional cleaning. The hydrogen peroxide technique was then used, or in some cases, the sulfuric acid method as described by Patrick and Reimer (1966).

Since the siliceous part of the diatom cell wall utilized for taxonomic purposes is impervious to the strong oxidants used, it is assumed that the diatom population is unaffected by different cleaning methods. However, it is possible that procedures for removing oxidizing agents may have an effect on the population. The beaker in which oxidation is accomplished is filled with distilled water which is then decanted after the inorganic remains and the diatom frustules have settled. More water is added and decanted until the solution is neutral as tested with litmus paper if acid cleaning was used. Following hydrogen peroxide cleaning enough dilution to remove the color of the potassium dichromate is required. The minimum settling interval is rather critical since it is possible to decant very small, or planktonic, forms if this is done too soon. I used a minimum settling period of four hours, a schedule followed at the Academy of Natural Sciences of Philadelphia (Dr. C. W. Reimer, personal communication). I also centrifuged and examined the decanted material several times to check for diatoms, always with negative results. Setty (1966) discusses the problems associated with cleaning fossil diatoms and describes several useful adaptations of the basic techniques described above.

Andrews (1966) was aware of the problem of removal of small forms by decanting and systematically investigated the effect of different settling periods. He found that very small individuals of Fragilaria construens var. venter required at least 8 hours of settling in 150 ml beakers. Not being interested in determining an unbiased population he decanted his material at shorter time intervals in an attempt to remove small diatoms which thus "allowed a more accurate estimate of the relative abundance of the larger species and varieties." This argument does not appear valid even for the determination of relative abundance. He mentions that these slides were also useful for photography with which I can agree. However, very thin preparations are equally useful for that purpose.

For microscopic examination several drops of water containing the cleaned material was added to a clean 22 x 22 mm coverslip, no. 1 thickness, on a warming tray set at 50°C. The water was allowed to evaporate and the coverslip was then heated to 250°C for several minutes to drive off all trapped water. It was then inverted in a drop of Hyrax (R. I. 1.65) mounting medium on a glass slide. The slide was gently heated to evaporate the solvent, cooled, and labelled.

Diatom slides from sediments ideally should contain sufficient numbers that approximately 500 frustules can be observed in one tranverse of the coverslip with a 1.3 N. A. objective. However, the presence of inorganic detritus not removed by the cleaning process often made it necessary to use more dilute preparations in order to observe individual diatoms clearly. With such preparations it was often necessary to count many rows

to find approximately 500 frustules. This situation arose primarily when the obscuring detritus was very small, on the size order of 0.01-0.50 microns. When the detritus was larger, 0.10-1.0 microns, it was found that the slides could be made somewhat thicker since the diatoms would settle among the particles and be readily identifiable. In the samples from the Lake core only the 640.5 cm, 854.0 cm, and 915.0 cm depths were found impossible to count due to this problem (Figure 3). The Kettle Hole samples were much worse in this respect. In fact, it was only with great difficulty that counts were made from ten of the samples at this site (Figure 4).

The process of sampling the diatom populations was accomplished by identifying and counting approximately 500 frustules at each level. This number was arrived at after consultation with Dr. David Jowett at the Iowa State Statistical Laboratory. The taxa found, number of each observed, and the total number counted in each level is given in Appendix B (Figure 12). All counting and taxonomic determinations were made with a Leitz Laborlux microscope equipped with a 1.32 N. A. fluorite objective and an oil immersion condenser.

It was assumed that the cleaned material would settle randomly on the coverslip. It was important, therefore, to dry the coverslips slowly to avoid a "winnowing" effect, which could, to some extent, sort the diatoms by size. The density of material did not effect the relative population count as long as all diatom valves could be identified. Even though diatom distribution was probably random on the coverslip, I attempted to eliminate any possible effect on distribution by counting only entire rows

from near the middle of the coverslip. By counting in this manner any biasing effect present would be consistent for the whole study.

#### Application of Orloci's Ordination Technique

There are several possible methods of abstracting the information contained in the population counts. In a similar study (Collins, 1964), I prepared graphs of those species that composed more than 5 per cent of the population at any one level in the core. The same method was followed by Colingsworth (1965, 1967) in a continuation of that investigation. In this manner one could follow population trends of the dominant species. This technique ignores taxa that occur in low numbers but may appear and disappear in the diatom floras at different levels in, it must be assumed, response to changes in the environment, and thus may be effective indicator species.

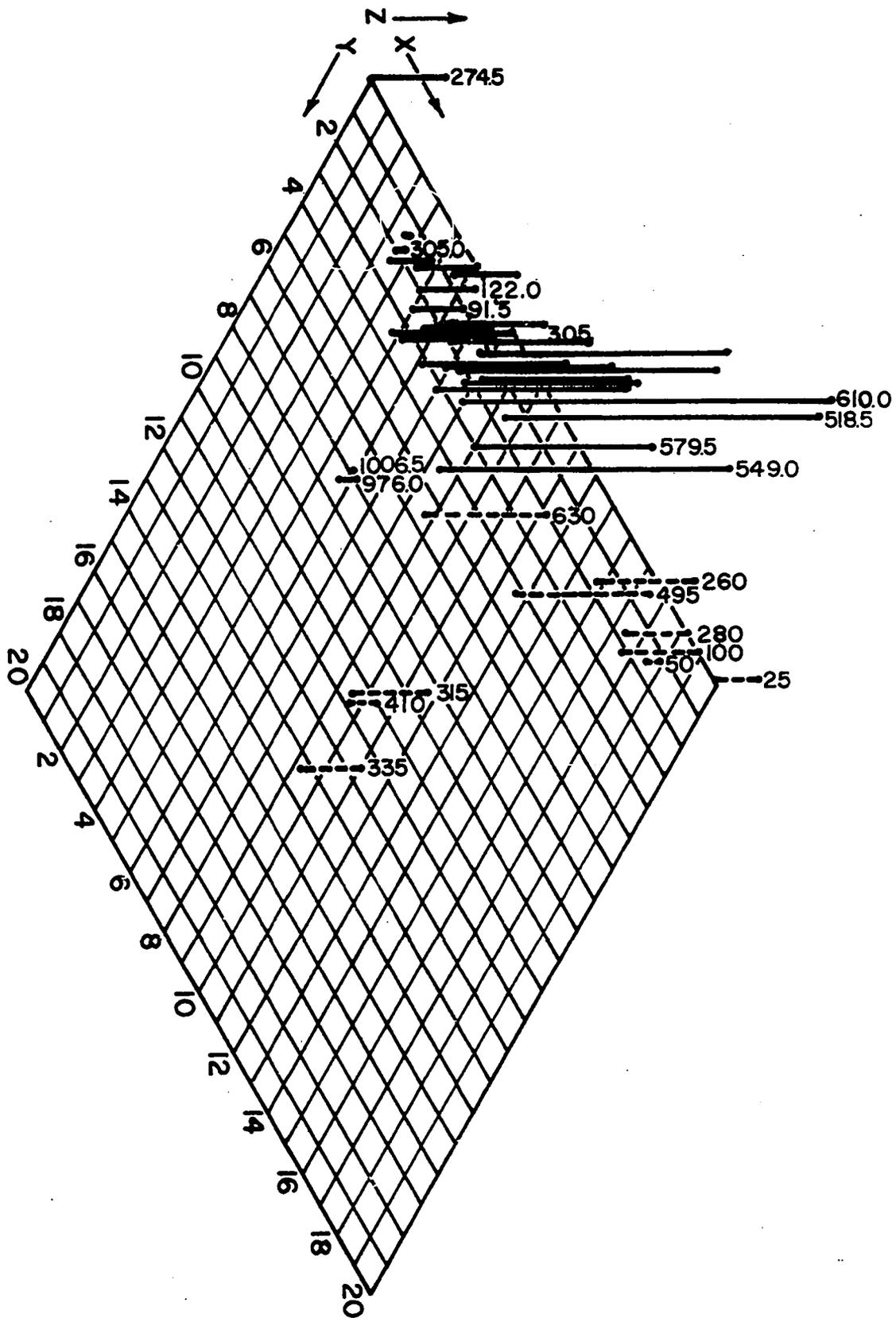
The amount of time involved in obtaining samples, preparing slides, learning the diatom floras, and becoming cognizant of the appropriate taxonomic and ecological literature, precluded the analyses of duplicate samples. Taxonomic problems were further complicated by the changes in floras from level to level in the cores. Often adjacent layers were so different that a whole new flora had to be identified. More subtle changes existed between every layer that were not readily apparent. A technique utilizing both frequency and occurrence but not requiring duplicate samples was needed to summarize the information gathered. Several ordination methods that could arrange both the levels and the species with respect to their similarity have been developed for similar ecological problems (Bray and Curtis, 1957; Curtis, 1955; Dix and Butler, 1960). The method

of Orloci (1966) was suggested by Dr. David Jowett as being most applicable to the present data.

To determine whether or not the ordination might work in practice it was decided to ordinate all levels studied from both sites and see if the technique would separate the sites. Mr. Roger Mrachek, a research assistant working under the direction of Dr. Jowett, wrote the program for the I. B. M. 360/65 computer. The levels of the Lake and Kettle Hole cores were clearly arranged in two separate groups by the analysis (Figure 5) and the method was, therefore, deemed satisfactory for my data.

By this technique the entities to be ordinated, levels or taxa, are arranged as points in a multidimensional space with their positions being determined by their attribute scores. In the case of levels, for example, these are determined by the frequency of each taxon in each level. Consider the first step in this process as a two dimensional graph on which the number of individuals observed of species A and B in level one are used to establish a point. If species C is added to the graph on an axis perpendicular to the first two axes, a point can then be established in three dimensional space. This is continued mathematically for all species producing an array of points in a multidimensional space. To summarize the information content of these points in multidimensional space, the points are projected into a space having fewer dimensions than the original. This process is continued until all points are located in a three dimensional space and the coordinate values of the points are given in the output of the computer program. (Tables 1 - 4). Information is lost in summarizing since distortion occurs as the points are projected into lower dimensional space. The points (species or levels) are

Figure 5. Ordination of levels from the Kettle Hole (----) and Lake (—) cores.  
Numbers are depths in cm.



nevertheless arranged in a manner that the mind can grasp and the similarities between them are clearly shown.

The technique was used to ordinate the levels in the cores from each site and the species from each site. This made it possible to determine both the depths in the core which are different from the rest and the species that caused those depths to be different. These species can quite unequivocally be called statistical indicator species.

To identify these taxa the coordinates for each were plotted on three two-dimensional graphs. These graphs of the x-y, x-z, and y-z planes were prepared on 17 x 22 inch graph paper ruled in inches and tenths of inches. Points, representing species, that occurred in one inch squares containing four or less points were considered outlying points. These points were recorded for all three planes and arranged into three groups; those outlying in all three planes (primary indicator species), those outlying in two planes (secondary indicator species) and those outlying in one plane (tertiary indicator species).

To dampen the effects of somewhat unequal population counts it was deemed necessary to transform them to the common log +1 of the actual number counted. Although an attempt was made to count very nearly 500 frustules the actual count varied from 444 to 761 in the Lake and 430 to 626 in the Kettle Hole. Actual counts were transformed to natural log +1 in the ordination program.

## RESULTS AND DISCUSSION

A total of 253 taxa was observed to occur in sediments of the Kettle Hole and Little Miller's Bay. During population counts, 210 of these were encountered on slides from the Lake, and 112 on slides from the Kettle Hole. Eighty-eight occurred at both sites. In the Lake the largest number of taxa found in one level was 61 at 823.5 cm, the smallest number was 41 at 976.0 cm. Forty-nine taxa were found in the 495 cm level of Kettle Hole, the largest number, and 18 at the 335 cm level, the smallest number.

The ages of the four levels dated from each site are given in Appendix A (Table 5). The amount of organic carbon in the 690-700 cm sample from the Kettle Hole first sent to Isotopes Inc. for dating was insufficient for an accurate analysis and additional material had to be obtained. The report of the age of this level was further delayed by difficulties encountered during the analysis. The population graphs (Figure 9) were based on data which included a preliminary analysis for this level, which indicated the age to be near 12,000 years B. P. The correct final age determined was 12,400 years B. P. Because of this the extrapolated age for the 630 cm level of the Kettle Hole is about 300 years older than indicated by Figure 9. Corrected values are used in the text.

### Taxonomic Section

Preliminary surveys of slides from both sites in which identifications were made of all taxa observed, allowed the development of a working knowledge of the floras. Due to the size of the samples, some of the

less common taxa observed in this preliminary work were not encountered during the population counts. In the Kettle Hole core, floras at some levels differed so drastically that many identifications had to be made during the counts. It is probable that throughout the roughly 12,500 year span of time involved, more than the recorded 112 taxa from the Kettle Hole and 210 taxa from Little Miller's Bay lived at each site. The 500 frustule counts made, however, can be considered valid samples of the diatom flora existing when the sediments were laid down.

The following section is an alphabetical list of genera and species within each genus. This arrangement is considered preferable to a systematic arrangement as followed by Stoermer (1963) and Ohl (1965) and has been used in recent large floristic studies (Hohn and Hellerman, 1963) primarily for ease in later use of the work. The description and illustration on which each identification was based is given along with other pertinent comments on occurrence or taxonomy.

#### ACHNANTHES Bory

##### Achnanthes clevei Grun.

Patrick and Reimer, Diatoms of U. S. p. 267. pl. 17, fig. 21-22.

This taxon was found in low numbers but in nearly every level of the upper half of the Lake core and in separated levels in the lower half. It was only observed at the 280 cm level in the Kettle Hole core.

##### Achnanthes clevei var. rostrata Hust.

Patrick and Reimer, Diatoms of U. S. p. 267. pl. 17, fig. 23-24.

This taxon was found at the 274.5 cm, 396.5 cm, and 457.5 cm levels in the Lake, always in low numbers. It was not observed in Kettle Hole material.

Achnanthes conspicua A. Mayer

Hustedt, in Pascher, p. 202. fig. 291.

This species was found at the 183.0 cm and 488.0 cm levels in the Lake core and was not observed on slides from the Kettle Hole.

Achnanthes deflexa Reim.

Patrick and Reimer, Diatoms of U. S. p. 256. pl. 16, fig. 18-20.

One valve of this taxon was observed at the 518.5 cm level in the Lake and two valves at the 25 cm level in the Kettle Hole. The taxon has not previously been recorded from Iowa.

Achnanthes exigua Grun.

Patrick and Reimer, Diatoms of U. S. p. 257. pl. 16, fig. 21-22.

This taxon was found in the three uppermost, the 579.5 cm, 610.0 cm, 701.5 cm, 732.0 cm, and the two deepest levels in the Lake core. It was observed only in the deepest level of the Kettle Hole core.

Achnanthes exigua var. heterovalvata Krasske

Patrick and Reimer, Diatoms of U. S. p. 258. pl. 16, fig. 25-26.

This taxon was found at the 213.5 cm, 244.0 cm, 274.5 cm levels in the Lake and at the 315 cm, 335 cm, and 410 cm levels of the Kettle Hole core.

Achnanthes haukiana Grun.

Patrick and Reimer, Diatoms of U. S. p. 267. pl. 17, fig. 25-32.

This taxon was found in all levels of the Lake core except the 305.0 cm, 335.5 cm, 396.5 cm, 427.0 cm, 488.0 cm, 518.5 cm, and 549.0 cm levels. It was found in the 260 cm, 495 cm, and 630 cm levels of the Kettle Hole core.

Achnanthes hungarica (Grun.) Grun.

Patrick and Reimer, Diatoms of U. S. p. 259. pl. 16, fig. 27-28.

This species was only observed in the 315 cm level of the Kettle Hole core.

Achnanthes lanceolata (Br eb.) Grun.

Patrick and Reimer, Diatoms of U. S. p. 269. pl. 18, fig. 1-10.

This taxon was found in all levels of the Lake core but 396.5 cm and 762.5 cm. At the Kettle Hole site it was observed at the 260 cm, 280 cm, 315 cm, 495 cm and 630 cm levels.

Achnanthes lanceolata var. dubia Grun.

Patrick and Reimer, Diatoms of U. S. p. 271. pl. 18, fig. 11-15.

This taxon was found at 183.0 cm, 213.5 cm, 762.5 cm in the Lake and at 335 cm and 410 cm in the Kettle Hole.

Achnanthes lewisana Patr.

Patrick and Reimer, Diatoms of U. S. p. 266. pl. 17, fig. 19-20.

This species was found only in the top four levels of the Lake core composing approximately five percent of the population at the 122.0 cm level.

Achnanthes microcephala (Kütz.) Grun.

Patrick and Reimer, Diatoms of U. S. p. 250. pl. 16, fig. 1-2.

This species was found only at the 549.0 cm, 579.5 cm, and 762.5 cm levels in the Lake core.

Achnanthes minutissima Kütz.

Patrick and Reimer, Diatoms of U. S. p. 253. pl. 16, fig. 9-10.

This species was observed at most levels of the Lake core and at the 50 cm, 335 cm, and 630 cm levels in the Kettle Hole.

Achnanthes pinnata Hust.

Patrick and Reimer, Diatoms of U. S. p. 266. pl. 17, fig. 17-18.

This entity was found at the 30.5 cm, 244.0 cm, and 1006.5 cm levels of the Lake core.

AMPHICAMPA Ehrenberg ex RalfsAmphicampa mirabilis Ehr. ex Ralfs

Patrick and Reimer, Diatoms of U. S. p. 161. pl. 9, fig. 8-9.

This is a rare taxon for which Patrick and Reimer (1966) list the United States distribution as Nebraska and California. It was originally described from fossil material from Mexico. I found this diatom only in the Kettle Hole and only in the top level.

AMPHIPLEURA KützingAmphipleura pellucida Kütz.

Patrick and Reimer, Diatoms of U. S. p. 303. pl. 21, fig. 2a-b.

Valves of the species were observed only at the 183.0 cm and

579.5 cm levels of the Lake core.

AMPHIPRORA Ehrenberg

Amphiprora ornata Bailey

Hustedt, in Pascher, p. 338. fig. 626.

This diatom was observed in the preliminary survey of slides from the core of the Lake at the 30.5 cm and 396.5 cm levels. Fragments of this taxon were found throughout the upper part of the Lake core while counts were being made but a specimen intact enough to be counted was never observed.

AMPHORA Ehrenberg

Amphora ovalis Kutz.<sup>"</sup>

Hustedt, in Pascher, p. 342. fig. 628.

This taxon was observed in most of the levels in the upper half of the Lake core and in the 823.5 cm and 884.5 cm levels. It was only observed at the 50 cm level of the Kettle Hole core.

Amphora ovalis var. affinis (Kutz.) V. H.<sup>"</sup>

Van Heurck, Synopsis, pl. 1, fig. 2.

This entity was found at every level of the Lake core and at all but the 335 cm level of the Kettle Hole core. This taxon appears under the name A. ovalis var. libyca (Ehr.) Cl. in Stoermer (1963) and Ohl (1965).

Amphora ovalis var. pediculus (Kutz.) V. H.<sup>"</sup>

Hustedt, in Pascher, p. 343. fig. 629.

This variety was found in all but the 579.5 cm level of the Lake core. It occurred at the 410 cm and 630 cm levels of the Kettle Hole core.

Amphora sabyii Salah

Salah, Hydrobiologia, 7(1/2) p. 99. pl. 2, fig. 10.

This identification can only be regarded as tentative. Salah (1955) states that A. sabyii has "delicate, scarcely visible striae." My specimens do not show striae at all. In other respects my specimens seem to be identical with this taxon. It was found at the 488.0 cm, 701.5 cm, and 884.5 cm levels of the Lake core and the 410 cm and 495 cm levels of the Kettle Hole core.

Amphora veneta Kütz.

Hustedt, in Pascher, p. 345. fig. 631.

This taxon was observed at the top level, and most of the levels in the lower half of the lake core. It was found at the 495 cm level of the Kettle Hole.

Amphora sp. 1.

One valve of this entity was observed at the 100 cm level of the Kettle Hole core.

ANOMOEONEIS Pfitzer

Anomoeoneis sphaerophora (Ehr.) Pfitz.

Patrick and Reimer, Diatoms of U. S. p. 374. pl. 32, fig. 1.

This diatom was found at the 427.0 cm, 610.0 cm, 732.0 cm,

762.5 cm, and 976.0 cm of the Lake core. In the Kettle Hole site it was observed at the 280 cm and 495 cm levels.

Anomoeoneis sphaerophora var. sculpta O. Mill.

Patrick and Reimer, Diatoms of U. S. p. 375. pl. 32, fig. 2.

This taxon was observed at the 396.5 cm level in the Lake core and the 260 cm level of Kettle Hole core.

Anomoeoneis vitrea (Grun.) Ross in Patrick and Reimer

Patrick and Reimer, Diatoms of U. S. p. 380. pl. 33, fig. 12-13.

This species was found only in the Kettle Hole at the 315 cm and 630 cm levels.

ASTERIONELLA Hassall

Asterionella formosa Hass.

Patrick and Reimer, Diatoms of U. S. p. 159. pl. 9, fig. 1-3.

This diatom was found only in the Lake at the 183.0 cm, 396.5 cm, 610.0 cm, and 701.5 cm levels.

CALONEIS Cleve

Caloneis bacillum (Grun.) Cl.

Patrick and Reimer, Diatoms of U. S. p. 586. pl. 54, fig. 8.

This taxon occurred at several levels of the Lake core, always in small numbers, and seems not to show any particular pattern of occurrence. In the Kettle Hole it was found at the 25 cm, 280 cm, and 495 cm levels.

Caloneis lewisii Patr.

Patrick and Reimer, Diatoms of U. S. p. 588. pl. 54, fig. 11.

This taxon was found only in the upper four levels of the Kettle Hole core.

Caloneis limosa (Kütz.) Patr.

Patrick and Reimer, Diatoms of U. S. p. 587. pl. 54, fig. 10.

Only one valve of this taxon was found at the 884.5 cm level of the Lake core.

Caloneis ventricosa (Ehr.) Meist.

Patrick and Reimer, Diatoms of U. S. p. 583. pl. 54, fig. 3.

This species was observed at the 91.5 cm and 610.0 cm levels in the Lake core. It was found at the 25 cm, 50 cm, 260 cm, and 335 cm levels of the Kettle Hole core.

Caloneis ventricosa var. subundulata (Grun.) Patr.

Patrick and Reimer, Diatoms of U. S. p. 584. pl. 54, fig. 4.

This taxon was only found at the 701.5 cm level of the Lake core.

Caloneis sp. 1.

Only one valve of this taxon was observed at the 91.5 cm level of the Lake core. A search of the literature failed to produce a suitable identification.

COCCONEIS EhrenbergCocconeis disculus (Schum.) Cl.

Patrick and Reimer, Diatoms of U. S. p. 239. pl. 15, fig. 1-2.

This taxon was observed at the 457.5 cm and 884.5 cm levels of the Lake core.

Cocconeis pediculus Ehr.

Patrick and Reimer, Diatoms of U. S. p. 240. pl. 15, fig. 3-4.

This taxon was observed at the 91.5 cm, 152.5 cm, 213.5 cm, and 274.5 cm levels of the Lake core.

Cocconeis placentula var. lineata (Ehr.) V. H.

Patrick and Reimer, Diatoms of U. S. p. 242. pl. 15, fig. 5-6.

While making preliminary surveys of slides from the Lake core and during the first several levels counted, I carefully separated the pseudoraphe valves of this taxon into C. placentula Ehr., C. placentula var. euglypta (Ehr.) Cl., and C. placentula var. lineata (Ehr.) V. H. The raphe valves were counted separately since they are identical for all the varieties. My intention was to apportion the raphe valves among the varieties as indicated by the counts of the pseudoraphe valves. It soon became clear that in the populations I was observing no valid separation could be maintained between the varieties. The majority of the specimens observed always fit the description of C. placentula var. lineata (Ehr.) V. H. I considered the varieties of C. placentula Ehr. to be morphologic variations around the typical member of this complex, C. placentula var. lineata (Ehr.) V. H. This taxon was found at all levels of the Lake core and occasionally composed 50 per cent of the population. It was found in all but the 50 cm, 280 cm, and 410 cm levels of the

Kettle Hole core but it never made up such a large part of the populations as in the Lake.

CYCLOTELLA <sup>"</sup>Kützing

Cyclotella bodanica Eulenstein

Hustedt, in Pascher, p. 103. fig. 76.

This taxon was found at all levels between 183.0 cm and 427.0 cm as well as the 549.0 cm, 610.0 cm, and 701.5 cm of the Lake core. At a few levels it approached ten per cent of the population.

Cyclotella kutzingiana Thwaites

Hustedt, in Pascher, p. 99. fig. 62.

This species was found at several levels in the lower half of the Lake core.

Cyclotella meneghiniana <sup>"</sup>Kütz.

Hustedt, in Pascher, p. 100. fig. 67.

The taxon was found at the 152.5 cm, 610.0 cm, 793.0 cm, 823.5 cm, and 884.5 cm levels of the Lake core.

Cyclotella ocellata Pant.

Hustedt, in Pascher, p. 99. fig. 68.

This taxon was only observed in the two deepest levels of the Lake core.

Cyclotella striata <sup>"</sup>(Kütz.) Grun.

Hustedt, in Pascher, p. 99. fig. 71.

This species was found at the 610.0 cm, 732.0 cm, and 762.5 cm

in the Lake core and the 335 cm, 410 cm, and 495 cm levels of the Kettle Hole core.

CYMATOPLEURA Wm. Smith

Cymatopleura elliptica (Bréb.) Wm. Smith

Hustedt, in Pascher, p. 426. fig. 825.

This taxon was found only at the 396.5 cm and 457.5 cm levels of the Lake core.

Cymatopleura solea (Bréb.) Wm. Smith

Hustedt, in Pascher, p. 425. fig. 823a.

This taxon was observed at the 91.5 cm, 427.0 cm, 457.5 cm, 488.0 cm, 610.0 cm, 671.0 cm, 701.5 cm, 762.5 cm, 793.0 cm and 823.5 cm levels of the Lake core.

CYMBELLA Agardh

Cymbella aspera (Ehr.) Cl.

Hustedt, in Pascher, p. 365. fig. 680.

This taxon was found only at the 823.5 cm level of the Lake core.

Cymbella cistula (Hemprich.) Grun.

Hustedt, in Pascher, p. 363. fig. 676a.

This taxon was found at all depths of the Lake core but the 305.0 cm, 335.5 cm, 396.5 cm, 549.0 cm, and 884.5 cm levels.

Cymbella cistula var. maculata (Kutz.) V. H.

Van Heurck, Synopsis, pl. 2, fig. 16-17.

This variety was observed at the 183.0 cm, 305.0 cm, 335.5 cm, and 823.5 cm levels of the Lake core. It was found only at the 495 cm level of the Kettle Hole core.

Cymbella cuspidata "Kutz.

Hustedt, in Pascher, p. 357. fig. 650.

This species occurred at many levels in the Lake core.

Cymbella ehrenbergii "Kutz.

Hustedt, in Pascher, p. 356. fig. 656.

This taxon is in particular need of careful taxonomic study. The existing problems seem to stem from lack of knowledge as to the range of variability exhibited. Populations from core material may provide the most effective method of establishing the range of variability. It was found in the 91.5 cm, 122.0 cm, 152.5 cm, 305.0 cm, 457.5 cm, and 1006.5 cm levels of the Lake core.

Cymbella mexicana (Ehr.) Cl.

A. S. A., pl. 10, fig. 32. and A. S. A., pl. 71, fig. 82.

This taxon was found at the 122.0 cm, 183.0 cm, 244.0 cm, 274.5 cm, 335.5 cm, 366.0 cm, 793.0 cm, and 823.5 cm levels of the Lake core.

Cymbella microcephala Grun.

Hustedt, in Pascher, p. 351. fig. 637.

This species was found at nine levels of the Lake core, in three groups, centered around the 152.5 cm, 579.5 cm, and 793.0 cm levels.

Cymbella muelleri Hust.

Hustedt, Albert Parc., p. 115. pl. 9, fig. 1-7.

This taxon was never abundant but occurred at several levels of the Lake core and the 50 cm and 495 cm levels of the Kettle Hole core.

Cymbella obtusiuscula Kutz.<sup>"</sup>

Hustedt, in Pascher, p. 352. fig. 640.

This entity was observed at the 610.0 cm and 762.5 cm levels of the Lake core.

Cymbella parvula Krasske

Hustedt, Archiv. f. Hydrobiol, 40(4):938. pl. 42, fig. 60-62.

This taxon was found in the two deepest levels of the Lake core.

Cymbella rhomboidea Boyer

Boyer, Philad., p. 63. pl. 18, fig. 11.

This taxon was observed only at the 823.5 cm level of the Lake core. I compared my specimens with the holotype (Boyer slide #243) with which they match very well. While working on this identification I looked at C. triangulatum (Ehr.) Cl. on Boyer slide #G-7-17. It appears that C. triangulatum is a small form of C. rhomboidea.

Cymbella ruttneri Hust.

A. S. A., pl. 373. fig. 39-44.

This taxon was found in the 30.5 cm, 122.0 cm, 152.5 cm, 183.0 cm, and 213.5 cm levels of the Lake core.

Cymbella turgida (Greg.) Cl.

Hustedt, in Pascher, p. 362. fig. 670.

This taxon was observed only during the preliminary survey at the 30.5 cm level of the Lake core.

Cymbella ventricosa Ag.

Hustedt, in Pascher, p. 359. fig. 661.

This species occurred in several levels near the middle of the Lake core, as well as the top five and two deepest levels of the Kettle Hole core.

Cymbella sp. 1

This small taxon proved to be unnamed after a thorough search of the literature. It was found at the 183.0 cm, 213.5 cm, 244.0 cm, and 366.0 cm levels in the Lake core.

Cymbella sp. 2.

This taxon was found in the three deepest levels of the Lake core. It was not identifiable with the literature available at Iowa State University but I feel it will not prove to be a new taxon when the literature can be more thoroughly searched.

DIPLONEIS EhrenbergDiploneis oculata (Bréb.) Cl.

Patrick and Reimer, Diatoms of U. S. p. 412. pl. 38, fig. 6.

This taxon was observed during the preliminary survey at the 427.0 cm level of the Lake core.

Diploneis ovalis var. oblongella (Naegeli) Cl.

Hustedt, in Pascher, p. 249, fig. 391 and Van Heurck, Synopsis, pl. 10, fig. 12.

This taxon was observed at the 488.0 cm and 518.5 cm levels of the Lake core.

EPITHEMIA BrébissonEpithemia intermedia Fricke

Hustedt, in Pascher, p. 387. fig. 732.

This taxon was found at the 671.0 cm level of the Lake core during the preliminary survey.

Epithemia sorex Kutz.

Hustedt, in Pascher, p. 388. fig. 736.

This species was found at many levels of the Lake core, most commonly near the middle, but single valves were observed in levels near either end.

Epithemia turgida (Ehr.) Kutz.

Hustedt, in Pascher, p. 387. fig. 733.

This taxon was found in nearly all levels of the Lake core and at the 280 cm and 495 cm levels of the Kettle Hole core.

Epithemia zebra (Ehr.) Kutz.

Van Heurck, Synopsis, pl. 3, fig. 5.

This taxon was only observed at the 518.5 cm level of the Lake core.

Epithemia zebra var. porcellus (Kutz.) Grun.

Hustedt, in Pascher, p. 385. fig. 731.

This variety was found at nearly all levels of the Lake core except those between 274.5 cm and 396.5 cm. It was also found in the deepest level of the Kettle Hole core.

Epithemia zebra var. saxonica (Kutz.) Grun.

Hustedt, in Pascher, p. 385. fig. 730.

This taxon was observed at several levels near the middle of the Lake core and at the 260 cm, 410 cm, and 495 cm levels of the Kettle Hole core.

EUNOTIA EhrenbergEunotia curvata (Kutz.) Lagerst.

Patrick and Reimer, Diatoms of U. S. p. 189. pl. 10, fig. 4.

One valve of this taxon was found at the 671.0 cm level of the Lake core. It was found in the top four levels of the Kettle Hole.

Eunotia pectinalis var. minor (Kutz.) Rabh.

Patrick and Reimer, Diatoms of U. S. p. 207. pl. 12, fig. 13-14.

This taxon was found at the 518.5 cm level of the Lake core and the 25 cm, 280 cm, and 495 cm levels of the Kettle Hole core.

Eunotia praerupta Ehr.

Patrick and Reimer, Diatoms of U. S. p. 193. pl. 10, fig. 14.

This species was found in the top five levels of the Kettle Hole core.

FRAGILARIA LyngbyeFragilaria brevistriata Grun.

Patrick and Reimer, Diatoms of U. S. p. 128. pl. 4, fig. 14.

This taxon was found at all levels of the Lake core often comprising a major part of the population. It was found at all levels of the Kettle Hole but 25 cm, 50 cm, and 280 cm.

Fragilaria capucina Desm.

Patrick and Reimer, Diatoms of U. S. p. 118. pl. 3, fig. 5.

This species was recorded at the 152.5 cm, 244.0 cm, 366.0 cm, and 396.5 cm levels of the Lake core.

Fragilaria capucina var. mesolepta Rabh.

Patrick and Reimer, Diatoms of U. S. p. 119. pl. 3, fig. 6.

This taxon was in general found throughout the Lake core except the deepest five levels.

Fragilaria construens (Ehr.) Grun.

Patrick and Reimer, Diatoms of U. S. p. 125. pl. 4, fig. 4.

This taxon is extremely variable. Work in progress on large populations of this taxon from the 315 cm, 335 cm, and 410 cm levels of the Kettle Hole core, representing a 2,000 year time span, suggest that many of the accepted varieties are not distinct entities but part of the taxon itself. Other varieties seem to fit the genus Opephora. In the population counts all valves having an angular shape with striae finer than 12 per 10 microns were considered F.

construens. Valves showing slight asymmetry, intermeshing striae of 11 per 10 microns or less and a smoothly rounded shape were considered to be Opephora ansata Hohn and Hell. The two following varieties seem distinct and were retained. F. construens was found, in general, throughout the length of the Lake core except for the 488.0 cm to 701.5 cm interval. It was found in all levels of the lower half of the Kettle Hole core.

Fragilaria construens var. binodis (Ehr.) Grun.

Patrick and Reimer, Diatoms of U. S. p. 125. pl. 4, fig. 7.

This variety seems to be distinct from the large, variable, F. construens complex. It was found at the 366.0 cm and 396.5 cm levels of the Lake core.

Fragilaria construens var. pumila Grun.

Patrick and Reimer, Diatoms of U. S. p. 126. pl. 4, fig. 5-6.

This taxon also does not seem to merge into the F. construens complex. It was found at the 335 cm, 410 cm, and 630 cm levels of the Kettle Hole core.

Fragilaria crotonensis Kitton

Patrick and Reimer, Diatoms of U. S. p. 121. pl. 3, fig. 11-12.

This long and rather delicate form is probably under-represented in the population counts due to breakage of the frustules. It was found at many levels throughout the length of the core.

Fragilaria crotonensis var. oregona Sov.

Patrick and Reimer, Diatoms of U. S. p. 122. pl. 3, fig. 13.

This taxon was found at the 335.5 cm, 579.5 cm, and 762.5 cm levels of the Lake core.

Fragilaria lapponica Grun.

Patrick and Reimer, Diatoms of U. S. p. 130. pl. 4, fig. 17.

This species was found at the 244.0 cm, 274.5 cm, 366.0 cm, 762.5 cm, 823.5 cm, 976.0 cm, and 1006.5 cm levels of the Lake core.

It made up over ten per cent of the population at the 1006.5 cm level.

Fragilaria pinnata Ehr.

Patrick and Reimer, Diatoms of U. S. p. 127. pl. 4, fig. 10.

This taxon was found in most levels of the upper half and the lower quarter of the Lake core. It was found at the 260 cm level and the four deepest levels of the Kettle Hole core.

Fragilaria pinnata var. lancettula (Schum.) Hust.

Patrick and Reimer, Diatoms of U. S. p. 128. pl. 4, fig. 12.

This variety was found at the 335.5 cm and 823.5 cm levels of the Lake core.

Fragilaria vaucheriae (Kutz.) Peters.

Patrick and Reimer, Diatoms of U. S. p. 120. pl. 3, fig. 14-15.

This species was found at all but the 213.5 cm and 488.0 cm levels of the Lake core.

Fragilaria virescens Ralfs

Patrick and Reimer, Diatoms of U. S. p. 119. pl. 3, fig. 7-9.

This taxon was found at all but the 335 cm level of the Kettle Hole core. It composed over 25 per cent of the population at several

levels.

Fragilaria sp. 1

This taxon could not be satisfactorily identified. I suspect the valves I found are slightly aberrant forms of a described taxon. It was found at the 122.0 cm and 152.5 cm levels of the Lake core.

GOMPHONEMA Agardh

Gomphonema acuminatum Ehr.

Hustedt, in Pascher, p. 370. fig. 683.

This taxon was found at several widely separated levels in the Lake core and the 100 cm, 260 cm, 280 cm, and 495 cm levels in the Kettle Hole core.

Gomphonema acuminatum var. brebissonii (Kutz.) Grun.

Hustedt, in Pascher, p. 370. fig. 685.

This taxon was found only in the Kettle Hole in the upper five levels and the 410 cm level.

Gomphonema acuminatum var. coronata (Ehr.) Wm. Smith

Hustedt, in Pascher, p. 370. fig. 684.

This variety was found only at the 630 cm level of the Kettle Hole core.

Gomphonema angustatum var. sarcophagus (Greg.) Grun.

Hustedt, in Pascher, p. 373. fig. 691.

This taxon was observed at the 488.0 cm and 884.5 cm levels of the Lake core. It was found in the upper five levels and the 495 cm

level of the Kettle Hole core.

Gomphonema constrictum var. capitatum (Ehr.) Grun.

Hustedt, in Pascher, p. 377. fig. 715.

This variety was only observed at the 579.5 cm level of the Lake core.

Gomphonema gallaudi Herib.

Heribaud, Diatomees D'Auvergne. Vol. 3. p. 63. pl. 13, fig. 19.

This taxon has never been reported from the United States. Moreover, a thorough search of the literature indicates that this entity has never been reported other than in the original description. It is interesting to note that it was described from fossil material. This species was observed only in the Kettle Hole at the 50 cm, 100 cm, 260 cm, 280 cm, and 410 cm levels. My specimens were compared with type material on Tempere and Peragallo slides #740 and #741. The variation in length observed on these slides was 32-61 microns. Only the very largest specimens exhibited the three isolated puncts as shown in the original illustration. The smaller specimens had two puncts. Specimens from the Kettle Hole core varied in length from 32-47 microns. The larger of these specimens possess three isolated puncts while the smaller usually have two. Occasional specimens from both my samples and the Tempere and Peragallo slides would exhibit somewhat different morphology on the two frustules of a given cell. The most striking difference in this respect was striae count, which occasionally was 8 per 10 microns on one frustule and 14 per 10 microns on the other. The more usual situation when this difference in

morphology existed was 10-11 striae per 10 microns on one frustule and 7-8 on the other. Many of the cells exhibiting this variation in morphology between valves showed another feature not mentioned in the original description. One valve may possess two puncts while the other may have three.

Gomphonema gracile Ehr.

Hustedt, in Pascher, p. 376. fig. 702.

This entity was observed in widely separated levels in both the Lake and Kettle Hole cores.

Gomphonema intricatum<sup>11</sup> Kutz.

Hustedt, in Pascher, p. 375. fig. 697.

This species was found in nearly all levels of the Lake core. It was observed in the top three and lower two levels of the Kettle Hole core.

Gomphonema intricatum var. pumila Grun.

Hustedt, in Pascher, p. 375. fig. 699.

This taxon was found in nearly all levels of the Lake core, its largest numbers being in the upper levels where it composed ten per cent of the population at the 122.0 cm level. It was also observed at the 410 cm and 495 cm levels of the Kettle Hole core.

Gomphonema intricatum var. 1

This taxon seems to be quite distinct but a population was never found. The one valve found at the 762.5 cm level of the Lake core may prove to be a post auxospore cell of the species.

Gomphonema mexicanum Grun.

Van Heurck, Synopsis, pl. 24. fig. 3.

This taxon was found at several widely separated levels of the Lake core and the 495 cm level of the Kettle Hole core.

Gomphonema olivaceum (Lyngb.) Kutz.

Hustedt, in Pascher, p. 378. fig. 719.

This species was found at the 91.5 cm, 183.0 cm, all levels between 335.5 cm and 488.0 cm, 671.0 cm, and 701.5 cm levels of the Lake core.

Gomphonema parvulum Kutz.

Hustedt, in Pascher, p. 372. fig. 713a

This taxon was observed in several widely separated levels of the Lake core and in the 25 cm, 100 cm, 260 cm, and 495 cm levels of the Kettle Hole core.

Gomphonema sphaerophorum Ehr.

Hustedt, in Pascher, p. 372. fig. 695.

This species was found in three widely separated levels in both the Lake and Kettle Hole cores.

Gomphonema sp. 1

This very distinct taxon is probably undescribed. Specimens were found at the 244.0 cm, 671.0 cm, 701.5 cm, and 884.5 cm levels of the Lake core.

GOMPHONEIS CleveGomphoneis eriense (Grun.) Skv.

Stoermer, Rare and Little Known Iowa Diatoms. p. 60. pl. 4, figs. 4-5.

This species was found in the 274.5 cm, 366.0 cm, and 671.0 cm levels of the Lake core.

GYROSIGMA Hassall

Gyrosigma attenuatum (Kutz.) Rabh.

Patrick and Reimer, Diatoms of U. S. p. 319. pl. 24, fig. 1.

This taxon was found generally in the upper half and at separated levels near the bottom of the Lake core.

Gyrosigma spencerii (Quek.) Griff and Henfr.

Patrick and Reimer, Diatoms of U. S. p. 315. pl. 23, fig. 4.

This taxon was commonly observed in levels of the upper half of the Lake core.

HANTZSCHIA Grunow

Hantzschia amphioxys (Ehr.) Grun.

Hustedt, in Pascher, p. 394. fig. 747.

This taxon was observed in widely separated levels of the Lake core.

Hantzschia amphioxys var. capitata (O. Mull.) Hust.

Hustedt, in Pascher, p. 394. fig. 748.

This variety was more common than the nominate variety being found in many levels of the lower half of the Lake core and several

separated levels in the upper part of the Lake core.

MASTOGOLIA Thwaites ex Wm. Smith

Mastogloia grevillei Wm. Smith

Patrick and Reimer, Diatoms of U. S. p. 298. pl. 20, fig. 8-9.

This entity was observed at the 457.5 cm and 1006.5 cm levels of the Lake core.

Mastogloia smithii var. lacustris Grun.

Patrick and Reimer, Diatoms of U. S. p. 300 pl. 20, fig. 12-13.

This variety was found at several widely separated levels in the Lake core.

MERIDION Agardh

Meridion circulare (Grev.) Ag.

Patrick and Reimer, Diatoms of U. S. p. 113. pl. 2, fig. 15.

This taxon was found in the 427.0 cm and 701.5 cm levels of the Lake core.

MELOSIRA Agardh

Melosira ambigua (Grun.) O. Mull.<sup>"</sup>

Hustedt, in Pascher, p. 89, fig. 49.

This taxon was observed only at the 884.5 cm level in the Lake core.

Melosira granulata (Ehr.) Ralfs

Hustedt, in Pascher, p. 87, fig. 9-16.

This diatom composed a major part of the populations being absent only from the 13 foot layer in the Lake and the 50 cm and 335 cm layers in the Kettle Hole. This taxon composed approximately 20 per cent of the population at the 549.0 cm level in the Lake and also the 260 cm level in the Kettle Hole.

NAVICULA Bory

Navicula americana Ehr.

Patrick and Reimer, Diatoms of U. S. p. 493. pl. 47, fig. 3.

This taxon was observed at the 213.5 cm level in the Lake and the 25 cm and 100 cm levels in the Kettle Hole.

Navicula amphibola Cl.

Patrick and Reimer, Diatoms of the U. S. p. 445. pl. 39. fig. 7-8.

This taxon was observed at the 25 cm, 50 cm, 100 cm and 280 cm levels in the Kettle Hole.

Navicula anglica Ralfs

Hustedt, in Pascher, p. 303. fig. 530-531.

This diatom was found at the 915.5 cm level, scattered through the middle levels, and at the 823.5 cm level in the Lake core.

Navicula anglica var. signata Hust.

Hustedt, F., Ber. Deutsch. Bot. Ges., 61(5); 287, pl. 8, fig. 26.

This variety was not observed during the population counts but was found during the preliminary survey at the 396.5 cm level in the

Lake core.

Navicula aurora Sov.

Patrick and Reimer, Diatoms of U. S. p. 532. pl. 51, fig. 3-4.

This taxon was found only at the 1006.5 cm level in the Lake core.

Navicula bacillum Ehr.

Patrick and Reimer, Diatoms of U. S. p. 494. pl. 47, fig. 4-5.

This species was found at the 274.5 cm and 488.0 cm levels in the Lake and the 50 cm level in the Kettle Hole.

Navicula biconica Patr.

Patrick and Reimer, Diatoms of U. S. p. 496. pl. 44, fig. 8.

This taxon was found at the 549.0 cm and 793.0 cm levels in the Lake core.

Navicula capitata Ehr.

Patrick and Reimer, Diatoms of U. S. p. 536. pl. 52, fig. 1-2.

This species was found at the 427.0 cm, 518.5 cm, 762.5 cm, 793.0 cm, and 823.5 cm levels of the Lake core.

Navicula capitata var. hungarica (Grun.) Ross

Patrick and Reimer, Diatoms of U. S. p. 537. pl. 52, fig. 3.

This taxon was rather generally distributed throughout the Lake core.

Navicula cincta (Ehr.) Ralfs

Patrick and Reimer, Diatoms of U. S. p. 516. pl. 49, fig. 8.

This species was found from the 183.0 cm through the 396.5 cm levels in the Lake core and at the 495 cm level in the Kettle Hole.

Navicula clementis Grun.

Patrick and Reimer, Diatoms of U. S. p. 521. pl. 49, fig. 22.

This species was found at the 213.5 cm, 335.5, and 488.0 cm levels in the Lake core.

Navicula cocconeiformis Greg. ex Grev.

Patrick and Reimer, Diatoms of U. S. p. 451. pl. 41, fig. 5.

This taxon was observed only at the 274.5 cm level in the Lake core.

Navicula confervacea (Kutz.) Grun.

Patrick and Reimer, Diatoms of U. S. p. 476. pl. 45, fig. 9.

This taxon was observed at the 610.0 cm and 701.5 cm levels in the Lake and the 25 cm, 260 cm, and 280 cm levels in the Kettle Hole.

Navicula confervacea var. peregrina (Wm. Smith) Grun.

Patrick and Reimer, Diatoms of U. S. p. 476. pl. 45, fig. 10.

This taxon was not observed during the population counts but was found in the preliminary survey at the 610.0 cm level in the Lake and the 495 cm level in the Kettle Hole.

Navicula cryptocephala var. veneta (Kutz.) Rabh.

Patrick and Reimer, Diatoms of U. S. p. 504. pl. 48, fig. 5.

This taxon occurred in the uppermost several layers, was not

found from the 244.0 cm through the 366.0 cm levels, then reappeared from the 396.5 cm through the 518.5 cm levels in the Lake core. It was found in the Kettle Hole at the 315 cm and 630 cm levels.

Navicula cuspidata " " (Kutz.) Kutz.

Patrick and Reimer, Diatoms of U. S. p. 464. pl. 43, fig. 9-10.

This taxon occurred at several levels in both the Lake and Kettle Hole cores.

Navicula cuspidata var. heribaudii Peragallo

Hustedt, in Rabenhorst, p. 60, fig. 1207.

This taxon was found at the 518.5 cm level in the Lake core and the 100 cm and 260 cm levels in the Kettle Hole core. One cell was found in the Kettle Hole material during the preliminary survey in which one valve was of the nominate variety while the other valve was of the variety heribaudii. Further investigation may prove that this variety is within the morphological range of the nominate variety.

Navicula cuspidata var. major Meist.

Patrick and Reimer, Diatoms of U. S. p. 465. pl. 44, fig. 1.

This taxon was found only during the preliminary survey at the 335.5 cm level in the Lake core.

Navicula elginensis (Greg.) Ralfs

Patrick and Reimer, Diatoms of U. S. p. 524. pl. 50, fig. 3.

This species was found at the 91.5 cm level and scattered through the bottom levels of the Lake core. It was found in the Kettle Hole

except at the 315 cm, 335 cm, and 410 cm levels. Specimens of this taxon exhibit an unusual spacing of the striae in which the space between striae is considerably broader than the striae themselves.

Navicula elginensis var. rostrata (A. Mayer) Patr.

Patrick and Reimer, Diatoms of U. S. p. 526. pl. 50, fig. 6.

This taxon was observed at the 30.5 cm level in the Lake core during the preliminary survey.

Navicula exigua var. capitata Patr.

Patrick and Reimer, Diatoms of U. S. p. 522. pl. 49, fig. 24.

This taxon was found in the 366.0 cm and 732.0 cm levels of the Lake core.

Navicula explanta Hust.

Patrick and Reimer, Diatoms of U. S. p. 526. pl. 50, fig. 7.

This species was observed at the 274.5 cm and 305.0 cm levels in the Lake core and the 315 cm level in the Kettle Hole core.

Navicula globosa Meist.

Hustedt, in Rabenhorst, p. 222. fig. 1339.

This taxon was found at the 315 cm, 335 cm, 410 cm, and the 495 cm levels in the Kettle Hole core. It made up more than 5 per cent of the population in the upper three of the levels listed. To the best of my knowledge this is the first report of this taxon from North America.

Navicula graciloides A. Mayer

Patrick and Reimer, Diatoms of U. S. p. 516. pl. 49, fig. 9-10.

This taxon was found in every level of the Lake core except the 579.5 cm level. At each of the following levels, 30.5 cm, 91.5 cm, 122.0 cm, 152.5 cm, 274.5 cm, 305.0 cm, and 884.5 cm, it made up more than 5 per cent of the population. It was also observed in the Kettle Hole core at the 495 cm level.

Navicula halophila (Grun.) Cl.

Patrick and Reimer, Diatoms of U. S. p. 467. pl. 44, fig. 4.

This taxon was found in widely scattered levels of the Lake core and at the 495 cm level in the Kettle Hole core.

Navicula helensis Schulz

Hustedt, in Rabenhorst, p. 179. fig. 1314.

This taxon was found at the 274.5 cm level in the Lake core.

Navicula heufleri Grun.

Patrick and Reimer, Diatoms of U. S. p. 515. pl. 49, fig. 6.

This species was found at widely scattered levels throughout the Lake core and at the 260 cm level of the Kettle Hole core.

Navicula heufleri var. leptocephala (Bréb. ex Grun.) Patr.

Patrick and Reimer, Diatoms of U. S. p. 515. pl. 49, fig. 7.

This taxon was found from the 549.0 cm to the 793.0 cm levels and at the 884.5 cm level. It composed approximately 5 per cent of the population at the 762.5 cm level.

Navicula ilopangoensis Hust.

Patrick and Reimer, Diatoms of U. S. p. 529. pl. 50, fig. 14.

This taxon was only found at the 183.0 cm level in the Lake core.

Navicula integra var. 1

My specimens differ from the nominate variety primarily by having a large central area. The striae bordering the central area are short and marginal, being clearly visible only with oblique light. This taxon was found only at the 732.0 cm level of the Lake core.

Navicula laevissima Kutz.

Patrick and Reimer, Diatoms of U. S. p. 497. pl. 47, fig. 13.

This species occurred in the 30.5 cm and 122.0 cm levels and rather generally throughout the bottom two-thirds of the Lake core. In the Kettle Hole it was found at the 25 cm, 100 cm, 280 cm, 335 cm, and 410 cm depths.

Navicula latens Krasske

Patrick and Reimer, Diatoms of U. S., p. 521. pl. 49, fig. 21.

This species was observed at the 884.5 cm level of the Lake core.

Navicula minima Grun.

Patrick and Reimer, Diatoms of U. S., p. 488. pl. 46, fig. 17-18.

This taxon was observed at the 884.5 cm level in the Lake and the 315 cm level in the Kettle Hole core.

Navicula minima var. pseudofossilis (Krasske) Reim.

Reimer, C. W., Notulae Naturae 397:6, pl. 1, fig. 17.

This taxon was found during the preliminary survey at the 315 cm

level of the Kettle Hole core.

Navicula mournei Patr.

Patrick and Reimer, Diatoms of U. S., p. 461. pl. 43, fig. 5.

This taxon was observed at the 976.0 cm and 1006.5 cm levels of the Lake core and the 335 cm and 410 cm levels of the Kettle Hole core.

Navicula mutica Kütz.

Patrick and Reimer, Diatoms of U. S., p. 454. pl. 42, fig. 2.

This taxon occurred irregularly through the bottom half of the Lake core and at the 25 cm and 495 cm levels of the Kettle Hole core.

Navicula mutica var. cohnii (Hilse) Grun.

Patrick and Reimer, Diatoms of U. S., p. 454. pl. 42, fig. 3.

This taxon was found at the 335.5 cm, 549.0 cm, 762.5 cm, 793.0 cm, and 1006.5 cm levels of the Lake core. In the Kettle Hole it was observed at the 50 cm, 100 cm, and 410 cm depths.

Navicula mutica var. undulata (Hilse) Grun.

Patrick and Reimer, Diatoms of U. S., p. 456. pl. 42, fig. 6-9.

This variety was only observed at the 427.0 cm level in the Lake core.

Navicula oblonga (Kütz.) Kütz.

Patrick and Reimer, Diatoms of U. S., p. 534. pl. 51, fig. 6.

This species was found rather generally throughout all levels of the Lake core and at the 495 cm level of the Kettle Hole core.

Navicula oppugnata Hust.

Hustedt, F., Archiv F. Hydrobiol., 43(3/4):351, pl. 37, fig. 38-41.  
1950.

This diatom was found at 366.0 cm, 396.5 cm, 518.5 cm, 579.5 cm,  
and 762.5 cm levels of the Lake core.

Navicula perventralis Hust.

Hustedt, in Rabenhorst, p. 224, fig. 1342.

This species was only found in the 30.5 cm level of the Lake  
core.

Navicula placentula (Ehr.) Kütz.

Patrick and Reimer, Diatoms of U. S., p. 523. pl. 50, fig. 1.

This diatom was found at the 183.0 cm, 457.5 cm, and 823.5 cm  
levels of the Lake core.

Navicula platycephala O. Mull.

Hustedt, Albert Parc., p. 351. pl. 37, fig. 38-41.

This taxon was found at the 30.5 cm, 122.0 cm, 152.5 cm, 335.5  
cm, and 457.5 cm levels of the Lake core. My specimens tend to be  
shorter than those illustrated by Hustedt but the characteristic  
change in striae direction quite clearly delineates this taxon.

Navicula pseudoventralis Hust.

Hustedt, in Rabenhorst, p. 153. fig. 1285.

This taxon was found at the 30.5 cm, 122.0 cm, 976.0 cm, and  
1006.5 cm levels of the Lake core and the 315 cm, 410 cm, and 495 cm

levels of the Kettle Hole core. It made up more than 5 per cent of the population at all three levels in the Kettle Hole.

Navicula pupula <sup>"</sup>Kust.

Patrick and Reimer, Diatoms of U. S., p. 496. pl. 47, fig. 7.

This taxon observed in the Kettle Hole at the 50 cm, 100 cm, 260 cm, and 315 cm levels.

Navicula pupula var. mutata (Krasske) Hust.

Patrick and Reimer, Diatoms of U. S., p. 496. pl. 47, fig. 9-10.

This species was observed at the 488.0 cm, 701.5 cm, and 762.5 cm levels of the Lake core.

Navicula pupula var. rectangularis (Greg.) Grun.

Patrick and Reimer, Diatoms of U. S., p. 497. pl. 47, fig. 12.

This taxon was found in a few separated levels near the top and bottom and at every layer through the middle of the Lake core. It was found at the 315 cm and 495 cm levels in the Kettle Hole core.

Navicula pupula var. rostrata Hust.

Hustedt, in Pascher, p. 282, fig. 467e.

This diatom was not found during the population counts but was observed during the preliminary survey at the 30.5 cm level.

Navicula pygmaea <sup>"</sup>Kutz.

Patrick and Reimer, Diatoms of U. S., p. 442. pl. 39, fig. 4.

This entity was observed at the 183.0 cm, 305.0 cm, 366.0 cm, 488.0 cm, and 884.5 cm levels in the Lake core.

Navicula radiosa <sup>"</sup>Kutz.

Patrick and Reimer, Diatoms of U. S., p. 509. pl. 48, fig. 15.

This diatom was found at all levels of the Lake core except the 244.0 cm, 274.5 cm, 305.0 cm, 335.5 cm, 671.0 cm, 976.0 cm, and 1006.5 cm levels. In the Kettle Hole it was observed at the 25 cm and 260 cm levels.

Navicula radiosa var. tenella (Bréb. ex Kutz.) <sup>"</sup>Grun.

Patrick and Reimer, Diatoms of U. S., p. 510. pl. 48, fig. 17.

This taxon was found in several levels near the top, and at separated levels from the 457.5 cm to the 884.5 cm level of the Lake core.

Navicula reinhardtii (Grun.) Grun.

Patrick and Reimer, Diatoms of U. S., p. 517. pl. 49, fig. 12.

This species was found throughout the entire length of the core from the Lake.

Navicula rhynchocephala <sup>"</sup>Kutz.

Patrick and Reimer, Diatoms of U. S., p. 505. pl. 48, fig. 6.

I observed this diatom during counts of the 213.5 cm, 335.5 cm, 396.5 cm, and 488.0 cm levels of the Lake core.

Navicula rhynchocephala var. amphiceros (Kutz.) <sup>"</sup>Grun.

Patrick and Reimer, Diatoms of U. S., p. 505. pl. 48, fig. 7.

This taxon was found regularly in the upper half of the Lake core and also at the 793.0 cm and 884.5 cm levels.

Navicula salinarum var. intermedia (Grun.) Cl.

Patrick and Reimer, Diatoms of U. S., p. 503. pl. 48, fig. 2.

This taxon was observed at the 701.5 cm and 762.5 cm levels in the Lake core.

Navicula scutelloides Wm. Smith ex Greg.

Patrick and Reimer, Diatoms of U. S., p. 450. pl. 41, fig. 3.

This taxon was observed regularly in the upper half of the Lake core and at the 884.5 cm, 976.0 cm, and 1006.5 cm levels. It composed approximately 5 per cent of the population at the 91.5 cm, 274.5 cm, and 305.0 cm levels.

Navicula secura Patr.

Patrick and Reimer, Diatoms of U. S., p. 409. pl. 46, fig. 21.

The taxon was found only at the 579.5 cm level of the Lake core.

Navicula seminuloides Hust.

Hustedt, in Rabenhorst, p. 244, fig. 1369.

This taxon was found at the 305.0 cm, 475.5 cm, 884.5 cm, 976.0 cm, and 1006.5 cm levels in the Lake core. In the Kettle Hole it was observed at the 315 cm, 335 cm, 410 cm, and 495 cm depths. It made up approximately 5 per cent of the population at the 315 and 335 cm levels.

Navicula seminulum Grun.

Hustedt, in Rabenhorst, p. 241, fig. 1367.

I observed this species only at the 315 cm depth in the Kettle Hole core.

Navicula skabitschewskyi Kiselev

Zabelina, M. M., *Opredelitel Presnovodnyek Vodorosley, U. S. S. R.*,  
p. 279. 1951.

This diatom was found at 213.4 cm, 274.5 cm, 305.0 cm, and 396.5 cm levels in the Lake core. It was also found at the 495 cm level in the Kettle Hole core.

Navicula stroesii A. Cl.

Cleve-Euler, A., *Die Diatomeen von Schweden und Finnland III.*, p. 122,  
fig. 743. 1953.

I observed this taxon only at the 457.5 cm depth in the Lake core.

Navicula tantula Hust.

A. S. A., pl. 399, fig. 54-57.

This diatom was found only in the Kettle Hole core at the 100 cm, 335 cm, and 495 cm levels.

Navicula texana Patr.

Patrick and Reimer, *Diatoms of U. S.*, p. 445. pl. 39, fig. 9.

This diatom was found only at the 732.0 cm and 762.5 cm levels of the Lake core.

Navicula tripunctata (O. F. Mull.) Bory

Patrick and Reimer, *Diatoms of U. S.*, p. 513. pl. 49, fig. 3.

I observed this diatom at the 732.0 cm and 762.5 cm levels in the Lake and the 495 cm level in the Kettle Hole.

Navicula tuscula Ehr.

Patrick and Reimer, Diatoms of U. S., p. 539. pl. 52, fig. 7.

This taxon was found in the Lake core at the 152.5 cm and 396.5 cm levels.

Navicula tuscula var. 1

This taxon was observed in the Lake core at the 305.5 cm and 396.5 cm levels. It differs from the nominate variety in being slightly smaller and most importantly, in having striae composed of a double row of punctae for half of their length. In the nominate variety only the marginal portion of each striae is doubly punctate (See Patrick and Reimer, 1966).

Navicula tuscula var. 2

This entity was found only at the 274.5 cm level of the Lake core. It differs from the two preceding taxa in having striae composed of double rows of punctae for their entire lengths. Further investigations may show that these varieties are better considered as part of N. tuscula. I have not observed a large population in this study but the specimens observed seemed quite distinct and separable on the bases mentioned above.

Navicula whittrockii fo. cruciata Hust.

Hustedt, Arch. F. Hydrobiol. 10:94. 1914.

This taxon was found at the 50 cm, 100 cm, and 495 cm levels of the Kettle Hole core.

Navicula sp. 1

This taxon was observed at the 30.5 cm and 274.5 cm levels.

Navicula sp. 2

This taxon was observed only during the preliminary survey at the 396.5 cm level in the Lake core.

Navicula sp. 3

This very distinct entity was found in the Lake core at the 213.5 cm, 244.0 cm, 305.0 cm, 335.5 cm, and 396.5 cm levels. Apparently this is an undescribed taxon.

Navicula sp. 4

Many specimens of this taxon were found in the Lake core. It occurred at the 152.5 cm, 244.0 cm, 274.5 cm, 305.0 cm, 335.5 cm, 366.0 cm, 396.5 cm, 427.0 cm, 457.5 cm, 488.0 cm, 671.0 cm, 701.5 cm, 732.0 cm, 793.0 cm, 823.5 cm, and 976.0 cm levels. This also seems to be an undescribed taxon.

Navicula sp. 5

This taxon was found only at the 274.5 cm level in the Lake core.

Navicula sp. 6

This taxon was observed only in the 305.0 cm level of the Lake core.

Navicula sp. 7

This entity was found only at the 488.0 cm level of the Lake core.

Navicula sp. 8

This taxon was observed at the 30.5 cm and 518.5 cm levels of the Lake core.

Navicula sp. 9

This diatom was found at the 762.5 cm and 884.5 cm levels of the Lake core.

Navicula sp. 10

This taxon was observed only at the 30.5 cm level of the Lake core.

Navicula sp. 11

This diatom was found at the 976.0 cm and 1006.5 cm levels of the Lake core.

Neidium affine (Ehr.) Pfitz.

Patrick and Reimer, Diatoms of U. S., p. 390. pl. 35, fig. 2.

This taxon was found irregularly in the deeper levels of the Lake core and at two levels in the Kettle Hole core.

Neidium affine var. longiceps (Greg.) Cl.

Patrick and Reimer, Diatoms of U. S. p. 390. pl. 35, fig. 4.

This taxon was observed only at the 100 cm level in the Kettle Hole core.

Neidium affine var. undulatum (Grun.) Cl.

Patrick and Reimer, Diatoms of U. S. p. 393. pl. 35, fig. 7-8.

This taxon was observed only at the 50 cm level in the Kettle Hole core.

Neidium dubium (Ehr.) Cl.

Patrick and Reimer, Diatoms of U. S. p. 404. pl. 37, fig. 5.

This entity was observed only at the 244.0 cm level in the Lake core.

Neidium dubium fo. constrictum Hust.

Patrick and Reimer, Diatoms of U. S. p. 405. pl. 37, fig. 8.

This taxon was observed only at the 30.5 cm level in the Lake core.

Neidium iridis (Ehr.) Cl.

Patrick and Reimer, Diatoms of U. S. p. 386. pl. 34, fig. 1.

This diatom was recorded irregularly in the upper half of the Lake core and the three upper levels of the Kettle Hole core.

Neidium iridis var. ampliatum (Ehr.) Cl.

Patrick and Reimer, Diatoms of U. S. p. 388. pl. 34, fig. 5.

This taxon was observed during the preliminary survey at the 30.5 cm level of the Lake core. It was not observed during the population counts.

Neidium kozolowi Meresch.

Hustedt, in Pascher, p. 247, fig. 387.

This diatom was observed during the preliminary survey, at the 396.5 cm level in the Lake core. It was not observed during the population counts.

Neidium sp. 1

This entity was observed only at the 488.0 cm level during the population counts of the Lake core. Only one specimen was found.

NITZSCHIA Hassall

Nitzschia amphibia Grun.

Hustedt, in Pascher, p. 414, fig. 793.

This taxon was found in all levels of the Kettle Hole core and all but the 213.5 cm and 274.5 cm levels in the Lake core. In the Lake it gradually increased in frequency with depth to the 610.0 cm level where it composed about 18 per cent of the population. It then decreased gradually and only one specimen was observed in the count of the 1006.5 cm level. No particular trends are evident in the Kettle Hole populations although, it was a heavy dominant comprising about 30 per cent of the population at the 495 cm level.

Nitzschia angustata (Wm. Smith) Grun.

Hustedt, in Pascher, p. 402, fig. 767.

This diatom occurred only in the Lake core, mostly in the upper levels.

Nitzschia commutata Grun.

Hustedt, in Pascher, p. 405, fig. 774.

This taxon was only observed at the 823.5 cm layer of the Lake core.

Nitzschia denticula Grun.

Hustedt, in Pascher, p. 407, fig. 780.

This taxon was observed only at the 579.5 cm layer of the Lake core.

Nitzschia frustulum (Kütz.) Grun.

Hustedt, in Pascher, p. 414, fig. 795.

This taxon was observed at scattered depths throughout the length of both cores.

Nitzschia frustulum var. perminuta Grun.

Hustedt, in Pascher, p. 414, fig. 795.

This taxon occurred between the 518.5 cm and 762.5 cm levels of the Lake core except for the 671.0 cm layer.

Nitzschia gracilis Hantz.

Hustedt, in Pascher, p. 416, fig. 794.

This taxon was observed at the 213.5 cm, 579.5 cm, and 701.5 cm levels in the Lake core.

Nitzschia palea (Kütz.) Wm. Smith

Hustedt, in Pascher, p. 416, fig. 801.

A. S. A., pl. 349, fig. 1-10.

This taxon was observed only in the 488.0 cm level of the Lake

core.

Nitzschia sigmoidea (Nitz.) Wm. Smith

Hustedt, in Pascher, p. 419, fig. 810.

This taxon occurred irregularly in the upper half of the Lake core.

Nitzschia sublinearis Hust.

Hustedt, in Pascher, p. 411, fig. 786.

This taxon was observed only in the 488.0 cm level of the Lake core.

Nitzschia vermicularis (Kutz.) Grun.

Hustedt, in Pascher, p. 419, fig. 811.

This taxon was observed only at the 122.0 cm and 152.5 cm levels of the Lake core.

Nitzschia sp. 1

This taxon was found at scattered levels in the upper half of the Lake core. Valves of this entity appear to be rather fragile and did not preserve well.

OPEPHORA Petit

Opephora ansata Hohn and Hell.

Hohn and Hellerman, Three North American Rivers. p. 321. pl. 1, fig. 15.

This taxon occurred commonly through the Lake core being absent from only the 488.0 cm, 518.5 cm, and 610.0 cm levels. At several

levels it made up 5 per cent or more of the population. In the Kettle Hole it occurred at the 315 cm, 335 cm, 410 cm, and 630 cm levels where it made up at least 5 per cent of the population at each level. This diatom seems to be considerably more variable than is indicated in the original description. Shape varies from very short (6.6 microns) oval forms to the shape illustrated by Hohn and Hellerman. Some specimens lose the obvious asymmetry associated with the genus Opephora. The alternation of striae that become meshed toward the ends remains in all cases. Some of the shorter forms observed had 12 striae per ten microns. In most cases the lineate nature of the striae usually associated with this genus was visible. In those cases where it was not visible it was thought due to degradation of the frustule.

Opephora martyi Herib.

Patrick and Reimer, Diatoms of U. S. p. 115. pl. 3, fig. 3.

This taxon occurred commonly in the top half of the Lake core and in the three deepest levels. It did not occur in the Kettle Hole.

PINNULARIA Ehrenberg

Pinnularia appendiculata (Ag.) Cl.

Patrick and Reimer, Diatoms of U. S. p. 593. pl. 55, fig. 2.

This taxon occurred at the 518.5 cm and 976.0 cm levels of the Lake core and the 260 cm level of the Kettle Hole core.

Pinnularia borealis Ehr.

Patrick and Reimer, Diatoms of U. S. p. 618. pl. 58, fig. 13.

Only one specimen of this very distinctive diatom was observed, and this was at the 976.0 cm level of the Lake core.

Pinnularia brebissonii (Kütz.) Rabh.

Patrick and Reimer, Diatoms of U. S. p. 614. pl. 58, fig. 6.

This taxon was found at scattered levels in the upper portion, and at nearly every level of the lower half of the Lake core. In the Kettle Hole core it was observed regularly in the upper levels and less frequently in the deeper levels.

Pinnularia brevicostata Cl.

Patrick and Reimer, Diatoms of U. S. p. 623, pl. 60, fig. 1.

This taxon occurred in the four upper levels of the Kettle Hole core.

Pinnularia kneuckeri Hust.

Hustedt, Hydrobiologica, 2(1):50, fig. 22-32, 1949.

This entity was observed only at the 335.5 cm level of the Lake core.

Pinnularia obscura Krasske

Patrick and Reimer, Diatoms of U. S. p. 617. pl. 58, fig. 9.

This taxon occurred only at the 823.5 cm level of the Lake core.

Pinnularia stomatophora (Grun.) Cl.

Patrick and Reimer, Diatoms of U. S. p. 609. pl. 57, fig. 5.

This taxon was observed in the 427.0 cm level of the Lake core

and the 50 cm level of the Kettle Hole core.

Pinnularia streptoraphe Cl.

Patrick and Reimer, Diatoms of U. S. p. 639. pl. 64, fig. 4.

This taxon was found at the 25 cm, 50 cm, and 280 cm levels of the Kettle Hole core.

Pinnularia stricta Hust.

Hohn and Hellerman, Three North American Rivers. p. 325. pl. 5, fig. 22.

This taxon was found only at the 50 cm level of the Kettle Hole core.

Pinnularia subcapitata Greg.

Patrick and Reimer, Diatoms of U. S. p. 596. pl. 55, fig. 8-10.

This species only occurred at the 25 cm and 50 cm levels of the Kettle Hole core.

Pinnularia viridis (Nitz.) Ehr.

Patrick and Reimer, Diatoms of U. S. p. 639. pl. 64, fig. 5.

This taxon was observed at the 25 cm, 100 cm, 280 cm, and 630 cm levels of the Kettle Hole core.

RHOICOSPHENIA Grunow

Rhoicosphenia curvata (Kutz.) Grun. ex Rabh.

Patrick and Reimer, Diatoms of U. S. p. 282. pl. 20, fig. 1-5.

This taxon was found in nearly all levels of the upper half, and at widely separated intervals in the lower half of the Lake core.

Those specimens observed in the deeper levels of the core tended to be very large.

RHOPALODIA O. Müller

Rhopalodia gibba O. Müll.

Hustedt, in Pascher, p. 390, fig. 740.

This taxon occurred rather generally throughout the Lake core except the 244.0 cm and 335.5 cm levels. It was observed in the Kettle Hole at the 100 cm, 280 cm, and 410 cm levels.

Rhopalodia gibberula var. protracta Grun.

Hustedt, in Pascher, p. 391, fig. 743.

This taxon was found in four deep layers of the Lake core and the 50 cm level of the Kettle Hole core.

STAURONEIS Ehrenberg

Stauroneis acuta Wm. Smith

Patrick and Reimer, Diatoms of U. S. p. 367. pl. 31, fig. 1.

This taxon was observed at the 701.5 cm level of the Lake core and at the 100 cm, 280 cm, and 315 cm levels of the Kettle Hole core.

Stauroneis anceps Ehr.

Patrick and Reimer, Diatoms of U. S. p. 361. pl. 30, fig. 1.

This species was found in the 5 upper layers of the Kettle Hole core.

Stauroneis phoenicenteron (Nitz.) Ehr.

Patrick and Reimer, Diatoms of U. S. p. 359. pl. 29, fig. 1-2.

This taxon was observed at the 30.5 cm and 396.5 cm levels in the Lake core during the preliminary survey. It was observed only at the 213.5 cm level in the population counts. In the Kettle Hole this species was observed in the six top-most levels.

Stauroneis smithii var. 1

One specimen of this taxon was found in the 396.5 cm level of the Lake core. It differs from the nominate variety in having a wide but very thin stauros, distant median raphe ends, and in being more delicately constructed in general.

Stauroneis sp. 1

See Stoermer, E. F., Iowa Academy of Sci. Vol. 71. p. 65. pl. 2, fig. 9. Stoermer no longer accepts his identification of this taxon as Stauroneis acutiuscula Per. and Herib. (personal communication). The present taxon differs from S. acutiuscula in being larger (up to 40 microns) and having a very thick, narrow stauros. The stauros of S. acutiuscula is flared, being much wider at the margins than at the center of the valve while the stauros is the same width across the valve in this taxon. Stauroneis reichelti Heiden (A. S. A. 241, fig. 15-16) looks much like this taxon. I searched all the slides in the diatom herbarium of the Academy of Natural Sciences of Philadelphia that were from the type locality of S. reichelti, the Demerara river in British Guiana, but no specimens were found. In addition, as best one can determine from the original illustration, the striae

are about 40 per 10 microns while in this taxon they are 18-19 per 10 microns. I am convinced that this is a new taxon. This entity was found only at the 274.5 cm level during the population counts but during the preliminary survey it was observed at the 366.0 cm and 427.0 cm levels.

Stauroneis sp. 2

Only one specimen of this taxon was observed at the 495 cm level of the Kettle Hole core during the preliminary survey.

STEPHANODISCUS Ehrenberg

Stephanodiscus astraea (Ehr.) Grun.

Hustedt, in Pascher, p. 110, fig. 85.

This taxon was found only in the Lake core at the 274.5 cm, 305.0 cm, 335.5 cm, 457.5 cm, 488.0 cm, 518.5 cm, 549.0 cm, 610.0 cm, 762.5 cm, and 793.0 cm levels.

Stephanodiscus astraea var. minutula (Kutz.) Grun.

Hustedt, in Pascher, p. 110, fig. 86.

This diatom composed a major part of the diatom flora in the Lake core, being absent only from the 30.5 cm, 915.5 cm, 122.0 cm, 549.0 cm, and 1006.5 cm levels. At many levels it composed over 5 per cent of the population and at one, the 366.0 cm level, it composed approximately 35 per cent of the population.

Stephanodiscus hantzschii Grun.

Hustedt, in Pascher, p. 110, fig. 87.

This diatom was observed at the 30.5 cm level in the preliminary survey but was not found during the counts.

Stephanodiscus invisitatus Hohn and Hell.

Hohn and Hellerman, Three North American Rivers, p. 325. pl. 1, fig. 7.

This taxon is scattered in the upper half of the Lake core but is found in nearly every level in the bottom half. It composed about 12 per cent of the population at the 630 cm level in the Kettle Hole.

Stephanodiscus niagarae Ehr.

A. S. A., pl. 227, fig. 1-9.

This taxon is scattered throughout the upper half of the Lake core. It then reappears in the bottom three levels.

Stephanodiscus niagarae var. magnifica Fricke

A. S. A., pl. 227, fig. 12-13.

This taxon was observed in nearly every level in the top half of the core from the Lake.

SURIRELLA Turpin

Surirella biseriata var. bifrons (Ehr.) Hust.

Hustedt, in Pascher, p. 433. fig. 833.

This taxon was found at the 457.5 cm, 884.5 cm, and 1006.5 cm levels in the Lake core.

Surirella pinnata Wm. Smith

Van Heurck, Synopsis, pl. 73, fig. 12.

This taxon was found scattered through the lower half of the Lake core.

Surirella turgida Wm. Smith

Hustedt, in Pascher, p. 433. fig. 836.

This taxon was found at scattered levels through the middle of the Lake core.

SYNEDRA Ehrenberg

Synedra capitata Ehr.

Patrick and Reimer, Diatoms of U. S. p. 147. pl. 6, fig. 15.

This taxon was observed at scattered levels in the lower half of the core from the Lake.

Synedra delicatissima Wm. Smith

Patrick and Reimer, Diatoms of U. S. p. 136. pl. 5, fig. 2.

This diatom was found scattered through the upper levels of the Lake core.

Synedra parasitica (Wm. Smith) Hust.

Patrick and Reimer, Diatoms of U. S. p. 140. pl. 5, fig. 12.

This taxon was found in nearly all levels in the upper half and the 762.5 cm, 793.0 cm, 823.5 cm, and 884.5 cm levels near the bottom of the Lake core.

Synedra ulna (Nitz.) Ehr.

Patrick and Reimer, Diatoms of U. S. p. 148. pl. 7, fig. 1-2.

This taxon was found scattered throughout the length of the Lake core.

Synedra rumpens var. fragilarioides Grun.

Patrick and Reimer, Diatoms of U. S. p. 144. pl. 6, fig. 1.

This taxon was observed in several levels near the middle and at the 823.5 cm level of the Lake core.

TABELLARIA Ehrenberg

Tabellaria fenestrata (Lyngb.) Kütz.

Patrick and Reimer, Diatoms of U. S. p. 103. pl. 1, fig. 102.

This taxon was observed in several of the levels of the upper half of the Kettle Hole core during the preliminary survey. Most of the frustules were broken. During the population counts it was observed only at the 315 cm level.

## Ecology of Indicator Species

All primary, secondary and tertiary indicator species from both sites, as established by the ordination technique (see Methods), are listed in Tables 6-11. The ecological parameters previously associated with all of the primary, and selected secondary and tertiary indicator species, have been established from the literature. Many references are made to the ecological notes provided by Stoermer (1963) in his study of a core from the deepest part of Lake West Okoboji.

Achnanthes exigua var. heterovalvata Krasske

Primary from K. H., secondary from L. M. B.

A widely distributed lake form considered eurythermal, euryphotic and alkaliphilous (Patrick and Reimer, 1966). Stoermer (1963) discusses problems involved with determining relative abundance of this taxon when the nominate variety is also present in the population. I attempted to avoid this by counting all pseudoraphe valves and raphe valves separately and dividing the pseudoraphe valves proportionally between the taxa at the end of the count. Stoermer (loc. cit.) and Ohl (1965) reported this taxon as rare.

Amphora ovalis Kutz.

Primary from L. M. B.

Cosmopolitan form of epipelagic habit in eutropic, alkaline water. Stoermer (1963) reported it common from collections of bottom detritus in shallow water and better represented than most littoral species in core material. Ohl (1965) found this taxon much less common

Table 6. Primary indicator species - Lake Okoboji core

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|   |  |
|---|--|
| <u>Amphora ovalis</u> Kütz.                                   | <u>Melosira granulata</u> (Ehr.)<br>Ralfs                                  |
| <u>Amphora ovalis</u> var. <u>affinis</u><br>Kütz.            | <u>Navicula capitata</u> var.<br><u>hungarica</u> (Grun.) Ross             |
| <u>Amphora ovalis</u> var. <u>pediculus</u><br>Kütz.          | <u>Navicula cincta</u> (Ehr.) Ralfs  |
| <u>Cymbella cistula</u> (Hemprich)<br>Grun.                   | <u>Navicula cryptocephala</u> var.<br><u>veneta</u> (Kütz.) Rabh.          |
| <u>Cymbella ehrenbergii</u> Kütz.                             | <u>Navicula graciloides</u> A. Mayer                                       |
| <u>Cymbella</u> sp. 2   | <u>Navicula oblonga</u> (Kütz.) Kütz.                                      |
| <u>Epithemia zebra</u> var. <u>porcellus</u><br>(Kütz.) Grun. | <u>Navicula pseudoventralis</u> Hust.                                      |
| <u>Fragilaria brevistriata</u> Grun.                          | <u>Navicula pupula</u> var. <u>rectangu-</u><br><u>laris</u> (Greg.) Grun. |
| <u>Fragilaria capucina</u> var.<br><u>mesolepta</u> Rabh.     | <u>Opephora ansata</u> Hohn and Hell.                                      |
| <u>Fragilaria construens</u> (Ehr.)<br>Grun.                  | <u>Rhoicosphenia curvata</u> (Kütz.)<br>Grun. ex Rabh.                     |
| <u>Fragilaria vaucheriae</u> (Kütz.)<br>Peters.               | <u>Rhopalodia gibba</u> O. Müll.   |
| <u>Gomphonema intricatum</u> var.<br><u>pumila</u> Grun.      | <u>Stephanodiscus astraee</u> var.<br><u>minutula</u> (Kütz.) Grun.        |
|   | <u>Stephanodiscus invisitatus</u> Hohn<br>and Hell.                        |

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in farm ponds than variety affinis.

Amphora ovalis var. affinis Kütz.

Primary from L. M. B., and K. H.

Much of the same as the nominate variety. Common as an epiphyte of vascular plants in almost all farm ponds studied by Ohl (1965).

Table 7. Secondary indicator species - Lake Okoboji core

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|   |  |
|---|--|
| <u>Achnanthes clevei</u> Grun.                                | <u>Fragilaria lapponica</u> Grun.                  |
| <u>Achnanthes exigua</u> var.<br><u>heterovalvata</u> Krasske | <u>Fragilaria pinnata</u> Ehr.                     |
| <u>Achnanthes haukiana</u> Grun.                              | <u>Gomphonema intricatum</u> Kütz."                |
| <u>Achnanthes lanceolata</u> (Bréb.)<br>Grun.                 | <u>Gomphonema</u> sp. 1                            |
| <u>Achnanthes lewisana</u> Patr.                              | <u>Navicula halophila</u> (Grun.)<br>Cl.           |
| <u>Cocconeis placentula</u> var.<br><u>lineata</u> Ehr.       | <u>Navicula mournei</u> Patr.                      |
| <u>Cyclotella bodanica</u> Eulenstein                         | <u>Navicula radiososa</u> Kütz."                   |
| <u>Cymbella parvula</u> Krasske                               | <u>Navicula scutelloides</u><br>Wm. Smith ex Greg. |
| <u>Cymbella ruttneri</u> Hust.                                | <u>Nitzschia amphibia</u> Grun.                    |

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Stoermer (1963) reported it from the same habitats as the nominate variety but less common especially in fossil material.

Amphora ovalis var. pediculus Kütz."

Primary from L. M. B.

Widely distributed, Hustedt (1938) considers optimum habitat to be alkaline highly aerated water. Ohl (1965) reports it as infrequent in littoral regions of Iowa farm ponds on Wisconsin drift. Stoermer (1963) reports it in littoral collections of Lake Okoboji.

Cocconeis placentula var. lineata Ehr.

Secondary from L. M. B., primary from K. H.

A cosmopolitan eurytopous species in alkaline water, usually an

Table 8. Tertiary indicator species - Lake Okoboji core

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|  |  |
|--|--|
| <u>Achnanthes microcephala</u> (Kütz.) | <u>Navicula heufleri</u> var. <u>leptocephala</u> (Bréb. ex Grun.) Patr. |
| <u>Achnanthes minutissima</u> Kütz.    | <u>Navicula reinhardtii</u> (Grun.) Grun.                                |
| <u>Achnanthes pinnata</u> Hust.        | <u>Navicula</u> sp. 4  |
| <u>Achnanthes exigua</u> Grun.         | <u>Nitzschia vermicularis</u> (Kütz.) Grun.                              |
| <u>Fragilaria crotenensis</u> Kitton   | <u>Stephanodiscus niagarae</u> Ehr.                                      |
| <u>Gomphonema gracile</u> Ehr.         | <u>Synedra parasitica</u> (Wm. Smith) Hust.                              |
| <u>Gomphonema mexicanum</u> Grun.      | <u>Synedra ulna</u> (Nitz.) Ehr.   |
| <u>Gomphonema olivaceum</u> Grun.      |  |

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epiphyte (Patrick and Reimer, 1966). Reported by Ohl (1965) as being found in nearly all farm ponds studied and very common in one pond as an epiphyte on vascular plants and filamentous algae. Stoermer (1963) found it common and sometimes dominant in collections from aquatic vascular plants and filamentous algae in Lake Okoboji and also in the upper part of his core material.

Cyclotella bodanica Eulenstein

Secondary from L. M. B.

A form considered characteristic of subalpine lakes in Europe (Hustedt, 1930). Stoermer (1963) reported it as common in the lower levels<sup>1</sup> of the core and declining in frequency toward the surface.

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<sup>1</sup>A radiocarbon age of 4,000 years B. P. has been more recently established for the deepest level of that core (Stoermer, personal communication).

Table 9. Primary indicator species - Kettle Hole core

---

|   |   |
|---|---|
| <u>Achnanthes exigua</u> var.<br><u>heterovalvata</u> Krasske         | <u>Gomphonema constrictum</u> Ehr.                                |
| <u>Amphora ovalis</u> var. <u>affinis</u><br>Kütz.                    | <u>Gomphonema gallaudi</u> Herib.                                 |
| <u>Cocconeis placentula</u> var.<br><u>lineata</u> Ehr.               | <u>Gomphonema intricatum</u> var.<br><u>pumila</u> Grun.          |
| <u>Cymbella ventricosa</u> Agardh                                     | <u>Hantzschia amphioxys</u> var. <u>capitata</u> (O. Müll.) Hust. |
| <u>Eunotia curvata</u> (Kütz.)<br>Lagerst.                            | <u>Melosira granulata</u> (Ehr.)<br>Ralfs                         |
| <u>Eunotia praerupta</u> Ehr.   | <u>Navicula confervaceae</u> (Kütz.)<br>Grun.                     |
| <u>Fragilaria brevistriata</u><br>Grun.                               | <u>Navicula elginensis</u> (Greg.)<br>Ralfs                       |
| <u>Fragilaria construens</u> (Ehr.)<br>Grun.                          | <u>Navicula globosa</u> Meist.                                    |
| <u>Fragilaria construens</u> var.<br><u>pumila</u> Grun.              | <u>Navicula pseudoventralis</u> Hust.                             |
| <u>Fragilaria lapponica</u> Grun.                                     | <u>Navicula seminuloides</u> Hust.                                |
| <u>Fragilaria virescens</u> Ralfs                                     | <u>Navicula tantula</u> Hust.                                     |
| <u>Gomphonema acuminatum</u> var.<br><u>brebissonii</u> (Kütz.) Grun. | <u>Nitzschia amphibia</u> Grun.                                   |
| <u>Gomphonema angustatum</u> var.<br><u>sarcophagus</u> (Greg.) Grun. | <u>Opephora ansata</u> Hohn and Hell.                             |
|   | <u>Stephanodiscus invisitatus</u><br>Hohn and Hell.               |

---

It was rare in his collections of present-day diatoms.

Cymbella cistula (Hemprich) Grun.

Primary from L. M. B.

A widely distributed form in alkaline water (Hustedt, 1938). Stoermer (1963) reports it in littoral collections of Lake Okoboji while Ohl

Table 10. Secondary indicator species - Kettle Hole core

---

|   |                                     |
|---|-------------------------------------|
| <u>Fragilaria pinnata</u> Ehr.  | <u>Gomphonema intricatum</u> Kutz." |
| <u>Gomphonema acuminatum</u> Ehr.                                     | <u>Gomphonema parvulum</u> Kutz."   |
| <u>Gomphonema acuminatum</u> var.<br><u>coronata</u> (Ehr.) Wm. Smith | <u>Navicula anglica</u> Ralfs       |
|   | <u>Navicula laevissima</u> Kutz."   |

---

(1965) found it most commonly as an epiphyte.

Cymbella ehrenbergii Kutz."

Primary from L. M. B.

Cosmopolitan in fresh water, Hustedt (1930). Ecology apparently not well known.

Cymbella ventricosa Agardh

Primary from K. H.

A widely distributed species in both flowing and standing water probably best adapted to alkaline habitats (Hustedt, 1930). See Ohl (1965) for a discussion of this taxon in relation to pollution. Stoermer (1963) reports it common from littoral collections and rare in fossil material.

Cymbella sp. 2

Primary from L. M. B.

Ecology not known.

Epithemia zebra var. porcellus (Kutz.) Grun."

Table 11. Tertiary indicator species - Kettle Hole core

---

|  |                                |
|--|--------------------------------|
| <u>Achnanthes minutissima</u> Kutz. "        | <u>Gomphonema gracile</u> Ehr. |
| <u>Amphicampa mirabilis</u> Ehr. ex<br>Ralfs | <u>Navicula bacillum</u> Ehr.  |
| <u>Caloneis lewisii</u> Patr.                | <u>Navicula heufleri</u> Grun. |

---

Primary from L. M. B.

A common diatom in alkaline lakes and ponds (Jørgenson, 1948; Hustedt, 1957). Ohl (1965) found it commonly as an epiphyte in one farm pond and infrequently as an epipelagic form in other ponds. Stoermer (1963) found it infrequently in littoral and plankton collections from Lake Okoboji.

Eunotia praerupta Ehr.

Primary from K. H.

Found in acid to circumneutral water in northern or mountainous locations (Patrick and Reimer, 1966). Not reported by Stoermer (1963) or Ohl (1965).

Fragilaria brevistriata Grun.

Primary from L. M. B. and K. H.

A cosmopolitan species found in the littoral zone in still water. Tolerant of a wide range of conductivity (Patrick and Reimer, 1966). Stoermer (1963) reported it common, frequently in large numbers, in recent collections and also in fossil material.

Fragilaria capucina var. mesolepta Rabh.

Primary from L. M. B.

A cosmopolitan species occurring as a littoral or plankton form in eutrophic water. Stoermer (1963) reports this taxon was sometimes dominant in winter plankton of Lake Okoboji. The most prevalent diatom observed by Ohl (1965) in his investigation of Iowa farm ponds, present as a littoral form throughout the year but becoming a dominant plankton form sporadically.

Fragilaria construens (Ehr.) Grun.

Primary from L. M. B. and K. H.

A very widely distributed diatom (Hustedt, 1930), listed as most commonly found in the littoral zone or as plankton in slightly alkaline water (Patrick and Reimer, 1966). I have included all varieties but F. construens var. pumila and F. construens var. binodis as part of the nominate variety based on a study of the morphology of a large population (see Taxonomic Section). Stoermer (1963) reported it not uncommon in recent collections and of scattered occurrence throughout the core samples. The taxon was not reported by Ohl (1965) which seems somewhat unusual as the habitat provided by farm ponds would not be expected to differ greatly from the Kettle Hole.

Fragilaria construens var. pumila Grun.

Primary from K. H.

The ecology of this variety apparently has not been differentiated from that of the species. Patrick and Reimer (1966) listed it as

being widely distributed with the nominate variety.

Fragilaria lapponica Grun.

Primary from K. H. and secondary from L. M. B.

Apparently not a cosmopolitan species usually found in circumneutral water of low mineral content (Patrick and Reimer, 1966). Hustedt (1938) considered it an indifferent littoral form most common in standing eutrophic water. Not reported by Ohl (1965) or Stoermer (1963) from recent collections, however, the latter did report it from the middle portions of his core material.

Fragilaria vaucheriae (Kütz.) Peters.

Primary from L. M. B.

Cosmopolitan as a benthic form perhaps finding optimum growth in cool water (Patrick and Reimer, 1966). Stoermer (1963) reported it common from littoral collections, not uncommon in fossil material, and often a dominant form on filamentous algae. Ohl (1965) found it frequently in most ponds on Wisconsin drift but rare in southern Iowa.

Fragilaria virescens Ralfs

Primary from K. H.

Cosmopolitan in fresh water (Patrick and Reimer, 1966). Not reported by Stoermer (1963) or Ohl (1965).

Gomphonema acuminatum var. brebissonii (Kütz.) Grun.

Primary from K. H.

The ecology of this taxon apparently has not been reported.

Hustedt (1938), referring to the nominate variety considered it a cosmopolitan oligohalobous littoral form of alkaline standing water. Stoermer (1963) reported it rare in recent collections and very rare in fossil material of Lake Okoboji.

Gomphonema angustatum var. sarcophagus (Greg.) Grun.

Primary from K. H.

Ecology unknown. Ohl (1965) found it infrequently in scattered collections from Iowa farm ponds.

Gomphonema constrictum Ehr.

Primary from K. H.

A cosmopolitan oligohalobic littoral form (Hustedt, 1938). See Ohl (1965) for comments on this taxon in relation to pollution. Ohl (loc. cit.) reported it uncommon in recent benthic collections from Lake Okoboji and rare in fossil material.

Gomphonema gallaudii Herib.

Primary from K. H.

This taxon has been reported only from fossil collections.

Gomphonema gracile Ehr.

Tertiary from L. M. B. and K. H.

Hustedt (1938) considered this species a cosmopolitan littoral form in slightly acid to alkaline water. Chohnoky (1958) observed that this diatom seemed to be a succession species indicating that the environment was recovering from heavy pollution. Stoermer (1963)

reported it uncommon in his core material of Lake Okoboji but common from littoral and aquatic vascular collections during the winter months. Ohl (1965) reported it frequent from many farm ponds.

Gomphonema intricatum var. pumila Grun.

Primary from L. M. B. and K. H.

Apparently not carefully observed ecologically. Hustedt (1930) states that it is common in standing water in Europe. Stoermer (1963) reported it from the littoral zone and some winter plankton collections from Lake Okoboji. He noted that it was more common in the core material than other members of the genus.

Gomphonema olivaceum Grun.

Tertiary from L. M. B.

An alkalibiontic species (Hustedt, 1957) that is cosmopolitan and characteristic of flowing water (Foged, 1948b). One of the most common diatoms in Iowa streams during the winter months (Drum, 1963). Stoermer (1963) reported it dominant in littoral collections of Lake Okoboji during the winter months. In the fossil material he studied, this taxon was more common than most members of the genus especially in the lower levels. Ohl (1965) found only single valves in three ponds he investigated.

Hantzschia amphioxys fo. capitata (O. Mull.)<sup>"</sup> Hust.

Primary from K. H.

The ecology of this variety is apparently the same as for the nominate variety. Commonly considered an aerophile but Hustedt (1938)

indicates it reaches optimum development in aquatic environments. Because of its extreme adaptability it is found almost everywhere. Probably best suited to alkaline environments. Ohl (1965) reported it as rare from three farm ponds. Stoermer (1963) reported this variety to be as common as the nominate variety and to occupy the same habitats.

Melosira granulata (Ehr.) Ralfs

Primary from L. M. B. and K. H.

Considered to be a cosmopolitan species. Ohl (1965) discusses its use as an indicator of pollution. Hustedt (1939) considers this species to be useful as a guide to determine eutrophication of lakes.

Navicula anglica Ralfs

Secondary from K. H.

A cosmopolitan oligohalobous littoral species found in alkaline water of pH 7 to over 8 (Hustedt, 1938). Common in recent littoral collections of Lake Okoboji and the deeper levels of the core sample (Stoermer, 1963).

Navicula capitata var. hungarica (Grun.) Ross

Primary from L. M. B. and secondary from K. H.

Considered cosmopolitan and tolerant of a great variety of water conditions (Patrick and Reimer, 1966), but Fjerdningstad (1950) states he found it only in very clean (Katharobic) water. Stoermer (1963) reported it common in sheltered littoral areas. Reported as rare in only two ponds by Ohl (1965).

Navicula cincta (Ehr.) Ralfs

Primary from L. M. B.

Patrick and Reimer (1966) state this taxon "prefers slightly brackish or slightly alkaline or hard water." Stoermer (1963) reported it most common from shallow, sheltered and I assume, littoral collections. It was uncommon in his core material. Found in only one collection by Ohl (1965) in his study of Iowa farm ponds.

Navicula confervacea (Kutz.) Grun.

Primary from K. H.

A cosmopolitan species indifferent to pH perhaps reaching maximum growth in slightly polluted water (Hustedt, 1962). Patrick and Reimer (1966) report it to be an aerophil or found in very shallow water seeming to "prefer" soft warm water.

Navicula cryptocephala var. veneta (Kutz.) Rabh.

Primary from L. M. B.

Hustedt (1938) considers it cosmopolitan but states it reaches its optimum development only in brackish water. Patrick and Reimer (1966) agree but state it also is found in fresh water with high mineral content. Stoermer (1963) reports it common in the recent flora and not uncommon in core material of Lake Okoboji. Ohl (1963) found it in several farm ponds but represented by only a few individuals.

Navicula elginensis (Greg.) Ralfs

Primary from K. H.

Hustedt (1938) considers this taxon cosmopolitan. Patrick and Reimer

(1966) state it is tolerant of a wide range of conditions in fresh to brackish water. From my experience I would not consider it cosmopolitan nor even common. Ohl (1965) found it only in ponds of Wisconsin drift. Stoermer (1963) does not report it from Lake Okoboji.

Navicula globosa Meist.

Primary from K. H.

Previously unreported from North America. In Europe, a fresh water form from northern or alpine regions (Hustedt, 1962).

Navicula graciloides A. Mayer

Primary from L. M. B.

Found in fresh to slightly brackish water with circumneutral pH (Patrick and Reimer, 1966). Stoermer (1963) reports it common from littoral regions of Lake Okoboji but uncommon in his fossil material.

Navicula oblonga (Kütz.) Kütz.

Primary from L. M. B.

Patrick and Reimer (1966) consider it tolerant of slightly brackish water or water with high mineral content. Stoermer (1963) found it in benthic habitats of Lake Okoboji and reported it rare in his fossil material.

Navicula pseudoventralis Hust.

Primary from L. M. B. and K. H.

Hustedt (1961) states this taxon is common in alkaline water in the

Baltic lake region and in the Alps. Stoermer (1963) found it commonly in littoral collections of Lake Okoboji and in greatest quantity on rocks at a depth of one meter. It was uncommon in his core material.

Navicula pupula var. rectangularis (Greg.) Grun.

Primary and secondary from L. M. B.

Hustedt (1938) considers the nominate variety to be cosmopolitan, being commonly found wherever diatoms have been studied and implies the same for this variety. Patrick and Reimer (1966) state this variety is more common in water of higher mineral content than the nominate variety. Not reported by Stoermer (1963) or Ohl (1965).

Navicula rhynchocephala var. amphiceros (Kutz.) Grun.

Primary from L. M. B.

Apparently widely distributed in fresh water, indifferent to low concentrations of chloride (Patrick and Reimer, 1966). Not reported by Stoermer (1963) who records the nominate variety as rare in both recent and fossil collections.

Navicula seminuloides Hust.

Primary from K. H.

The ecology of this taxon is not known. Considered a fresh water form of tropical Asia and Africa by Hustedt (1962). Reported by Ohl (1965) as frequent in one farm pond and infrequent from many southern Iowa farm ponds.

Navicula tantula Hust.

Primary from K. H.

Hustedt (1962) reported it as a widely distributed littoral form finding optimum conditions in slightly acidic, well aerated water.

Stoermer (1963) reports it uncommon in recent collections and rare in fossil material. Ohl (1965) found it in all ponds investigated, ranging in frequency from common to infrequent.

Nitzschia amphibia Grun.

Primary from K. H. and secondary from L. M. B.

A cosmopolitan species found in littoral regions of lakes as well as in flowing water (Hustedt, 1938). Stoermer (1963) reported it very common and sometimes dominant in littoral and occasionally in plankton collections from Lake Okoboji. Ohl (1965) found it in all ponds he investigated.

Opephora ansata Hohn and Hell.

Primary from L. M. B. and K. H.

See taxonomic section. Ecology not known.

Rhopolodia gibba O. Mull.

Primary from L. M. B.

A cosmopolitan species of alkaline water reaching optimum development in very hard water (Hustedt, 1938). Stoermer (1963) reported it common in collections from aquatic vascular plants. It was rare in the deeper parts of his core becoming more common in more recent sediments. Reported as infrequent in most Iowa farm ponds studied by Ohl (1965) being common in one only during the late fall.

Rhoicosphenia curvata (Kutz.) Grun. ex Rabh.

Primary from L. M. B.

Generally considered a cosmopolitan species. Most common in alkaline flowing water and probably an oligohalobe (Patrick and Reimer, 1966). See Ohl (1965) for considerations of it referring to pollution. Ohl (op. cit.) found it a winter dominant as an epiphyte and/or epilith in one farm pond. Common in periphyton communities and not uncommon in fossil collections of Lake Okoboji (Stoermer, 1963).

Stauroneis phoenicenteron (Nitz.) Ehr.

Secondary from K. H.

Hustedt (1959) considers this species cosmopolitan in alkaline to slightly acid water. Ohl (1965) reported it as frequent in only one farm pond he investigated and infrequent in others, always being found in collections from the mud surface. Not uncommon in littoral and plankton collections and occasional in the sediment sample of Lake Okoboji (Stoermer, 1963).

Stephanodiscus astraea var. minutula (Kutz.) Grun.

Primary from L. M. B.

Considered a cosmopolitan species in eutrophic water (Foged, 1948a), Stoermer (1963) found it common and occasionally dominant in winter plankton of Lake Okoboji. It was dominant in the deeper part of his core material becoming less so in more recent sediments. Ohl (1965) found that in Iowa farm ponds it was common and reached peak growth in the summer.

Stephanodiscus invisitatus Hohn and Hell.

Primary from L. M. B. and K. H.

Ecology not known.

Stephanodiscus niagarae var. magnifica Fricke

Secondary from L. M. B.

The ecology of this variety apparently has not been specifically reported. Huber-Pestalozzi (1942) considered the nominate variety a cold water plankton from of North and Central America. Stoermer (1963) reported this taxon one of the major dominants in recent plankton collections of spring and early summer in Lake Okoboji. It was common in his core material especially the more recent sediments. Ohl (1965) reported the nominate variety as a rare winter form in one farm pond he studied.

### Interpretation of Diatom Floras from Little Miller's Bay

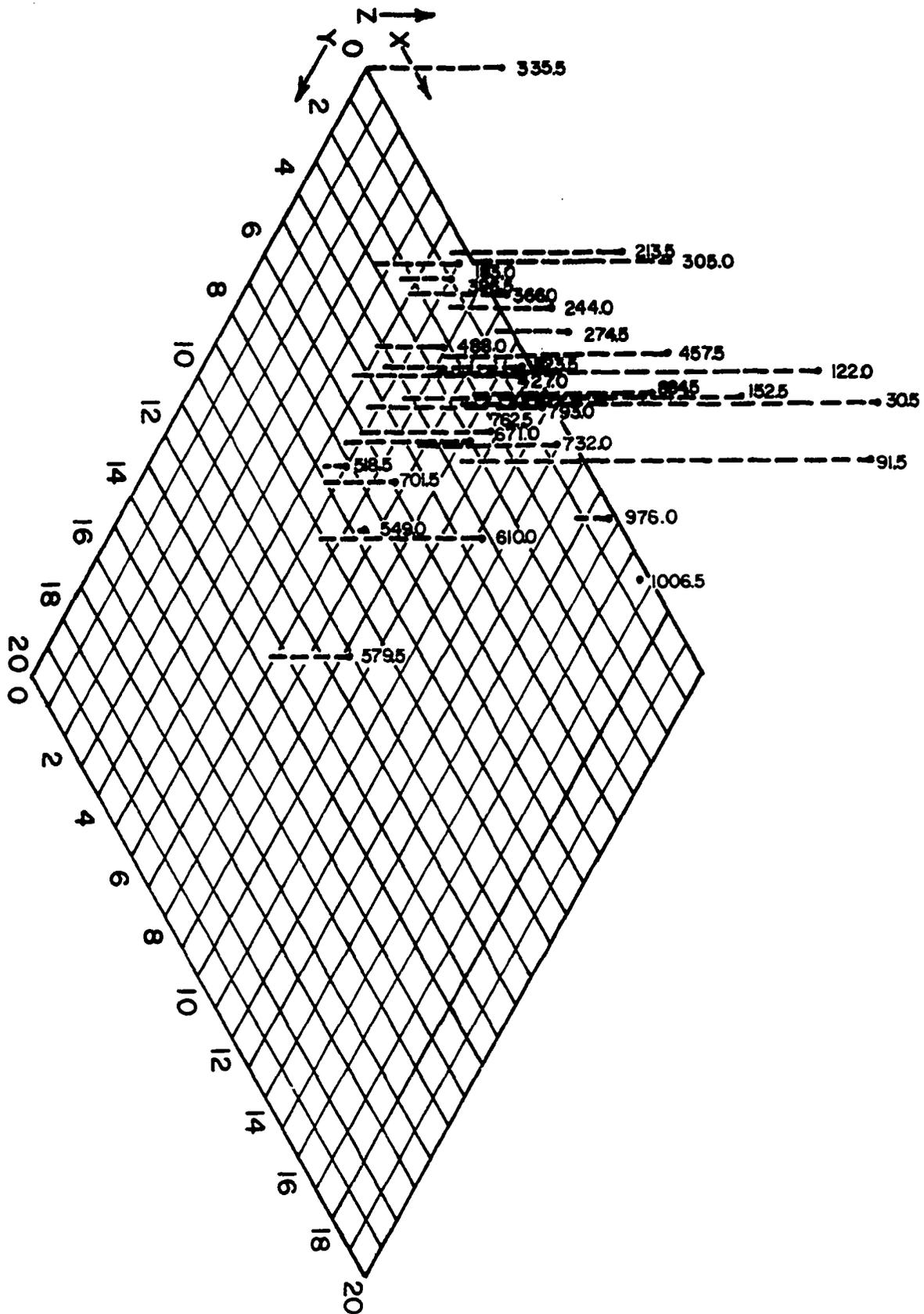
The large amount of data gathered (Appendix B, Figure 12) was analyzed by the ordination technique of Orloci (1966), as discussed in Methods, in an attempt to extract the most useful information and separate those elements that contain this information from the mass. Negative numbers were removed from the coordinate values by adding a certain number to them so all points would fall on or above the reference plane of the three dimensional figures (6, 7, 9, 10). The information content of the various axes of the ordination should be considered when analyzing the three dimensional graphs. The axes are so constructed by Orloci's (1966) technique that the most different stands form the ends of the x axis and it contains the maximum amount of information in one plane. The y axis is the next most significant and the z least.

The graphic representation of the ordination of levels from the Lake (Figure 6) provides an appropriate place to begin an interpretation of the data. The x axis in Figure 6 was multiplied by two to help in the visualization of the three dimensional graph. Some distortion is caused by multiplication and this should be considered when observing this graph. Figure 3 may be helpful in following this discussion.

Several observations can be made. The 1006.5 cm and 976.0 cm levels, the two deepest levels studied in which diatoms occur, are distinct from the main group. Extrapolated radiocarbon ages for these two depths are respectively, 12,400 and 12,050 years B. P.

The 579.5 cm and 610.0 cm levels also fall out of the main group. The 579.5 cm level was dated at 5,800 years B. P. The 335.5 cm level

Figure 6. Ordination of levels from Little Miller's Bay core. Z axis multiplied by 2.  
Numbers are depths in cm.



is distinctly different from all other levels suggesting a major environmental change may have occurred at that time. Extrapolation from the radiocarbon data provides a 3,400 years B. P. date for this level. The four upper levels in the Lake core form a cluster indicating that these recent populations were much alike. It is informative to follow this ordination of levels from bottom to top in sequence. As one does this it becomes clear that the levels tend to stay near a certain point in the vicinity of levels 762.5 cm and 793.0 cm.

The two deepest levels, 1006.5 cm and 976.0 cm, indicate a diverging trend from the main group. The next six points are a part of the main group and show a trend of position change, decreasing on the z axis and increasing on the x and y axes. The proximity of the 823.5 cm level to the 427.0 cm level should be noted. The next two levels, 610.0 cm and 579.5 cm lie out of the main group and are separated to some extent from each other. The 549.0 cm and 518.5 cm levels are on the edge of the cluster and rather close together. The next five levels vary within the main group. However, the 457.5 cm level is displaced somewhat from this group on the z axis placing it quite near level 152.5 cm in the upper group indicating similarity between them. Level 335.5 cm is clearly separated from the main cluster while the next five points are varied on the edge of the main group. The closeness of the 213.5 cm and 305.0 cm levels, indicating considerable similarity between them, should be noted. The top four levels trend up the z axis away from the main group. Briefly then, the ordination of levels in the lake core show four major deviations around a general location; the deepest level, the 579.5 cm level, the 335.5 cm level and the top four levels. These data would suggest that

the above levels should be especially scrutinized for evidence relating to conditions existing when they were laid down. In time these points represent roughly 12,400 years B. P., 6,700 years B. P., 3,400 years B. P. and 1,500 years B. P. to the present.

Figure (7) indicates the position of the primary indicator species from the Lake site and their relation to most of the remaining taxa. The contorted solid shape indicated above the reference plane represents the volume occupied by approximately 40 per cent of the 210 taxa found in populations counted from this site. The secondary and tertiary indicator species would, in general, be represented by points lying in line with the mass of points in the solid shape when viewed from the direction of one or two of the three axes.

Graphs were prepared (Figure 8) of the populations of all primary indicator species and a few selected secondary and tertiary indicator species from the Lake site.

The early post-glacial interval seems to have been quite distinct. It should be noted that certain taxa occurred only then, eg. Cymbella sp. 2 (Figure 8-6), while others occurred very early in the lake's history, disappeared with the approaching hypsithermal and then reappeared relatively recently, Amphora ovalis, Cymbella ehrenbergii, Fragilaria construens, Navicula pseudoventralis and Navicula rhynchocephala var. amphiceros (Figure 8-1, 5, 10, 19, and 21). The increasing populations of epiphytic species are indicative of increasing numbers of submerged aquatic vascular plants living in the lake and indirectly, therefore, of a lowering of the water level. In this regard, note especially Epithemia

Figure 7. Ordination of species from Little Miller's Bay core. Y axis + 2. Z axis + 10. Position the primary indicator species shown.

1. Amphora ovalis Kütz.
2. Amphora ovalis var. affinis Kütz.
3. Amphora ovalis var. pediculus Kütz.
4. Cymbella cistula (Hemprich) Grun.
5. Cymbella ehrenbergii Kütz.
6. Cymbella sp. 2
7. Epithemia zebra var. porcellus (Kütz.) Grun.
8. Fragilaria brevistriata Grun.
9. Fragilaria capucina var. mesolepta Rabh.
10. Fragilaria construens (Ehr.) Grun.
11. Fragilaria vaucheriae (Kütz.) Peters.
12. Gomphonema intricatum var. pumila Grun.
13. Melosira granulata (Ehr.) Ralfs
14. Navicula capitata var. hungarica (Grun.) Ross
15. Navicula cincta (Ehr.) Ralfs
16. Navicula cryptocephala var. veneta (Kütz.) Rabh.
17. Navicula graciloides A. Mayer
18. Navicula oblonga (Kütz.) Kütz.
19. Navicula pseudoventralis Hust.
20. Navicula pupula var. rectangularis (Greg.) Grun.
21. Navicula rhyncocephala var. amphiceros (Kütz.) Grun.
22. Opephora ansata Hohn and Hell.
23. Rhoicosphenia curvata (Kütz.)
24. Rhopalodia gibba O. Müll.
25. Stephanodiscus astraea var. minutula (Kütz.) Grun.
26. Stephanodiscus invisitatus Hohn and Hell.
27. Cyclotella bodanica Eulenstein
28. Gomphonema olivaceum Grun.
29. Cocconeis placentula var. lineata Ehr.
30. Stephanodiscus niagarae var. magnifica Fricke

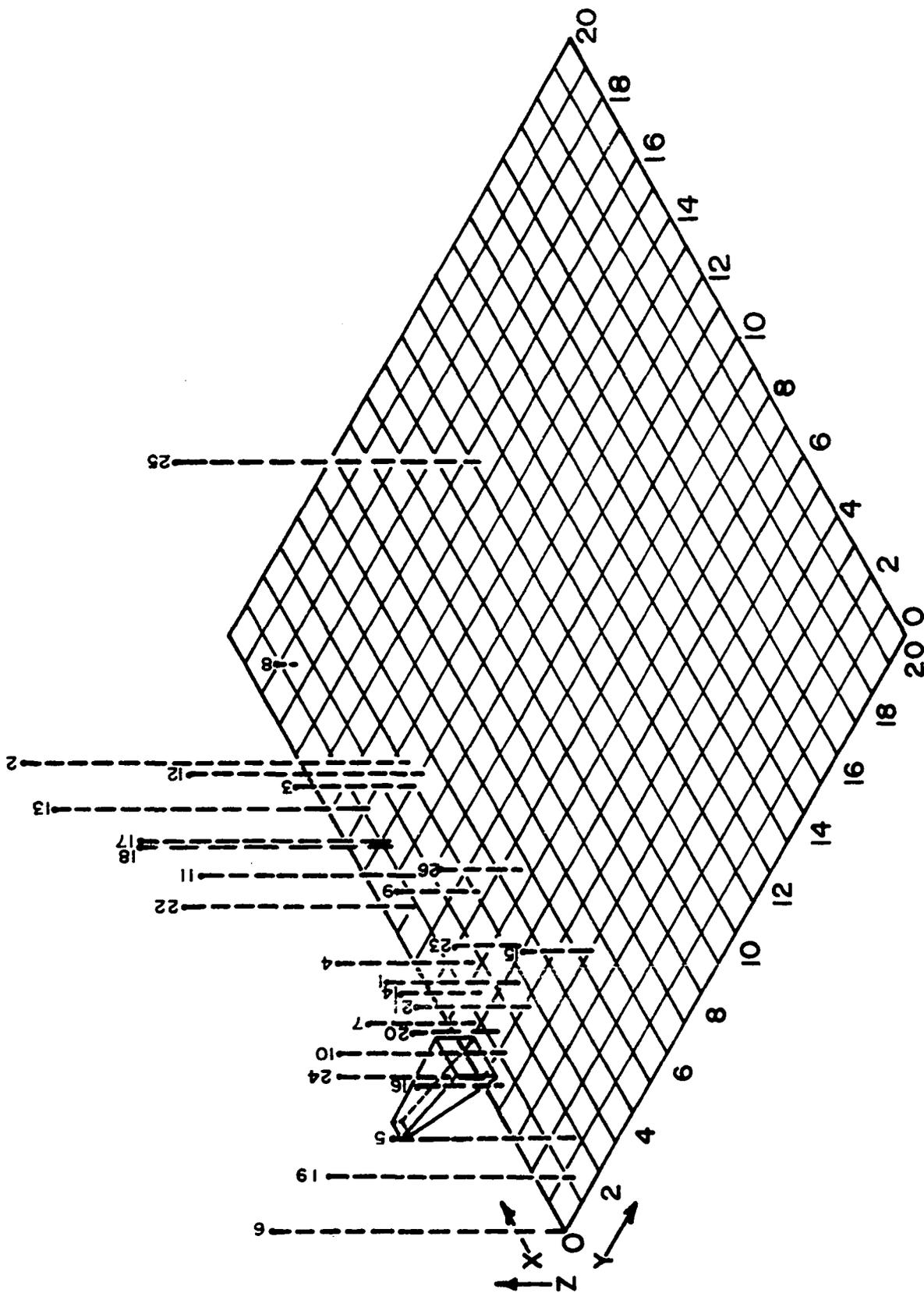


Figure 8. Populations of primary indicator species (1-26) and selected secondary and tertiary species (27-30) from Little Miller's Bay core. The common log of the number counted is plotted against time in thousands of years. Arrows at bottom indicate levels for which a radiocarbon date was obtained. Numbers at top indicate depths in cm for which a diatom population was determined.

1. Amphora ovalis Kütz.
2. Amphora ovalis var. affinis (Kütz.) V. H.
3. Amphora ovalis var. pediculus Kütz.
4. Cymbella cistula (Hemprich) Grun.
5. Cymbella ehrenbergii Kütz.
6. Cymbella sp. 2

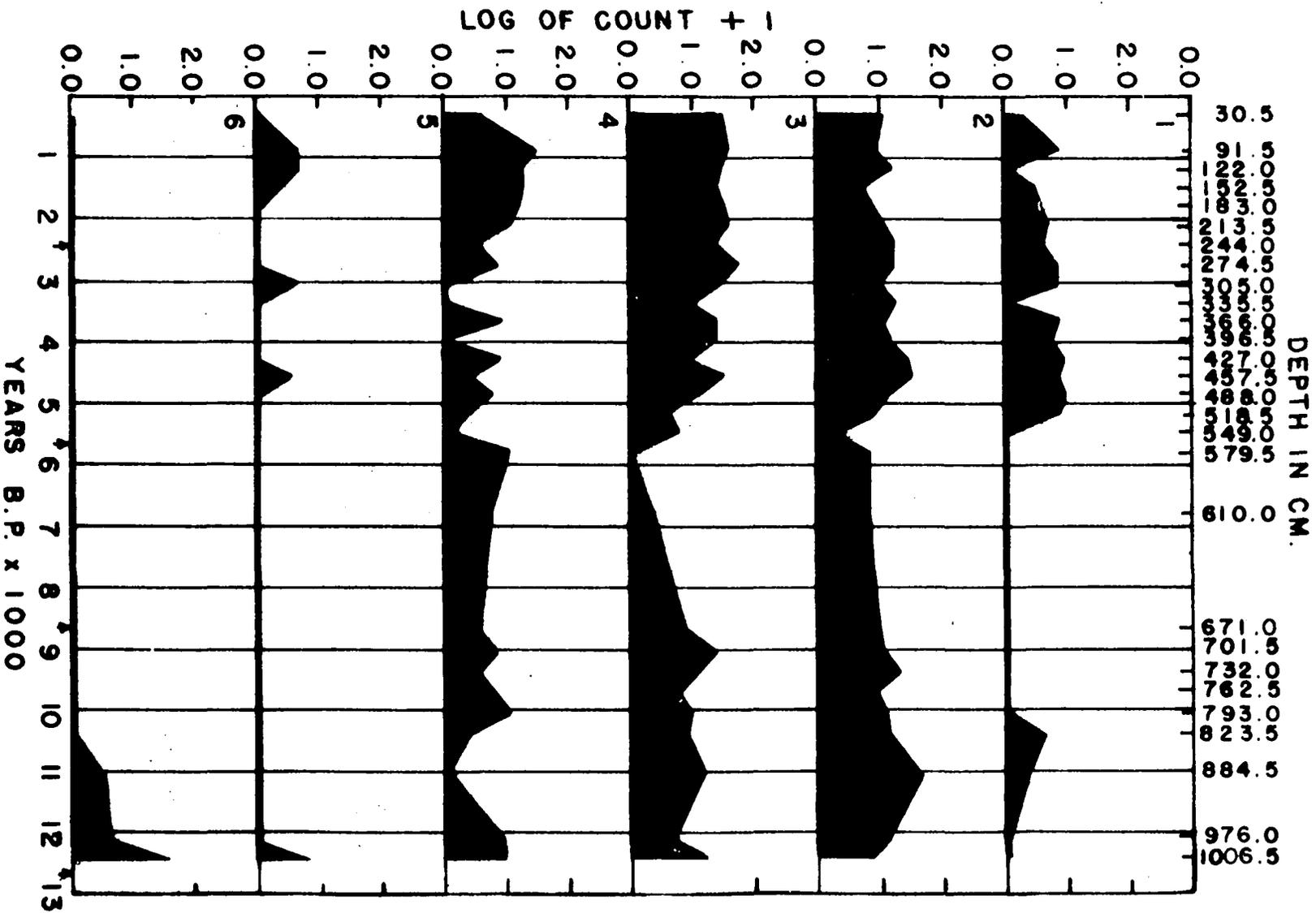


Figure 8 (Continued).

7. Epithemia zebra var. porcellus (Kütz.) Grun.
8. Fragilaria brevistriata Grun.
9. Fragilaria capucina var. mesolepta Rabh.
10. Fragilaria construens (Ehr.) Grun.
11. Fragilaria vaucheriae (Kütz.) Peters.
12. Gomphonema intricatum var. pumila Grun.



Figure 8 (Continued).

13. Melosira granulata (Ehr.) Ralfs
14. Navicula capitata var. hungarica (Grun.) Ross
15. Navicula cincta (Ehr.) Ralfs
16. Navicula cryptocephala var. veneta (Kütz.)  
Rabh.
17. Navicula graciloides A. Mayer
18. Navicula oblonga (Kütz.) Kütz.



Figure 8 (Continued).

19. Navicula pseudoventralis Hust.
20. Navicula pupula var. rectangularis (Greg.)  
Grun.
21. Navicula rhynococephala var. amphiceros  
(Kütz.) Grun.
22. Opephora ansata Hohn and Hell.
23. Rhoicosphenia curvata (Kütz.) Grun. ex Rabh.
24. Rhopalodia gibba O. Mill.

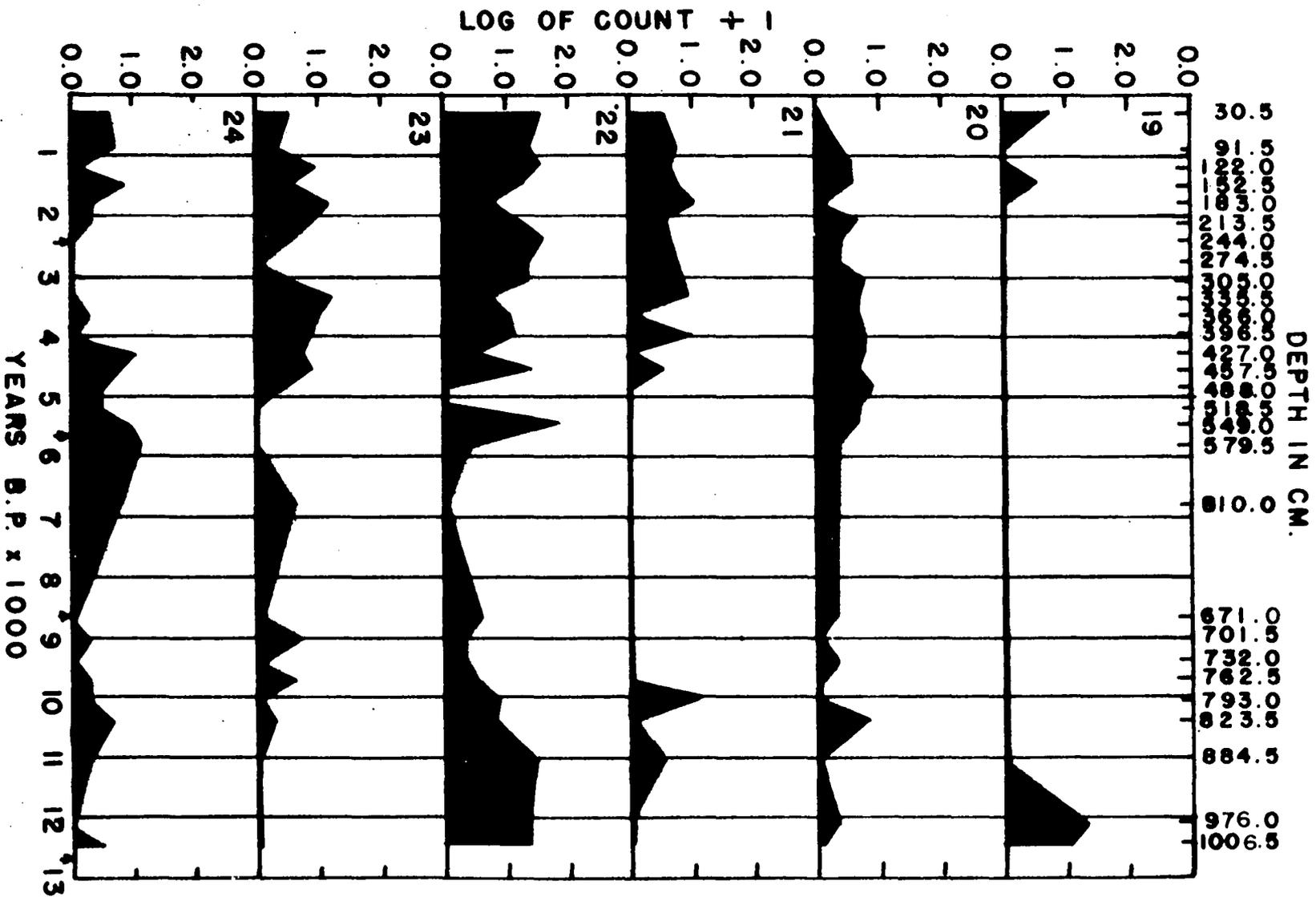


Figure 8 (Continued).

25. Stephanodiscus astraea var. minutula (Kütz.)  
Grun.
26. Stephanodiscus invisitatus Hohn and Hell.
27. Cyclotella bodanica Eulenstein
28. Gomphonema olivaceum Grun.
29. Cocconeis placentula var. lineata Ehr.
30. Stephanodiscus niagarae var. magnifica Fricke



zebra var. porcellus, Rhopalodia gibba and Cocconeis placentula (Figure 8-7, 24, 29). The diatom population changes suggest a gradual climatic change to about 10,400 years B. P. coincident with the retreat of glacial ice.

Between approximately 10,400-9,400 years B. P. more drastic changes in diatom populations occurred. The ecology of the indicator species does not clearly indicate the nature of the change although a lowering of the water level and an accompanying concentration of dissolved solutes are not contraindicated. In a hypothesis discussed by Dodd et al. (In Press) it is considered that wind from the glacial high pressure center would have been predominately northwesterly in the study area. Precipitation probably occurred mostly as snow in winter. Summers would have been cool and dry at first but became warmer and drier as the glacier retreated. When the glacier had retreated far enough or perhaps diminished sufficiently in area, the glacial high pressure center began to break down and the continental weather pattern we presently have took hold. Mean annual temperatures seem to have been somewhat higher (Cullen, 1966) than at present at the time the glacial weather pattern disintegrated. Major amounts of precipitation occurred as rains, probably in the spring and early summer, just as they do now. Autumns and winters became much drier than they had been previously. These conditions were less favorable to the growth of the coniferous forests and it is probable that they became extremely vulnerable to destruction by fire. The elevated temperatures diminished the effect of the rain to some extent but lake levels seem to have become higher until about 9,000 years B. P. as

evidenced by increasing numbers of plankton diatoms (Figure 8-9, 25, 26). Cullen (1966) has indicated that sea levels rose drastically, 60 meters, between 11,000 years B. P. and 9,000 years B. P. This rise was undoubtedly due to the melting of glacial ice and further confirms the date indicated by fossil diatom populations as the time when glacial effects on climate in this area began to diminish about 10,000 years B. P.

By 8,700 years B. P. diatom populations had changed markedly. This period, detected by many previous workers, has been called the hypsithermal interval (Deevey and Flint, 1957). Walker (1966) has recorded this period as one of high erosion rates in Iowa. The depleted terrestrial flora probably could not control the erosion caused by heavy spring rains. This period continued, apparently with little change, as indicated by the diatom floras, until about 5,500 years B. P.

Fragilaria brevistriata, Fragilaria capucina var. mesolepta, and Fragilaria vaucheriae (Figure 8-8, 9 and 11) show populations that are higher than average during the 8,700-5,500 years B. P. period. The reported ecology of these taxa would suggest that all are primarily littoral, lake species. F. capucina var. mesolepta can occur in plankton while F. vaucheriae has been considered a cool water form. This apparently would not support a change toward higher temperatures during the period. However since diatoms tend, as a group, to be cool water organisms we may be observing the effects of higher mean annual temperature on prolonging the fall and spring optimum growth periods. The presence of a cool water form in sediments from a warm climatic period is more understandable from this point of view.

Stephanodiscus invisitatus (Figure 8-26) maintained relatively high populations during this period and although its ecology is not well known it probably can be considered a plankton organism. Considering that Little Miller's Bay was about seven meters deeper at the onset of the hypsithermal it seems reasonable that plankton might be found there. Another planktonic species Cyclotella bodanica (Figure 8-27) first appeared at the onset of this period but did not really flourish until approximately 3,700 years ago. It would seem that my record of this species agrees very well with that of Stoermer (1963) whose core showed the highest populations at the bottom and declining numbers toward the top. Hustedt (1930) considers this taxon characteristic of subalpine European lakes. Conditions apparently suited it well in Lake West Okoboji in the post-hypsithermal period. Stephanodiscus astraea var. minutula (Figure 8-25) was found at high levels at the onset of this period and maintained a significant population throughout the interval. Stoermer (1963) reported this taxon as an occasional dominant in winter plankton collections from Lake West Okoboji. Ohl's (1965) observations seem to conflict with this, as he found it reached peak growth in farm ponds in summer. It is generally regarded as a form common in eutrophic water, and in this light, populations of this taxon indicate the increasing trophic levels in the lake in postglacial time. Just how to best interpret this taxon during the 9,000-5,500 year B. P. period is not clear.

Only one taxon, Fragilaria construens, (Figure 8-10) was found to have large populations prior to and after the 9,000-5,500 year B. P. interval, while not being found during the interval itself. F. construens is a ubiquitous littoral form found in alkaline water. There is a

relatively large proportion of sand in the sediments deposited during the hypsithermal period while organic sedimentation rates were low. Whether this or other factors were the limiting conditions, obviously the littoral zone was not suited to this diatom during this period. Little Miller's Bay was deeper then than now, but it obviously was even deeper about 12,100 years B. P. when large populations existed. Perhaps increasing temperatures restricted its most favorable yearly growth period while the conditions that produced sandy sediments eliminated its choice habitat. Amphora ovalis (Figure 8-1) occurred both before and after the 5,500-9,000 year B. P. period but never reached large populations in the older sediments. Navicula rhyncocephala var. amphiceros (Figure 8-21) occurred in a similar manner but never reached large populations. The low population levels and somewhat disjunct, in time, occurrence of Cymbella ehrenbergii (Figure 8-5), make it difficult to interpret. It too, was found before and after the 9,000-5,500 year B. P. interval.

Many of the indicator species have occurred only after about 5,800 years B. P. Certainly conditions were changed at the close of this period but in addition, the length of time involved may have allowed new species to be introduced to the lake. Those species occurring only after about 5,800 years B. P. are Navicula cincta, N. cryptocephala var. veneta and Stephanodiscus niagarae var. magnifica. N. cincta (Figure 8-15) is considered a littoral, alkaline, hard water form and N. cryptocephala var. veneta (Figure 8-16) a species flourishing in brackish water or water of high mineral content. Stephanodiscus niagarae var. magnifica (Figure 8-30) is a plankton form, perhaps best adapted to cooler water. Stoermer's

(1963) observations from his core coincide well with mine as in both cases this taxon seems to have become more generally abundant in the last 4,000 years. The temperature shift and other associated climatic changes at the end of the 9,000-5,500 year B. P. period seem to have been favorable to this taxon.

The only previous comment of which I am aware on the period beginning with the end of the hypsithermal about 5,500 years B. P. and the onset of more modern climate about 2,500 years B. P. was made by Fries (1962). Based on pollen profiles from a northeastern Minnesota lake he detected changes reflecting cooler or moister conditions during this interval. The usual implication has been that it was a period of gradual and slight cooling combined with increased rainfall in this geographic area (Walker, 1966). A glance at Figure 8 shows that the diatom populations in Little Miller's Bay fluctuated widely implying similar climatic shifts. Navicula cincta (Figure 8-15) was found only in this interval and Cyclotella bodanica (Figure 8-27) reached its highest populations then after first appearing early in the hypsithermal.

Many indicator species show a consistent change at the 2,800 years B. P. point. The two species just mentioned as well as Cocconeis placentula var. lineata, Gomphonema intricatum var. pumila, Melosira granulata, Rhoicosphenia curvata, Rhopalodia gibba, Stephanodiscus astraea var. minutula (Figure 8-12, 13, 23, 24, 25, and 29) all were found to have depressed populations at 2,800 years B. P. while Fragilaria brevis-triata, Fragilaria capucina var. mesolepta, and Stephanodiscus invisitatus (Figure 8-8, 9, 26) had larger populations. The decrease in population of epiphytic forms and the increase in planktonic forms would suggest a

general rise in the level of the lake which seems reasonable to assume was the result of increased precipitation. Stephanodiscus astraea var. minutula (Figure 8-25) is a plankton form and although it shows a somewhat lower population at 2,800 years B. P. it still made up a major part of the diatom flora.

The decrease in epiphytic taxa, especially Cocconeis placentula var. lineata (Figure 8-25) at 2,500 years B. P. may indicate that the lake level was at an all time high. The period from 2,500 years B. P. to the present seems to have been one of gradual change to more eutrophic lake conditions. The diatom populations suggest that precipitation rates and average temperatures have gradually increased during the last 2,500 years.

The physical filling in of Little Miller's Bay probably began to have a marked effect during the late post-hypsithermal period, perhaps accounting for the increased populations of epiphytes and decreased populations of planktonic forms from 2,500 years B. P. to the present. The decline of Cyclotella bodanica, (Figure 8-27) a plankton form, was also reported by Stoermer (1963) from a core taken from the deepest part of the lake, a location that would not have been affected by accumulating sediments. The decline of this taxon may indicate increasing temperatures or environmental changes directly related to the temperature change as it is common in subalpine lakes in Europe (Hustedt, 1930). If this interpretation is valid it would seem that the larger populations of C. bodanica from 3,600-2,300 years B. P. indicate a period of relative coolness.

### Interpretation of Diatom Floras from Kettle Hole

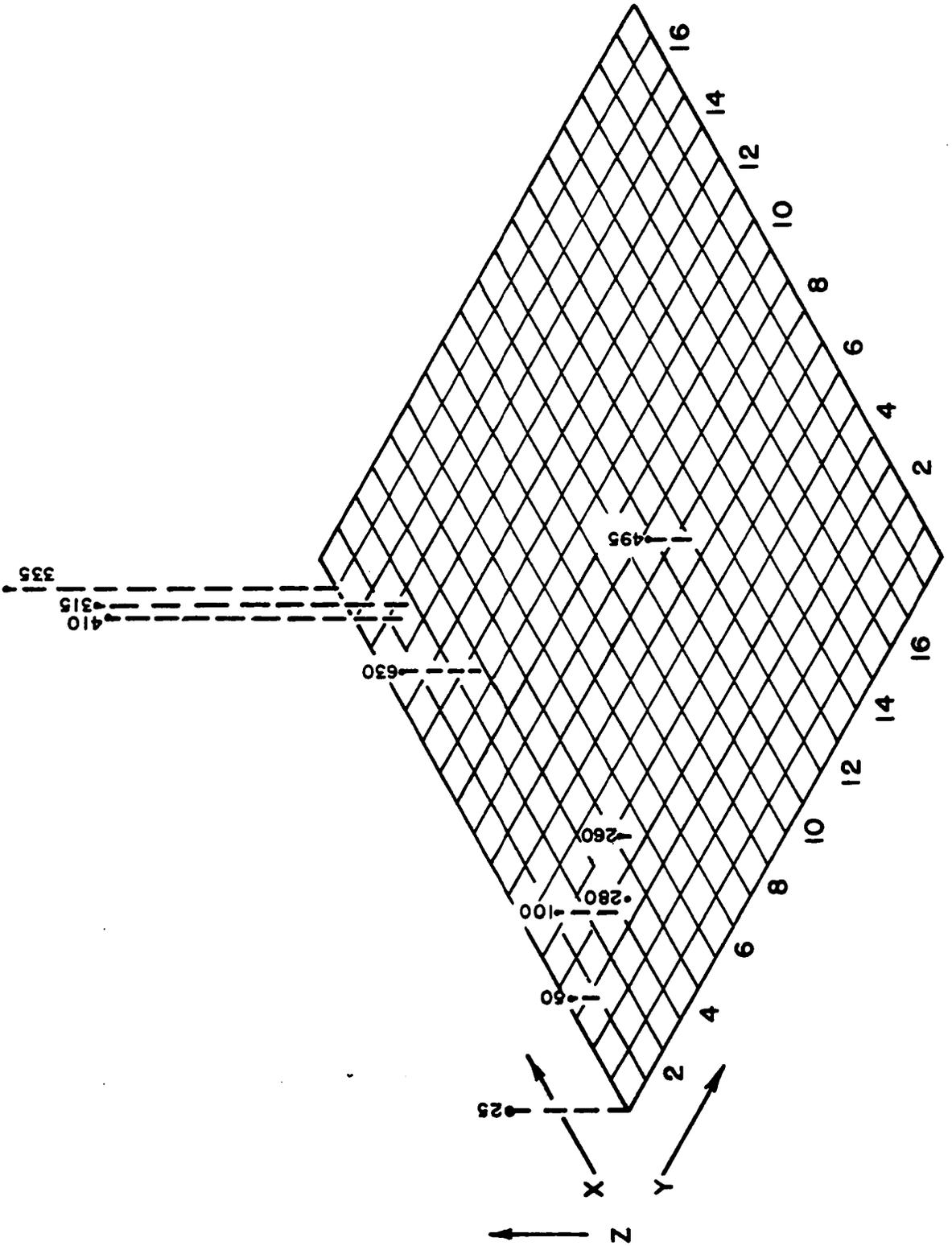
Figure 9 illustrates the ordination of the depths studied from the Kettle Hole. There seems to be four groups in this ordination.

The first, beginning with the oldest sediments, consists of only one point, the 630 cm level, which is quite distinct from all other levels especially on the z axis. The extrapolated age for this level is 11,800 years B. P.

The second group, consisting only of the 495 cm level, was dated at 10,310 years B. P. and stands very far from the other levels on the ordination. The very distinct difference between this level and the 410 cm level is surprising since the time interval separating the two is on the order of only 400 years. There was a discontinuity in the physical nature of the sediments at this level that was first thought to represent the transition from postglacial sediments to glacial till. The apparently inorganic nature of the underlying sediments prompted this reaction in the field but the later discovery of a few diatoms and bits of organic matter resembling wood in the sediments, suggested the postglacial interface was deeper. The most likely explanation for the difference in the flora at this level is that an open body of water existed. The basin would have been 5 meters deeper at that time which would make this a more plausible situation.

The next three depths, progressing up the core, form a very distinct group. The estimated ages for these three levels are 9,800 B. P. (410 cm), 8,480 B. P. (335 cm), and 7,300 B. P. (315 cm). The 335 cm level is somewhat separated from the 315 cm and 410 cm levels suggesting that it differs

Fig. 9. Ordination of levels from the Kettle Hole core. Numbers are depths in cm.



from them to some extent. This probably indicates the most extreme conditions of the hypsithermal episode. The 335 cm level is just at the top of a layer called "brown organic sediment" (Figure 4). Wood bits and pieces of larger tree parts occur throughout this layer. A stand of coniferous trees probably grew in the Kettle Hole basin in the early post-glacial period and it seems reasonable that their remains form the very organic layer of sediments between 485 cm and 320 cm.

It is interesting to note how closely the 315 cm and 410 cm levels are on the ordination. The deeper sample must have been laid down during the cool postglacial period while the upper sample would seem to have been in the late to mid-hypsithermal period. An explanation for the similarities indicated by their floras is not obvious .

The last group consists of the top five levels and shows a trend toward the origin of the x and y axes and higher on the z axis. The 25 cm level is the most removed from the other points indicating it differs most from the other members of this group. As shown on Figure 4, a sandy layer was found in the core at 265-280 cm. This was interpreted as a transition period and was chosen for dating. As shown in Table 1 the 270-280 cm level was dated 4,880 years B. P. but the diatom populations show the beginnings of a pattern of change at least 1,500 years earlier. This can be interpreted to mean precipitation increase began about 7,000 years B. P. and by about 5,000 years B. P. was sufficient to wash large amounts of sand into the Kettle Hole basin. If these events immediately preceded the end of the hypsithermal then that event may have occurred earlier than previous reports would indicate (Walker, 1966).

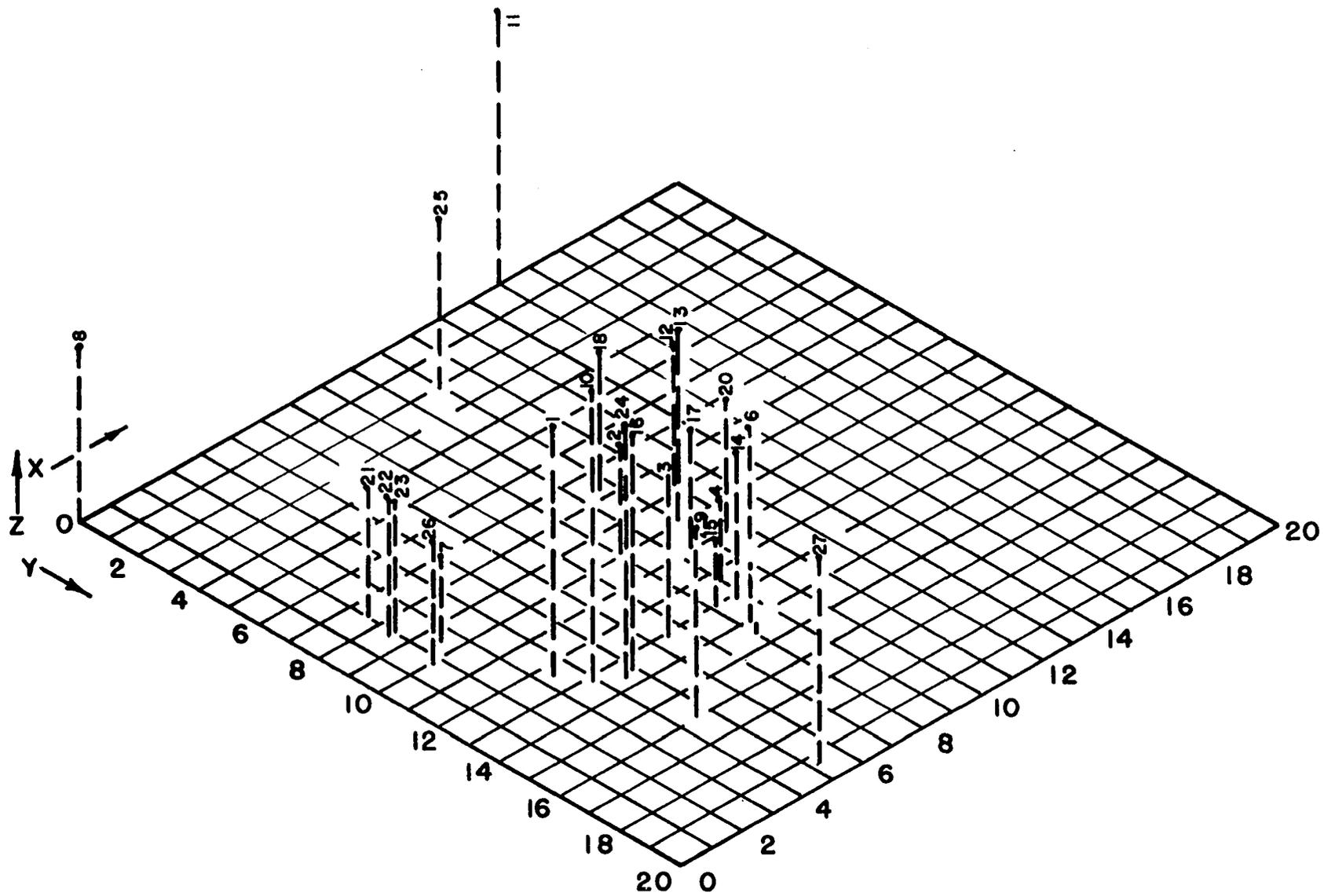
If a constant rate of sedimentation is assumed from 4,880 years B. P. to the present the 25 cm depth represents about 480 years B. P.; however, accuracy of this estimate is in question since other evidence indicates that precipitation rates were quite variable and probably so were erosion and sedimentation rates during this period. Nevertheless it seems likely that the 25 cm depth sample is very recent. No significant changes are noted in the physical appearance of the Kettle Hole sediments laid down during the past 4,880 year time span but the diatom populations included in them have changed considerably as will be discussed later.

As the gradual drying out process that led to the hypsithermal continued from about 10,300-9,000 years B. P. the pond probably lowered and the forest at its edge followed it until a swamp-forest existed across the whole bottom of the basin. During the most extreme hypsithermal conditions the trees died and when the rains came again, what was left of the trees was buried. This may account for the buried wood in the deeper levels of the core.

The ordination of the primary indicator species from the Kettle Hole (Figure 10) shows several clumps of species as well as some very distinctly separate species. An attempt to indicate the location of the great mass of species was not useful in this case since they lie among the indicator species and would have made the figure more difficult to visualize.

The flora of the deepest level in which diatoms occur (630 cm - 11,800 B. P.) was dominated by Stephanodiscus invisitatus (Figure 11-27) a planktonic form that was only observed at this level. Unfortunately little has been reported about its ecological range of tolerance. Navicula

Figure 10. Ordination of species from Kettle Hole core. Z axis + 6. Y axis x 2. Position of the primary indicator species shown.



anglica was selected to be graphed (Figure 11-29) from among the secondary indicator species because of its occurrence at only this level. It is a littoral form typical of alkaline water. Fragilaria brevistriata (Figure 11-7) shows a decrease in numbers at the 495 cm level as compared with the 630 cm level, indicating its littoral habitat was becoming less favorable.

Planktonic forms, Fragilaria virescens, Melosira granulata, (Figure 11-11, 18) increased to a peak at the 495 cm level while many forms common to the previous period disappeared. The numbers of epiphytic taxa such as Amphora ovalis var. affinis and Cocconeis placentula (Figure 11-2, 3) suggest that at least some aquatic vascular plants were present. This probably indicates stable conditions in which the water level remained relatively constant. Several other taxa show population changes but their ecology is disappointingly uninformative.

From the information that can be gleaned from the diatom flora it would seem the Kettle Hole basin contained a moderately deep lake in which some plankton diatoms existed at some time during the year. There were vascular plants present at the waters' edge and the water was hard and alkaline.

The next group of points in the ordination of levels, 410 cm, 335 cm, and 315 cm, represent the interval from approximately 9,600 to 7,400 years B. P. Diatom populations changed markedly during this period, many that were major contributors to the flora of the lower levels disappeared or almost disappeared while several taxa appeared and became major components of the flora.

Figure 11. Populations of primary indicator species (1-27) and selected secondary and tertiary indicator species (28-30) from the Kettle Hole core. The common log of the number counted is plotted against time in thousands of years. Arrows at bottom indicate levels for which a radiocarbon date was obtained. Numbers at top indicate depths in cm for which a diatom population was determined.

1. Achnanthes exigua var. heterovalvata Krasske
2. Amphora ovalis var. affinis (Kütz.) V. H.
3. Cocconeis placentula var. lineata Ehr.
4. Cymbella ventricosa Ag.
5. Eunotia curvata (Kütz.) Lagerst.
6. Eunotia praerupta Ehr.

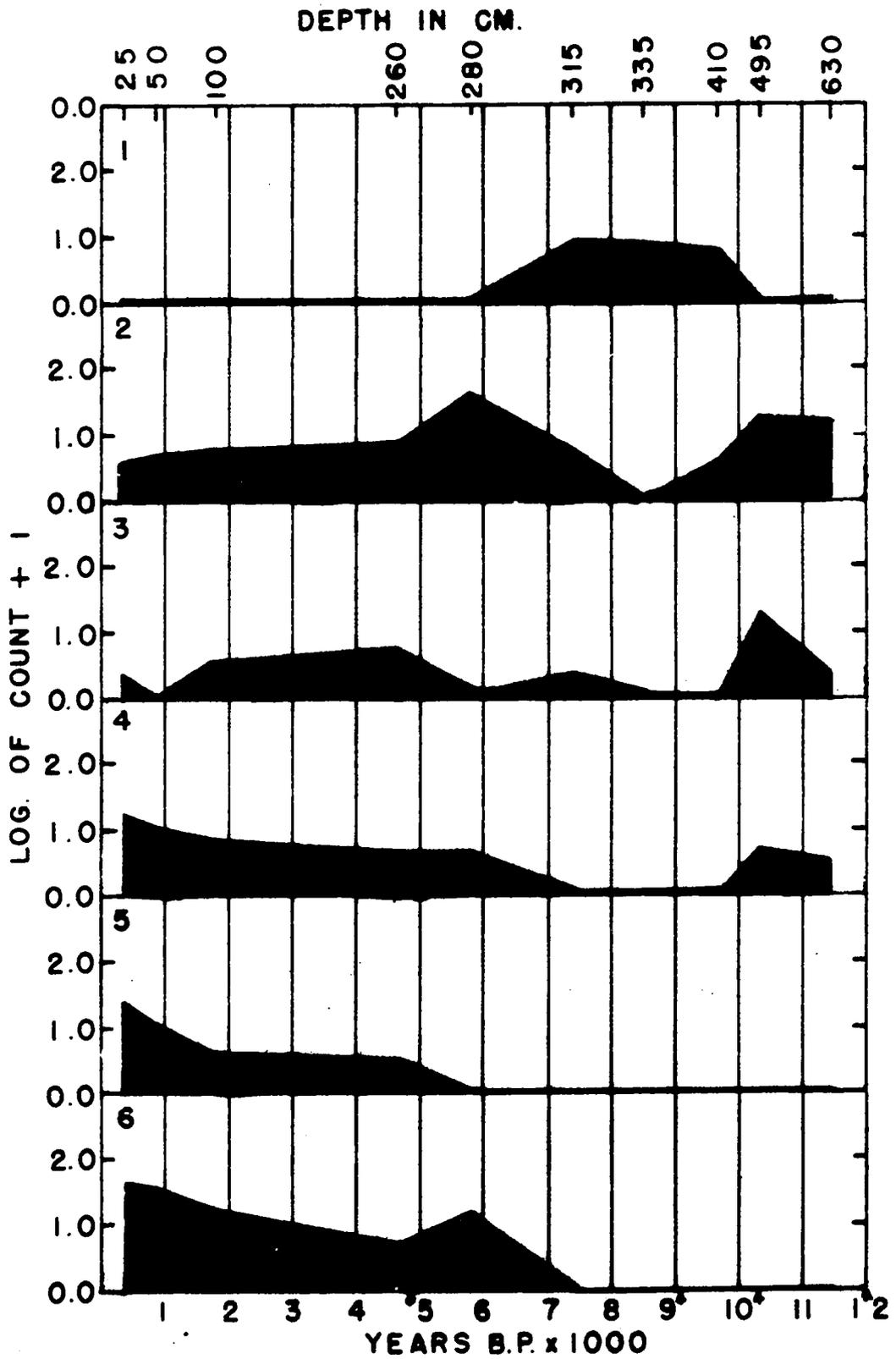


Figure 11 (Continued).

7. Fragilaria brevistriata Grun.
8. Fragilaria construens (Ehr.) Grun.
9. Fragilaria construens var. pumila Grun.
10. Fragilaria lapponica Grun.
11. Fragilaria virescens Ralfs
12. Gomphonema acuminatum var. brebissonii  
(Kutz.) Grun.

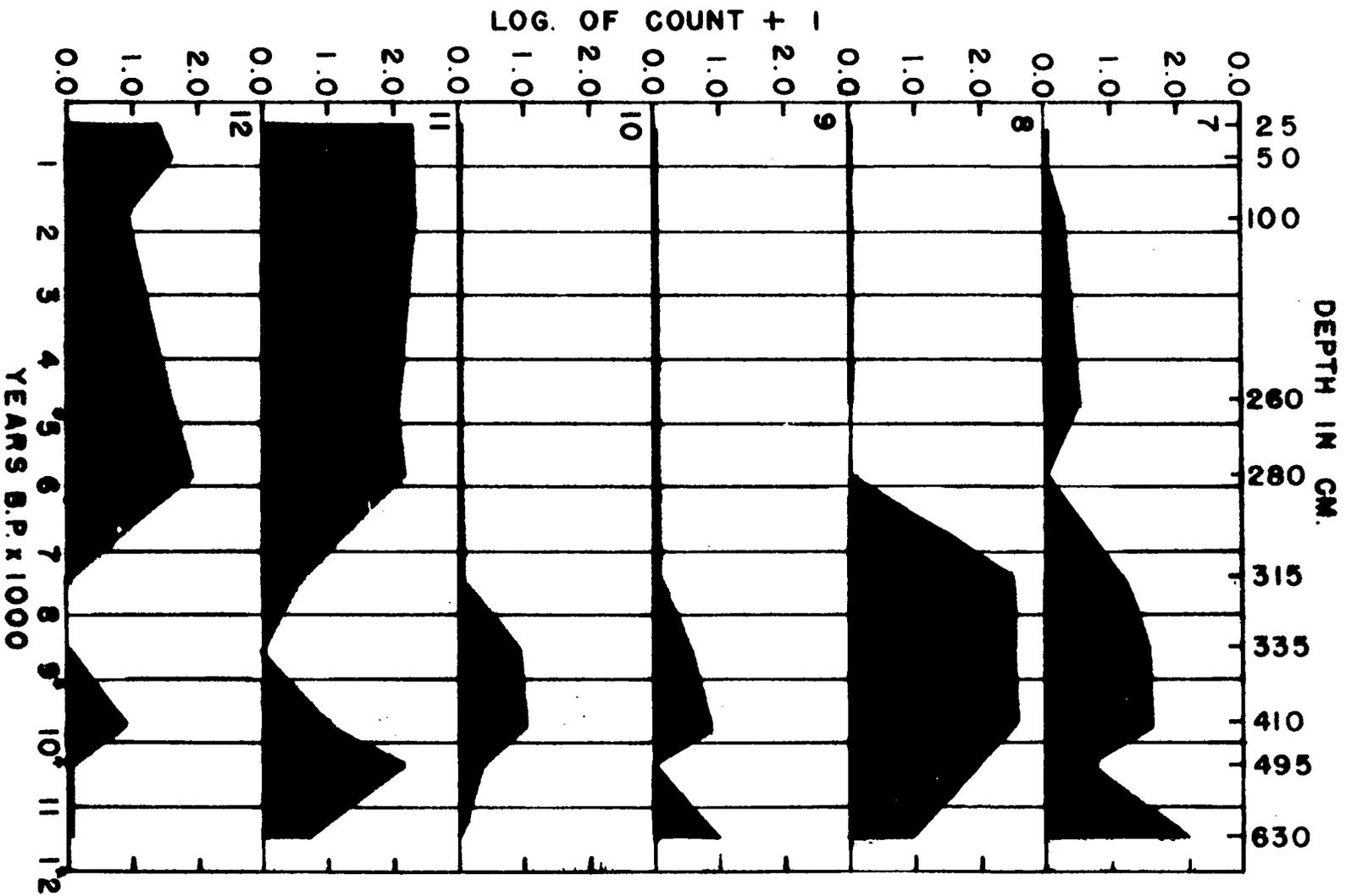


Figure 11 (Continued).

13. Gomphonema angustatum var. sarcophagus (Greg.)  
Grun.
14. Gomphonema constrictum Ehr.
15. Gomphonema gallaudi Herib.
16. Gomphonema intricatum var. pumila Grun.
17. Hantzschia amphioxys var. capitata  
(O. Müll.) Hust.
18. Melosira granulata (Ehr.) Ralfs

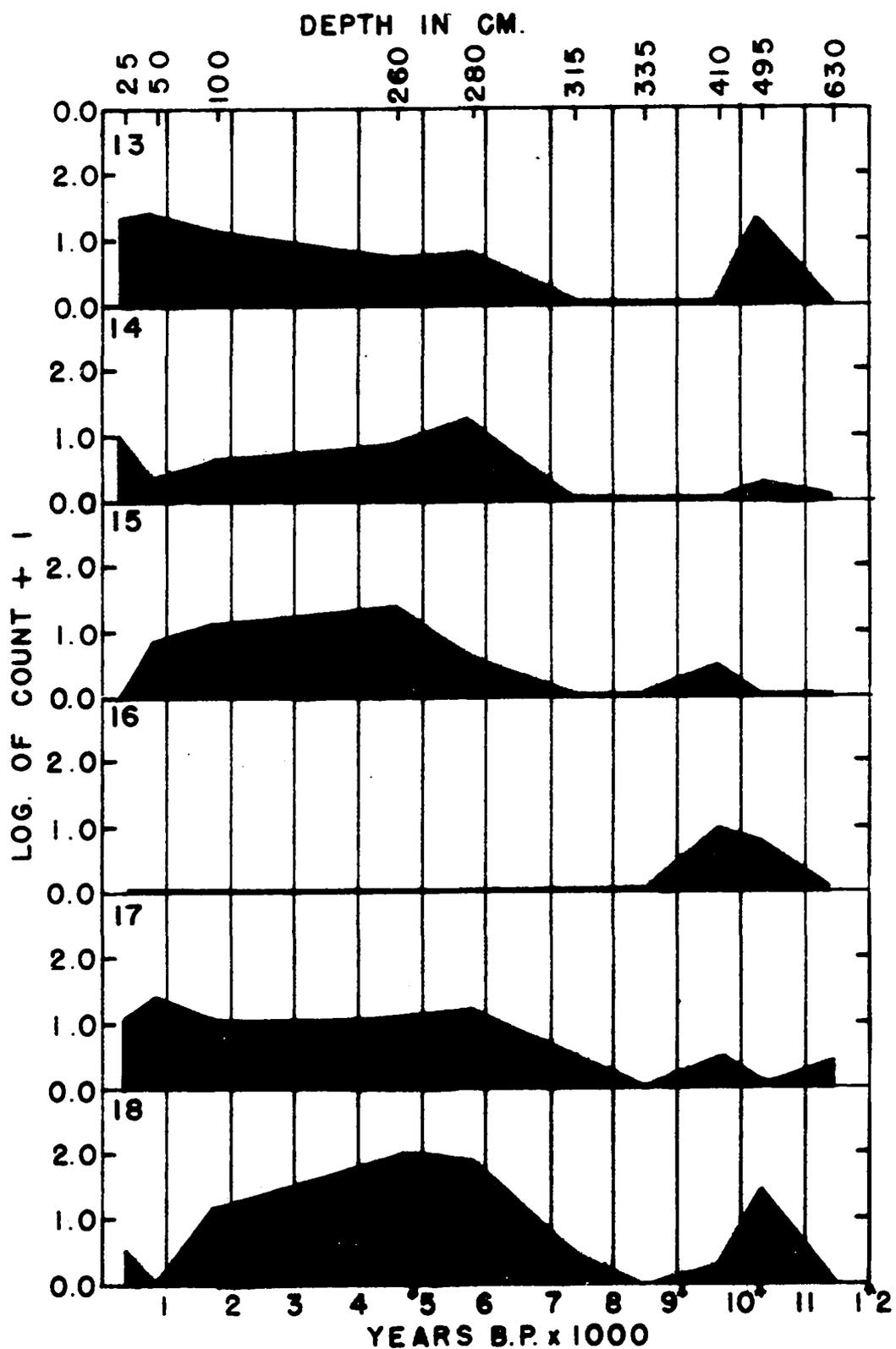


Figure 11 (Continued).

19. Navicula confervaceae (Kutz.) Grun.
20. Navicula elginensis (Greg.) Ralfs
21. Navicula globosa Meist.
22. Navicula pseudoventralis Hust.
23. Navicula seminuloides Hust.
24. Navicula tantula Hust.

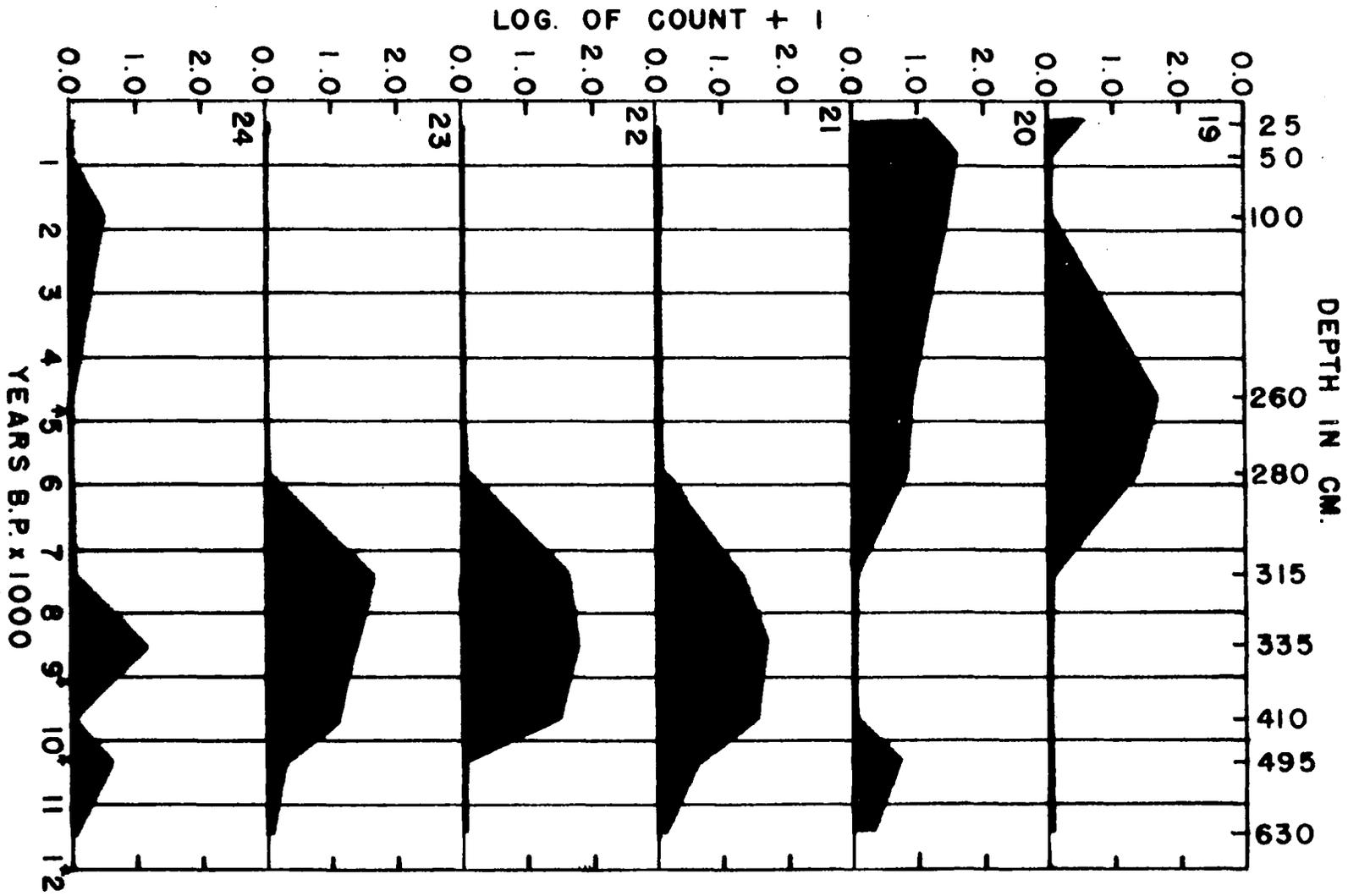


Figure 11 (Continued).

25. Nitzschia amphibia Grun.
26. Opephora ansata Hohn and Hell.
27. Stephanodiscus invisitatus Hohn and Hell.
28. Gomphonema gracile Ehr.
29. Navicula anglica Ralfs
30. Stauroneis phoenicenteron (Nitz.) Ehr.



Achnanthes exigua var. heterovalvata (Figure 11-1) was present only during this interval which suggests alkaline hard water filled the lake. This taxon is considered eurythermal as well as euryphotic and does not provide much insight into other conditions of the period. Fragilaria construens (Figure 11-8) was the major dominant during this period probably indicating littoral conditions almost ideal for it. Considering that the basin was 3-4 m deeper than at present the water level could have been lower than the present level and still too deep for extensive establishment of aquatic vascular plants. The low numbers of epiphytic taxa tend to confirm that the conditions were not suitable for their growth. F. lapponica (Figure 11-10) a form common to circumneutral water of low mineral content occurred at this time for which no clear interpretation seems apparent. Navicula globosa (Figure 11-21) a taxon not previously reported from North America was a dominant species during this interval and was also present in low numbers in older sediments. Its ecology is not well known but it is found in northern and alpine regions of Europe. Its presence may be an indication of prolonged cool spring and fall growing seasons in this interval. Navicula pseudoventralis (Figure 11-22) has a very similarly reported habitat from Europe. It was reported by Stoermer (1963) from Lake West Okoboji. The ecology of Navicula seminuloides (Figure 11-23) has been poorly reported. It has been considered a fresh water form of tropical Asia and Africa. This may indicate the elevation of summer temperatures during this period. Navicula tantula (Figure 11-24) occurred in low numbers at the 335 cm level. Its reported ecology does not seem to fit the picture so far obtained from other taxa since its

presence would indicate the water was acidic. Presence of this species may reflect the existence of a restricted microhabitat in which conditions were especially favorable to it. If the general habitat had been acidic at least several species of the genus Eumotia, a genus that in general, finds optimum development in acid water, should have been present.

Opephora ansata (Figure 11-26) formed a rather large part of the diatom flora during this interval and it is unfortunate that its ecology has not been reported.

The disappearance of some species during this period can add to the interpretation of conditions existing then. Cocconeis placentula (Figure 11-3) was absent at the 410 cm and 335 cm levels and only provided a minor part of the flora at 315 cm level. This would imply a very poor aquatic vascular plant flora in the Kettle Hole since C. placentula is an epiphyte. Fragilaria virescens (Figure 11-11) was observed to have the same general response. However, in this case, the decline is probably not associated with the aquatic vascular plant flora but with other unknown conditions. Hantzschia amphioxys var. capitata (Figure 11-17) was found to be present at either end of this period in low numbers and absent in the middle. This taxon is commonly considered an aerophil. Melosira granulata (Figure 11-18), a plankton form, was essentially absent during this interval which suggests that the water was shallow.

In general the diatom flora in sediments of the Kettle Hole which cover the approximate time span 9,600 to 7,400 years B. P. indicate elevated summer temperatures. The overall temperature rise may have prolonged

the cool spring and fall periods allowing several taxa considered alpine to develop considerable populations. The water level in the basin was probably not deep since planktonic or potentially planktonic species were not present. It seems likely that the basin dried up completely at rather regular intervals, perhaps every year, impeding the establishment of an extensive aquatic vascular plant flora in the basin, as epiphytic diatoms essentially disappear. The many aberrant frustules of Fragilaria construens would support this since the unfavorable conditions induced by the drying up of the habitat tends to lead to changes in diatom valve morphology. As its name indicates this taxon seems to be especially susceptible to changes in morphology. Work in progress based on these floras indicates that many of the varieties of Fragilaria construens are probably not valid and also that some varieties may belong to the genus Opephora.

The ordination of levels indicates the five uppermost levels are somewhat alike and will be discussed as a group covering the time period 5,800 to 500 years B. P.

The populations of Eunotia curvata and E. praerupta (Figure 11-5, 6) at the 25 cm level suggest the water of the pond was rather soft and perhaps the pH was at its lowest point in the postglacial period. Numbers of these two species increase in successively higher levels from the 280 cm level indicating a trend toward lower pH and softer water. The former appears in the flora at 5,800 years B. P. and the latter at 7,400 years B. P. The reported ecology of E. curvata indicates it is the more sensitive of the two and its populations seem to agree with this observation since it became established later and increased in numbers more slowly as

the environment became more suitable. The suggested tendency toward soft water is probably related to the leaching of lime from the till which began to affect the pond water about 6,000 years B. P.

Epiphytic taxa, Amphora ovalis var. affinis and Cocconeis placentula var. lineata (Figure 11-2, 3) both show slight decreases in population from about 6,000 to 900 years B. P. after which numbers of the latter increased slightly.

Littoral forms such as Fragilaria virescens (Figure 11-11) and perhaps Hantzschia amphioxys var. capitata and Navicula elginensis (Figure 11-17, 20) gradually increased in numbers to the 50 cm level and then declined at 25 cm. This would indicate a favorable bottom habitat for these taxa increased until approximately 900 years B. P. and has decreased since then.

The only taxon usually considered planktonic that occurred in this interval was Melosira granulata (Figure 11-18), populations of which decreased gradually from the 260 cm level about 4,900 years B. P. This would seem to indicate the reduction of water depth from 6,000 years B. P. to the present.

## Discussion

The expected difference in diatom floras from the two sites chosen for this study was confirmed. Figure 5, in addition to showing the effectiveness of the ordination technique, indicates that the earliest floras in both sites were more similar to each other than to any succeeding floras from either site. The general trend is to higher values on the x axis for succeeding higher levels from the Kettle Hole while the opposite is true for the levels of the Lake, indicating the floras of the two sites responded oppositely to those factors affecting the x axis. If the ecology of diatoms were more precisely understood it should be possible to assign various factors of the environment to the axes of the ordination. The x axis might primarily reflect temperature, the y axis pH, and the z axis water hardness, for example. It would not be this simple since multiple factors would effect each axis; however, the trend in the aquatic environment probably could be followed with considerably greater precision than is possible at present.

The ordination method of Orloci (1966) utilized the pattern and frequency of occurrence of the taxa to establish their relative positions in three dimensional space. The closer two taxa are located to each other by the ordination the more similar their populations were throughout the core. Those that fell a given distance from the main group of species have been called indicator species. This distance was determined in an arbitrary manner by plotting the coordinate values for each taxon (Appendix A) on three two dimensional graphs as explained in Methods. A more reliable and accurate method should be developed in which the computer

utilizes the coordinate values to establish the location of all points and then very precisely selects the outlying points.

As used here the term indicator species has a different meaning from that used in terrestrial ecology. Rather than being indicators of specific factors in the environment these species are those whose pattern and frequency of occurrence are different from most members of the populations. Thus, a taxon that had identical populations in every level would have a very broad range of tolerance and not tell us much about changes in the environment. But a taxon that shows pulses of growth, through time, indicates that conditions favorable to it are more limited and as climatic changes occurred it was influenced by them. A number of such species were identified by the ordination and it is in this sense that I have called them indicator species.

The general patterns shown by the indicator species (Figures 8 and 11) from both sites agree very well. Aquatic vascular plants were not plentiful early in either location, as indicated by the paucity of epiphytic diatoms. They developed gradually to about 10,000 years B. P. and then declined at both sites, apparently disappearing from the Kettle Hole for several thousand years. There seems to have been no barrier to the arrival of species at either site.

The indicator species populations from the Lake (Figure 8) show marked fluctuations between approximately 5,500 and 2,500 years B. P. This same period of time is not easy to study in the Kettle Hole core since meaningful counts of diatom populations cannot be made in sandy sediments due to the low relative abundance of diatoms and the fact that many of the frustules are badly broken. Heavy rains at some time during

this period may have caused erosion of the steep Kettle Hole slopes, which resulted in the sandy sediments. A major oscillation at 3,400 years B. P. stands out in the Lake populations. High populations of several planktonic species suggests a short period of high water levels and, thus, of high precipitation.

Our knowledge of the sequence and correlation of events during the Wisconsin glacial period has been considerably amplified by the technique of radiocarbon dating in the last few years (Black and Rubin, 1967). Most radiocarbon dates on which error limits can be placed indicate phenomena related to the Wisconsin glaciation were occurring by or prior to 30,000 years B. P. (Ruhe, et al., 1957; Black and Rubin, 1967). In light of this, there may be some question of Heusser's (1964) interpretation of a date greater than 30,000 years B. P. as representing the Sangamon interglacial period. Most chronologies of the Wisconsin place its beginning at about 70,000 years B. P. (Black and Rubin, 1967). Since this is beyond the effective range of the radiocarbon method other techniques must be developed to confirm the chronology of the early Wisconsin, such as the age dependent fluorescence properties of spores and pollen (Van Gijzel et al., 1967). Another very significant use of this technique would be to determine the occurrence and extent of mixing of old material with recent sediments.

Small pieces of wood present in the 690-700 cm level of the Kettle Hole core were identified as coniferous, probably spruce, by Dr. D. W. Benseid, Department of Forestry, Iowa State University. This level was radiocarbon dated at 12,400 years B. P. This wood probably represents the remains of a stand of coniferous trees that occupied the Kettle Hole

basin in very early postglacial time.

The predominantly inorganic sediments from 520 cm to 700 cm in which diatoms are usually broken and bits of wood are present, poses some interesting problems. I suggest that the ice block that presumably formed the basin became covered with outwash, and that vegetation subsequently grew over the buried ice. As it became warmer, the ice block would have melted more each summer until the soil covering it gradually sank and finally broke down, creating an open water situation, as indicated by the diatom flora, for the first time about 11,800 years B. P. Trees growing in the soil above the buried ice block would have sunk to the bottom and provided the source for the bits and pieces of wood in the lower sediments. Some support for this sequence of events is given by Black and Rubin (1967) who state that "ice blocks of different sizes and depth of burial presumably melted out during a relatively long period of time---many hundreds to several thousand years."

Changes noted in the diatom populations in both sites at about 10,400 years B. P. may indicate a lowered water level. Perhaps this is the earliest observable effect of modifications in the weather pattern mentioned previously. The changes begun at this time continued and by 9,500 years B. P. a period of relative stability was established in which the Kettle Hole may have been seasonally dry and the Lake level much lower than at present forming a marsh situation in Little Miller's Bay. The degree of drought necessary to accomplish this is brought more clearly into focus when the depth of the sites at that time is considered. The Kettle Hole basin would have been 5 meters deeper than at present and Little Miller's Bay about 8 meters deeper. The open water area of Lake West Okoboji may

have been significantly reduced in size between approximately 9,000 and 6,000 years B. P.

The occurrence of several species of the genus Eunotia, in the upper half of the Kettle Hole sediments, whose populations increase toward the surface, is a strong indication of the decreasing hardness and pH of the pond water. The presence of soft water in the Lake Okoboji region is not common as the till contains abundant limestone. It seems likely that the soils of the Kettle Hole basin have been gradually leached of calcium carbonate. What was available earlier has been precipitated and buried by the sediments. One possible way in which the calcium could have been removed from the pond cycle is through the activity of certain aquatic plants such as Chara, parts of which occur in the deeper sediments. The appearance of soft water diatoms in the sediments at about 6,000 years B. P. would indicate that the soils of the Kettle Hole basin were becoming depleted of calcium by that time.

Comparison of diatom data with that of recent palynological studies, (West, 1961; Watts and Wright, 1966; Fries, 1962) suggests that diatom populations are more sensitive to environmental change than is the terrestrial phanerogam flora. This is to be expected, since the state of maturity (sensu Margalef, 1963) of aquatic ecosystems is lower than that of terrestrial ecosystems. The greater the maturity of an ecosystem the more capable it is of perpetuating itself in the face of climatic change. Thus pollen profiles may not show minor changes and tend to lag considerably behind the actual environmental changes before they reflect them. This work confirms the concept of a hypsithermal period in postglacial time proposed by Deevy and Flint (1957) and suggests possible time limits

on the period, for this area.

The rapid change in sea level reported to have occurred between 11,000 and 9,000 years B. P. (Cullen, 1967) indicates how rapidly the ice melted. The hypothesis (Dodd et al., In Press) that a change in the weather pattern over northern Iowa began during this period has been previously discussed. The ice mass would probably have retreated sufficiently by this time that its effects on the continental weather pattern rapidly diminished.

Only three taxa reported by Hanna (1932) from a deposit of Pliocene diatoms were not found in the material I studied. This may indicate the relative similarity of climates and the morphologic stability of diatoms or, possibly, that the material Hanna studied was actually of Wisconsin age. He illustrates several morphologic variations of diatoms I have also observed in material radiocarbon dated at less than 12,000 years B. P. Lohman (1938) discusses the distribution of Miocene and Pliocene diatoms in High Plains deposits and reports more taxa that do not occur in post-glacial northern Iowa sediments than does Hanna (1932).

The sediment layers reported by Walker (1966) in Iowa bog profiles were not clearly identifiable as such in the present study. However, the dates which he suggests for the transition between the various levels do agree quite well with observed changes in the diatom floras. The transition from the upper sediment to the upper muck at 3,000 years B. P. (Walker, 1966) seems to represent a point near the end of the post-hypsithermal period. Climatic conditions probably had stabilized sufficiently by this time for the slopes of the bogs he studied to have become well vegetated and the erosion rate was thus reduced. The post-hypsithermal

period seems to have begun about 5,500 years B. P., about midway in the period identified by Walker (1966) as the upper silt. The next major change in the diatom flora prior to 5,500 years B. P. is at 9,000 years B. P. and probably corresponds to the upper silt-lower muck transition of Walker, which he placed at 8,000 years B. P. The period 11,500 to 9,000 years B. P. probably corresponds with Walker's lower muck which he felt represented a period of relative stability and extended from 10,500 to 8,000 years B. P. Diatom populations fluctuate during this period probably reflecting varying precipitation rates. A general trend perhaps reflecting changes associated with increasing temperatures leading to the hypsithermal is also evident. The period prior to 11,500 years B. P. contained some of the most distinct diatom floras found. The area undoubtedly was still strongly effected by the proximity of glacial ice at that time. Diatom floras appeared in the Lake at about 12,400 years B. P. and in the Kettle Hole about 11,800 years B. P. The transition to Cary drift at 13,000 years B. P. estimated by Walker (1966) seems reasonable.

## SUMMARY

1. This investigation suggests that fossil diatoms provide a sensitive record of past climatic events.
2. Potentially, the study of diatom floras should provide very accurate estimates of the physicochemical conditions of their aquatic environment, past or present, but the present state of knowledge related to optimum growth conditions for given taxa makes this impossible.
3. A need is recognized for ecological records of the seasonal extent of optimal growth periods for the various taxa. These would be useful in more accurate interpretations of fossil diatom floras.
4. Orloci's (1966) ordination technique has provided a most useful method for identifying relative similarities between levels and species in each core making it possible to identify those levels and taxa that are different. Indicator species and levels obtained in this way were emphasized in the interpretation of the cores.
5. Two hundred fifty-three taxa were identified in the course of the investigation. Of these 210 were observed in counts from the Lake site and 112 were found in the Kettle Hole. Eighty-eight taxa occurred in both sites.
6. The Kettle Hole developed a diatom flora about 11,800 years B. P. and the Lake about 12,400 years B. P.
7. A period of gradual climatic change is indicated by the diatom floras until approximately 10,400 years B. P. when a more abrupt change occurred. It is suggested that this change was related to the diminishing effect of the retreating glacier on local climate.

8. Gradual climatic change occurred from 10,400 to 9,000 years B. P. at which time a period of relatively constant conditions were established and continued until about 6,000 years B. P. Evidence is not conclusive but conditions during this period probably were warmer than present and precipitation rates lower and/or generally restricted to a brief period during the year. This is the so-called hypsithermal interval.
9. A period of oscillating climatic changes, not previously reported, is indicated by diatom floras in the 6,000 to 2,800 year B. P. interval. The probable trends in climatic conditions were steadily lowering temperatures to about 3,400 years B. P., after which a warming trend was established, and widely varying precipitation rates throughout the whole interval. The modern climate seems to have been established about 2,800 years B. P. with changes since that time being toward higher temperatures.
10. The chronology of climatic change suggested here is in general agreement with that proposed by soil scientists and palynologists. However, the periods of change reflected by diatom floras are consistently placed earlier than in comparable investigations based on fossil pollen.
11. Both sites originally contained diatom floras characteristic of hard alkaline water. All succeeding Lake floras have been indicative of alkaline hard water while the Kettle Hole floras suggest a trend toward softer water beginning at 6,000 years B. P.

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**APPENDIX A**

Table 1. Coordinates for three-dimensional ordination of levels from Little Miller's Bay core

| Depths<br>in cm | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|-----------------|------------------|------------------|------------------|
| 30.5            | 8.325            | 2.403            | 4.864            |
| 91.5            | 9.299            | 3.398            | 4.683            |
| 122.0           | 7.072            | 2.672            | 4.199            |
| 152.5           | 6.504            | 4.060            | 3.456            |
| 183.0           | 3.626            | 2.632            | -0.853           |
| 213.5           | 5.578            | 0.183            | 0.616            |
| 244.0           | 6.437            | 1.148            | -0.528           |
| 274.5           | 8.312            | 0.164            | -1.114           |
| 305.0           | 6.397            | -0.378           | 1.023            |
| 335.5           | 0.000            | -0.000           | 0.000            |
| 366.0           | 5.129            | 1.994            | -0.956           |
| 396.5           | 4.543            | 2.070            | -1.393           |
| 427.0           | 4.603            | 5.097            | 0.364            |
| 457.5           | 7.004            | 2.103            | 1.534            |
| 488.0           | 4.796            | 3.887            | -1.155           |
| 518.5           | 5.191            | 7.616            | -2.029           |
| 549.0           | 7.272            | 7.598            | 2.229            |
| 579.5           | 5.883            | 12.271           | -1.016           |
| 610.0           | 6.276            | 8.834            | 0.431            |
| 671.0           | 5.291            | 6.447            | -0.123           |
| 701.5           | 5.508            | 7.745            | -1.139           |
| 732.0           | 7.821            | 4.360            | 0.046            |
| 762.5           | 5.857            | 5.858            | -0.153           |
| 793.0           | 5.658            | 5.321            | 0.633            |
| 823.5           | 5.440            | 4.227            | 0.031            |
| 884.5           | 8.605            | 1.839            | 0.700            |
| 976.0           | 13.753           | 0.917            | -1.780           |
| 1006.5          | 16.523           | 0.000            | -2.360           |

Table 2. Coordinates for three-dimensional ordination of taxa from Little Miller's Bay core

| <u>Taxon</u>  | <u>x</u><br><u>coordinates</u> | <u>y</u><br><u>coordinates</u> | <u>z</u><br><u>coordinates</u> |
|---|--------------------------------|--------------------------------|--------------------------------|
| <u>Achnanthes clevei</u>                            | 3.746                          | 1.871                          | -7.010                         |
| <u>Achnanthes clevei</u> v.<br><u>rostrata</u>      | 1.093                          | 1.049                          | -4.237                         |
| <u>Achnanthes conspicua</u>                         | 1.141                          | 0.799                          | -5.117                         |
| <u>Achnanthes deflexa</u>                           | 0.546                          | 0.869                          | -3.805                         |
| <u>Achnanthes exigua</u>                            | 2.296                          | 0.280                          | -4.310                         |
| <u>Achnanthes exigua</u> v.<br><u>heterovalvata</u> | 1.110                          | 2.076                          | -3.999                         |
| <u>Achnanthes haukiana</u>                          | 4.960                          | 0.936                          | -4.679                         |
| <u>Achnanthes lanceolata</u>                        | 7.809                          | 0.800                          | -4.289                         |
| <u>Achnanthes lanceolata</u> v.<br><u>dubia</u>     | 1.007                          | 1.120                          | -4.344                         |
| <u>Achnanthes lewisana</u>                          | 2.279                          | -1.178                         | -5.865                         |
| <u>Achnanthes microcephala</u>                      | 1.016                          | 0.511                          | -4.100                         |
| <u>Achnanthes minutissima</u>                       | 4.240                          | -0.438                         | -6.541                         |
| <u>Achnanthes pinnata</u>                           | 0.864                          | 0.845                          | -3.821                         |
| <u>Amphipleura pellucida</u>                        | 0.885                          | 0.935                          | -4.375                         |
| <u>Amphora ovalis</u>                               | 5.518                          | 0.798                          | -7.527                         |
| <u>Amphora ovalis</u> v. <u>affinis</u>             | 12.534                         | 1.293                          | 3.563                          |
| <u>Amphora ovalis</u> v.<br><u>pediculus</u>        | 12.411                         | 0.496                          | 1.839                          |
| <u>Amphora sabyii</u>                               | 0.847                          | 1.034                          | -4.095                         |
| <u>Amphora veneta</u>                               | 3.576                          | 0.119                          | -6.852                         |
| <u>Anomoeoneis sphaerophora</u>                     | 1.189                          | 0.632                          | -4.232                         |

Table 2 (Continued).

| <u>Taxon</u>   | <u>x</u><br><u>coordinates</u> | <u>y</u><br><u>coordinates</u> | <u>z</u><br><u>coordinates</u> |
|--|--------------------------------|--------------------------------|--------------------------------|
| <u>Anomoeoneis sphaerophora</u><br><u>v. sculpta</u> | 0.576                          | 0.878                          | -3.741                         |
| <u>Asterionella formosa</u>                          | 1.387                          | 1.041                          | -4.911                         |
| <u>Caloneis bacillum</u>                             | 1.872                          | 0.821                          | -5.357                         |
| <u>Caloneis limosa</u>                               | 0.468                          | 0.924                          | -3.394                         |
| <u>Caloneis ventricosa</u>                           | 0.655                          | 0.633                          | -3.749                         |
| <u>Caloneis ventricosa v.</u><br><u>subundulata</u>  | 0.601                          | 1.126                          | -3.680                         |
| <u>Caloneis sp. 1</u>                                | 0.530                          | 0.651                          | -3.621                         |
| <u>Cocconeis disculus</u>                            | 0.661                          | 0.786                          | -3.638                         |
| <u>Cocconeis pediculus</u>                           | 1.019                          | 0.460                          | -4.205                         |
| <u>Cocconeis placentula v.</u><br><u>lineata</u>     | 23.353                         | 0.000                          | -6.612                         |
| <u>Cyclotella bodanica</u>                           | 5.531                          | 4.732                          | -7.573                         |
| <u>Cyclotella kutzingiana</u>                        | 2.246                          | 1.684                          | -5.513                         |
| <u>Cyclotella meneghiniana</u>                       | 1.340                          | 0.506                          | -4.666                         |
| <u>Cyclotella ocellata</u>                           | 0.277                          | 0.501                          | -2.202                         |
| <u>Cyclotella striata</u>                            | 0.864                          | 0.847                          | -3.884                         |
| <u>Cymbella aspera</u>                               | 0.575                          | 0.869                          | -3.777                         |
| <u>Cymbella cistula</u>                              | 7.257                          | -0.124                         | -5.644                         |
| <u>Cymbella cistula v.</u><br><u>maculata</u>        | 2.064                          | 1.217                          | -6.352                         |
| <u>Cymbella cuspidata</u>                            | 1.573                          | 0.837                          | -4.128                         |
| <u>Cymbella ehrenbergii</u>                          | 1.268                          | -0.124                         | -3.731                         |

Table 2 (Continued).

| <u>Taxon</u>                                  | <u>x</u><br><u>coordinates</u> | <u>y</u><br><u>coordinates</u> | <u>z</u><br><u>coordinates</u> |
|---|--------------------------------|--------------------------------|--------------------------------|
| <u>Cymbella mexicana</u>                      | 1.596                          | 1.589                          | -4.689                         |
| <u>Cymbella microcephala</u>                  | 2.821                          | -0.363                         | -6.052                         |
| <u>Cymbella muelleri</u>                      | 1.237                          | 0.773                          | -4.011                         |
| <u>Cymbella obtusiuscula</u>                  | 0.668                          | 0.847                          | -3.769                         |
| <u>Cymbella parvula</u>                       | 0.130                          | 0.268                          | -1.363                         |
| <u>Cymbella rhomboidea</u>                    | 0.575                          | 0.869                          | -3.777                         |
| <u>Cymbella ruttneri</u>                      | 1.969                          | -0.209                         | -5.865                         |
| <u>Cymbella ventricosa</u>                    | 2.023                          | 1.082                          | -5.685                         |
| <u>Cymbella sp. 1</u>                         | 1.590                          | 1.916                          | -5.248                         |
| <u>Cymbella sp. 2</u>                         | 0.000                          | -0.000                         | 0.000                          |
| <u>Cymatopleura elliptica</u>                 | 0.736                          | 0.711                          | -4.012                         |
| <u>Cymatopleura solea</u>                     | 2.083                          | 0.444                          | -5.484                         |
| <u>Diploneis oculata</u>                      | 0.789                          | 0.835                          | -4.352                         |
| <u>Epithemia sorex</u>                        | 1.911                          | 0.268                          | -4.931                         |
| <u>Epithemia turgida</u>                      | 6.099                          | -0.153                         | -6.170                         |
| <u>Epithemia zebra v.</u><br><u>porcellus</u> | 6.344                          | -1.242                         | -6.287                         |
| <u>Epithemia zebra v.</u><br><u>saxonica</u>  | 2.407                          | 0.407                          | -5.372                         |
| <u>Epithemia zebra v. zebra</u>               | 0.760                          | 0.859                          | -4.350                         |
| <u>Eunotia curvata</u>                        | 0.532                          | 1.019                          | -3.638                         |
| <u>Eunotia pectinalis v. minor</u>            | 0.546                          | 0.869                          | -3.805                         |
| <u>Eunotia valida</u>                         | 0.535                          | 0.886                          | -3.534                         |

Table 2 (Continued).

| Taxon   | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|---|------------------|------------------|------------------|
| <u>Fragilaria brevistriata</u>                        | 17.557           | 0.584            | -9.630           |
| <u>Fragilaria capucina</u>                            | 1.527            | 1.605            | -4.989           |
| <u>Fragilaria capucina</u> v.<br><u>mesolepta</u>     | 8.281            | 1.146            | -7.057           |
| <u>Fragilaria construens</u>                          | 4.957            | -0.811           | -4.434           |
| <u>Fragilaria construens</u> v.<br><u>binodis</u>     | 1.324            | 1.324            | -4.876           |
| <u>Fragilaria construens</u> v.<br><u>pumila</u>      | 0.418            | 0.804            | -3.267           |
| <u>Fragilaria crotonensis</u>                         | 3.979            | -0.673           | -6.810           |
| <u>Fragilaria crotonensis</u> v.<br><u>oregona</u>    | 1.290            | 1.150            | -4.928           |
| <u>Fragilaria lapponica</u>                           | 0.752            | 0.501            | -0.983           |
| <u>Fragilaria pinnata</u>                             | 8.201            | 1.476            | -3.658           |
| <u>Fragilaria pinnata</u> v.<br><u>lancettula</u>     | 1.123            | 1.137            | -4.974           |
| <u>Fragilaria vaucheriae</u>                          | 10.486           | -0.548           | -2.719           |
| <u>Fragilaria</u> sp. 1                               | 0.875            | 0.501            | -4.289           |
| <u>Gomphonema acuminatum</u>                          | 1.758            | 0.834            | -5.440           |
| <u>Gomphonema angustatum</u> v.<br><u>sarcophagus</u> | 0.631            | 0.894            | -3.774           |
| <u>Gomphonema constrictum</u>                         | 2.848            | 0.713            | -5.774           |
| <u>Gomphonema constrictum</u> v.<br><u>capitata</u>   | 0.534            | 0.912            | -3.630           |
| <u>Gomphonema gracile</u>                             | 3.147            | 1.645            | -6.652           |
| <u>Gomphonema intricatum</u>                          | 8.625            | 1.101            | -6.022           |

Table 2 (Continued).

| Taxon   | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|---|------------------|------------------|------------------|
| <u>Gomphonema intricatum</u> v.<br><u>pumila</u>  | 11.885           | -1.479           | -2.009           |
| <u>Gomphonema intricatum</u> v. 1                 | 0.543            | 0.865            | -3.640           |
| <u>Gomphonema mexicanum</u>                       | 2.436            | -0.162           | -6.072           |
| <u>Gomphonema olivaceum</u>                       | 3.078            | 1.337            | -6.877           |
| <u>Gomphonema parvulum</u>                        | 1.884            | 0.511            | -5.479           |
| <u>Gomphonema sphaerophorum</u>                   | 0.806            | 1.040            | -3.971           |
| <u>Gomphonema</u> sp. 1                           | 1.308            | 2.118            | -4.245           |
| <u>Gomphoneis erienne</u>                         | 0.791            | 1.314            | -3.836           |
| <u>Gyrosigma attenuatum</u>                       | 1.702            | 1.113            | -4.306           |
| <u>Gyrosigma spencerii</u>                        | 2.529            | 1.982            | -5.702           |
| <u>Hantzschia amphioxys</u>                       | 1.170            | 1.022            | -4.455           |
| <u>Hantzschia amphioxys</u> v.<br><u>capitata</u> | 2.417            | 0.958            | -5.254           |
| <u>Mastogloia grevellei</u>                       | 0.386            | 0.414            | -2.765           |
| <u>Mastogloia smithii</u> v.<br><u>lacustris</u>  | 0.966            | 0.190            | -2.540           |
| <u>Meridion circulare</u>                         | 0.690            | 0.961            | -3.892           |
| <u>Melosira ambigua</u>                           | 0.468            | 0.924            | -3.394           |
| <u>Melosira granulata</u>                         | 12.854           | -0.082           | 0.936            |
| <u>Navicula americana</u>                         | 0.526            | 1.036            | -3.654           |
| <u>Navicula anglica</u>                           | 2.658            | 0.624            | -6.271           |
| <u>Navicula aurora</u>                            | 0.318            | 0.728            | -2.953           |
| <u>Navicula bacillum</u>                          | 0.672            | 1.016            | -3.851           |

Table 2 (Continued).

| <u>Taxon</u>  | <u>x</u><br><u>coordinates</u> | <u>y</u><br><u>coordinates</u> | <u>z</u><br><u>coordinates</u> |
|---|--------------------------------|--------------------------------|--------------------------------|
| <u>Navicula biconica</u>                            | 0.891                          | 0.796                          | -4.178                         |
| <u>Navicula capitata</u>                            | 1.789                          | 0.718                          | -5.264                         |
| <u>Navicula capitata v.</u><br><u>hungarica</u>     | 6.485                          | -0.515                         | -7.271                         |
| <u>Navicula cincta</u>                              | 3.911                          | 3.525                          | -7.464                         |
| <u>Navicula clementis</u>                           | 1.431                          | 1.297                          | -5.472                         |
| <u>Navicula cocconeiformis</u>                      | 0.565                          | 1.147                          | -3.483                         |
| <u>Navicula confervacea</u>                         | 0.775                          | 1.173                          | -3.866                         |
| <u>Navicula cryptocephala v.</u><br><u>veneta</u>   | 4.258                          | -1.543                         | -7.405                         |
| <u>Navicula cuspidata</u>                           | 2.571                          | 0.228                          | -5.887                         |
| <u>Navicula cuspidata v. heri-</u><br><u>baudii</u> | 0.625                          | 0.865                          | -3.999                         |
| <u>Navicula elginensis</u>                          | 1.508                          | 0.763                          | -4.848                         |
| <u>Navicula exigua v. capitata</u>                  | 0.861                          | 1.133                          | -4.014                         |
| <u>Navicula explanta</u>                            | 0.757                          | 1.384                          | -3.633                         |
| <u>Navicula graciloides</u>                         | 11.707                         | -0.736                         | -1.454                         |
| <u>Navicula halophila</u>                           | 1.961                          | -0.882                         | -5.237                         |
| <u>Navicula helensis</u>                            | 0.508                          | 1.047                          | -3.476                         |
| <u>Navicula heufleri</u>                            | 3.586                          | 0.873                          | -6.112                         |
| <u>Navicula heufleri v.</u><br><u>leptocephala</u>  | 3.164                          | 0.863                          | -5.832                         |
| <u>Navicula ilopangoensis</u>                       | 0.563                          | 0.885                          | -3.809                         |
| <u>Navicula integra v. 1</u>                        | 0.535                          | 0.886                          | -3.534                         |

Table 2 (Continued).

| <u>Taxon</u>   | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|--|------------------|------------------|------------------|
| <u>Navicula laevissima</u>                             | 3.990            | 0.927            | -6.097           |
| <u>Navicula latens</u>                                 | 0.501            | 0.953            | -3.354           |
| <u>Navicula minima</u>                                 | 0.468            | 0.924            | -3.394           |
| <u>Navicula mournei</u>                                | 0.209            | 0.392            | -1.810           |
| <u>Navicula mutica</u>                                 | 2.026            | 1.207            | -5.170           |
| <u>Navicula mutica</u> v. <u>cohnii</u>                | 1.973            | 1.231            | -4.917           |
| <u>Navicula mutica</u> v. <u>undulata</u>              | 0.571            | 0.803            | -3.795           |
| <u>Navicula oblonga</u>                                | 5.086            | -0.238           | -7.365           |
| <u>Navicula oppugnata</u>                              | 1.895            | 0.619            | -5.865           |
| <u>Navicula perventralis</u>                           | 0.626            | 0.471            | -3.811           |
| <u>Navicula planentula</u>                             | 0.982            | 0.709            | -4.491           |
| <u>Navicula playtcephala</u>                           | 1.584            | 0.071            | -5.376           |
| <u>Navicula pseudoventralis</u>                        | 0.641            | -0.923           | -1.710           |
| <u>Navicula pupula</u> v. <u>mutata</u>                | 1.192            | 1.045            | -4.686           |
| <u>Navicula pupula</u> v.<br><u>rectangularis</u>      | 5.282            | 0.817            | -7.074           |
| <u>Navicula pygmaea</u>                                | 1.161            | 1.210            | -4.503           |
| <u>Navicula radiosa</u>                                | 5.438            | -0.605           | -6.676           |
| <u>Navicula radiosa</u> v. <u>tenella</u>              | 3.044            | 0.280            | -6.352           |
| <u>Navicula reinhardtii</u>                            | 4.707            | 1.612            | -6.390           |
| <u>Navicula rhynchocephala</u>                         | 1.193            | 1.341            | -4.810           |
| <u>Navicula rhynchocephala</u> v.<br><u>amphiceros</u> | 4.802            | 0.781            | -7.046           |

Table 2 (Continued).

| Taxon   | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|---|------------------|------------------|------------------|
| <u>Navicula salinarum</u> v.<br><u>intermedia</u> | 0.859            | 1.176            | -3.969           |
| <u>Navicula scutelloides</u>                      | 4.150            | 0.257            | -5.618           |
| <u>Navicula securo</u>                            | 0.534            | 0.912            | -3.630           |
| <u>Navicula seminuloides</u>                      | 0.795            | 0.632            | -2.908           |
| <u>Navicula skabitschewskyi</u>                   | 1.331            | 1.746            | -4.474           |
| <u>Navicula stroesii</u>                          | 0.572            | 0.708            | -3.780           |
| <u>Navicula texana</u>                            | 0.744            | 0.870            | -3.772           |
| <u>Navicula tripunctata</u>                       | 0.837            | 0.610            | -3.926           |
| <u>Navicula tuscula</u>                           | 0.803            | 0.633            | -4.123           |
| <u>Navicula tuscula</u> v. 1                      | 0.791            | 0.474            | -4.040           |
| <u>Navicula tuscula</u> v. 2                      | 0.565            | 1.147            | -3.483           |
| <u>Navicula</u> sp. 1                             | 0.740            | 0.963            | -3.672           |
| <u>Navicula</u> sp. 3                             | 1.085            | 1.449            | -4.392           |
| <u>Navicula</u> sp. 4                             | 4.210            | 1.069            | -6.629           |
| <u>Navicula</u> sp. 5                             | 0.508            | 1.047            | -3.476           |
| <u>Navicula</u> sp. 6                             | 0.532            | 0.985            | -3.625           |
| <u>Navicula</u> sp. 7                             | 0.671            | 0.827            | -4.105           |
| <u>Navicula</u> sp. 8                             | 0.757            | 0.618            | -4.224           |
| <u>Navicula</u> sp. 9                             | 0.600            | 0.914            | -3.539           |
| <u>Navicula</u> sp. 10                            | 0.626            | 0.471            | -3.811           |
| <u>Navicula</u> sp. 11                            | 0.329            | 0.616            | -2.594           |

Table 2 (Continued).

| <u>Taxon</u>                            | <u>x</u><br><u>coordinates</u> | <u>y</u><br><u>coordinates</u> | <u>z</u><br><u>coordinates</u> |
|---|--------------------------------|--------------------------------|--------------------------------|
| <u>Neidium affine</u>                   | 1.159                          | 0.710                          | -4.205                         |
| <u>Neidium dubium</u>                   | 0.595                          | 1.227                          | -3.689                         |
| <u>Neidium dubium v. constrictum</u>    | 0.682                          | 0.365                          | -3.909                         |
| <u>Neidium iridis</u>                   | 1.744                          | 0.776                          | -5.215                         |
| <u>Neidium sp. 1</u>                    | 0.575                          | 0.844                          | -3.874                         |
| <u>Nitzschia amphibia</u>               | 11.591                         | 0.263                          | -3.710                         |
| <u>Nitzschia angustata</u>              | 1.469                          | 0.720                          | -5.014                         |
| <u>Nitzschia commutata</u>              | 0.575                          | 0.869                          | -3.777                         |
| <u>Nitzschia denticula</u>              | 0.546                          | 0.869                          | -3.805                         |
| <u>Nitzschia frustulum</u>              | 2.466                          | 0.180                          | -6.368                         |
| <u>Nitzschia frustulum v. perminuta</u> | 1.942                          | 0.774                          | -5.127                         |
| <u>Nitzschia gracilis</u>               | 0.768                          | 1.231                          | -3.877                         |
| <u>Nitzschia palea</u>                  | 0.791                          | 0.804                          | -4.405                         |
| <u>Nitzschia sigmoidea</u>              | 1.270                          | 0.697                          | -4.748                         |
| <u>Nitzschia sublinearis</u>            | 0.575                          | 0.844                          | -3.874                         |
| <u>Nitzschia vermicularis</u>           | 0.670                          | 0.704                          | -3.909                         |
| <u>Nitzschia sp. 1</u>                  | 1.167                          | 1.138                          | -4.742                         |
| <u>Opephora ansata</u>                  | 9.926                          | -1.000                         | -2.204                         |
| <u>Opephora martyi</u>                  | 2.264                          | 1.667                          | -3.039                         |
| <u>Pinnularia appendiculata</u>         | 0.588                          | 0.703                          | -3.473                         |
| <u>Pinnularia borealis</u>              | 0.418                          | 0.804                          | -3.267                         |
| <u>Pinnularia brebissonii</u>           | 2.687                          | 0.801                          | -5.999                         |
| <u>Pinnularia intermedia</u>            | 0.628                          | 0.757                          | -3.679                         |

Table 2 (Continued).

| <u>Taxon</u>                                | <u>x</u><br><u>coordinates</u> | <u>y</u><br><u>coordinates</u> | <u>z</u><br><u>coordinates</u> |
|---|--------------------------------|--------------------------------|--------------------------------|
| <u>Pinnularia kneuckeri</u>                 | 0.570                          | 0.952                          | -3.830                         |
| <u>Pinnularia maior</u>                     | 0.659                          | 0.850                          | -3.844                         |
| <u>Pinnularia obscura</u>                   | 0.575                          | 0.869                          | -3.777                         |
| <u>Pinnularia stomatophora</u>              | 0.572                          | 0.708                          | -3.780                         |
| <u>Rhoicosphenia curvata</u>                | 6.093                          | 1.412                          | -7.665                         |
| <u>Rhopalodia gibba</u>                     | 5.001                          | -1.982                         | -6.050                         |
| <u>Rhopalodia gibberula v. protracta</u>    | 0.940                          | 1.109                          | -4.230                         |
| <u>Stauroneis acuta</u>                     | 0.531                          | 1.033                          | -3.601                         |
| <u>Stauroneis smithii v. 1</u>              | 0.576                          | 0.878                          | -3.741                         |
| <u>Stauroneis sp. 1</u>                     | 0.508                          | 1.047                          | -3.476                         |
| <u>Stephanodiscus astraea</u>               | 2.792                          | 0.343                          | -5.732                         |
| <u>Stephanodiscus astraea v. minutula</u>   | 15.506                         | 8.241                          | -0.483                         |
| <u>Stephanodiscus invisitatus</u>           | 7.378                          | 2.727                          | -7.009                         |
| <u>Stephanodiscus niagarae</u>              | 4.119                          | -0.444                         | -6.086                         |
| <u>Stephanodiscus niagarea v. magnifica</u> | 5.487                          | -0.639                         | -7.636                         |
| <u>Surirella biseriata v. bifrons</u>       | 0.537                          | 0.574                          | -2.793                         |
| <u>Surirella pinnata</u>                    | 1.191                          | 1.360                          | -4.500                         |
| <u>Surirella turgida</u>                    | 1.016                          | 0.775                          | -4.399                         |
| <u>Synedra capitata</u>                     | 0.735                          | 0.645                          | -3.393                         |
| <u>Synedra delicatissima</u>                | 1.339                          | 0.265                          | -5.071                         |
| <u>Synedra parasitica</u>                   | 4.639                          | 1.352                          | -6.925                         |
| <u>Synedra ulna</u>                         | 3.162                          | 1.318                          | -6.165                         |
| <u>Synedra rumpens v. fragilarioides</u>    | 2.202                          | 1.359                          | -5.866                         |

Table 3. Coordinates for three-dimensional ordination of levels from Kettle Hole core.

| Depths<br>in cm | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|-----------------|------------------|------------------|------------------|
| 25              | 0.000            | -0.000           | 0.000            |
| 50              | 2.699            | 1.057            | -3.547           |
| 100             | 3.645            | 2.863            | -2.944           |
| 260             | 4.484            | 4.424            | -3.834           |
| 280             | 3.402            | 3.283            | -3.912           |
| 315             | 14.741           | 1.767            | 6.327            |
| 335             | 17.092           | 0.000            | 7.130            |
| 410             | 14.758           | 1.430            | 5.907            |
| 495             | 7.727            | 11.025           | -2.425           |
| 630             | 11.482           | 2.838            | -1.224           |

Table 4. Coordinates for three-dimensional ordination of levels from Kettle Hole core

| Taxon   | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|---|------------------|------------------|------------------|
| <u>Achnanthes clevei</u>                            | 5.769            | 8.515            | -1.702           |
| <u>Achnanthes deflexa</u>                           | 5.791            | 8.503            | -1.425           |
| <u>Achnanthes exigua</u>                            | 5.355            | 8.888            | -0.865           |
| <u>Achnanthes exigua v.</u><br><u>heterovalvata</u> | 3.395            | 6.221            | 2.479            |
| <u>Achnanthes haukiana</u>                          | 5.915            | 8.363            | -2.007           |
| <u>Achnanthes hungarica</u>                         | 5.162            | 8.433            | -0.705           |
| <u>Achnanthes lanceolata</u>                        | 6.006            | 7.104            | -1.640           |
| <u>Achnanthes lanceolata v.</u><br><u>dubia</u>     | 4.528            | 7.586            | -0.031           |
| <u>Achnanthes minutissima</u>                       | 5.039            | 8.567            | 0.428            |
| <u>Amphicampa mirabilis</u>                         | 5.898            | 8.445            | -1.536           |

Table 4 (Continued).

| Taxon  | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|--|------------------|------------------|------------------|
| <u>Amphora ovalis</u>                                | 5.640            | 8.584            | -1.136           |
| <u>Amphora ovalis</u> v. <u>affinis</u>              | 8.083            | 4.990            | -1.624           |
| <u>Amphora ovalis</u> v.<br><u>pediculus</u>         | 5.069            | 8.480            | -0.467           |
| <u>Amphora sabyii</u>                                | 5.245            | 8.075            | -0.730           |
| <u>Amphora veneta</u>                                | 5.417            | 8.392            | -0.920           |
| <u>Amphora</u> sp. 1                                 | 5.646            | 8.580            | -1.143           |
| <u>Anomoeoneis sphaerophora</u>                      | 5.858            | 7.743            | -1.606           |
| <u>Anomoeoneis sphaerophora</u><br>v. <u>sculpta</u> | 5.609            | 8.601            | -1.494           |
| <u>Anomoeoneis vitrea</u>                            | 5.012            | 8.426            | -0.490           |
| <u>Caloneis bacillum</u>                             | 6.642            | 7.319            | -2.731           |
| <u>Caloneis lewisii</u>                              | 6.838            | 7.938            | -3.060           |
| <u>Caloneis ventricosa</u>                           | 6.363            | 7.788            | -2.686           |
| <u>Caloneis placentula</u> v.<br><u>lineata</u>      | 6.518            | 6.553            | -0.754           |
| <u>Cyclotella striata</u>                            | 4.960            | 7.822            | -0.477           |
| <u>Cymbella cistula</u> v.<br><u>maculata</u>        | 5.439            | 8.198            | -0.881           |
| <u>Cymbella muelleri</u>                             | 5.678            | 8.251            | -1.138           |
| <u>Cymbella ventricosa</u>                           | 9.005            | 6.284            | -3.168           |
| <u>Epithemia turgida</u>                             | 6.082            | 7.267            | -1.706           |
| <u>Epithemia zebra</u> v.<br><u>porcellus</u>        | 5.341            | 8.984            | -0.792           |

Table 4 (Continued).

| Taxon   | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|---|------------------|------------------|------------------|
| <u>Epithemia zebra</u> v.<br><u>saxonica</u>          | 5.913            | 7.163            | -1.796           |
| <u>Eunotia curvata</u>                                | 8.323            | 7.137            | -4.145           |
| <u>Eunotia pectinalis</u> v.<br><u>minor</u>          | 6.449            | 7.524            | -2.418           |
| <u>Eunotia praerupta</u>                              | 10.719           | 5.845            | -2.008           |
| <u>Eunotia valida</u>                                 | 5.769            | 8.515            | -1.702           |
| <u>Fragilaria brevistriata</u>                        | 2.578            | 4.662            | -3.132           |
| <u>Fragilaria capucina</u> v.<br><u>mesolepta</u>     | 6.170            | 7.804            | -2.455           |
| <u>Fragilaria construens</u>                          | 0.000            | -0.000           | 0.000            |
| <u>Fragilaria construens</u> v.<br><u>pumila</u>      | 4.405            | 8.045            | 0.619            |
| <u>Fragilaria crotonensis</u>                         | 5.429            | 7.397            | -1.364           |
| <u>Fragilaria lapponica</u>                           | 3.992            | 6.578            | 4.071            |
| <u>Fragilaria pinnata</u>                             | 4.945            | 7.919            | 1.988            |
| <u>Fragilaria virescens</u>                           | 13.880           | 0.000            | 3.240            |
| <u>Gomphonema acuminatum</u>                          | 7.172            | 6.769            | -2.867           |
| <u>Gomphonema acuminatum</u> v.<br><u>brebissonii</u> | 11.032           | 4.445            | -0.970           |
| <u>Gomphonema acuminatum</u> v.<br><u>coronata</u>    | 5.332            | 9.051            | -0.724           |
| <u>Gomphonema angustatum</u> v.<br><u>sarcophagus</u> | 10.046           | 4.908            | -0.853           |
| <u>Gomphonema constrictum</u>                         | 8.750            | 6.595            | -4.425           |

Table 4 (Continued).

| Taxon   | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|---|------------------|------------------|------------------|
| <u>Gomphonema constrictum</u> v.<br><u>capitata</u> | 5.379            | 8.725            | -0.925           |
| <u>Gomphonema gallaudi</u>                          | 8.348            | 6.473            | -3.855           |
| <u>Gomphonema gracile</u>                           | 6.919            | 7.733            | -3.027           |
| <u>Gomphonema intricatum</u>                        | 7.925            | 6.539            | -1.663           |
| <u>Gomphonema intricatum</u> v.<br><u>pumila</u>    | 4.906            | 6.811            | 1.777            |
| <u>Gomphonema mexicanum</u>                         | 5.417            | 8.392            | -0.920           |
| <u>Gomphonema parvulum</u>                          | 7.345            | 6.729            | -2.566           |
| <u>Gomphonema sphaerophorum</u>                     | 6.638            | 8.285            | -2.776           |
| <u>Gyrosigma attenuatum</u>                         | 5.355            | 8.888            | -0.865           |
| <u>Mastogloia grevellei</u>                         | 5.506            | 7.620            | -0.601           |
| <u>Mastogloia smithii</u> v.<br><u>lacustris</u>    | 9.648            | 5.364            | -2.086           |
| <u>Melosira granulata</u>                           | 9.705            | 3.789            | -1.208           |
| <u>Navicula americana</u>                           | 7.376            | 7.336            | -3.117           |
| <u>Navicula amphibola</u>                           | 7.573            | 7.541            | -3.957           |
| <u>Navicula anglica</u>                             | 5.318            | 9.147            | -0.601           |
| <u>Navicula anglica</u> v.<br><u>signata</u>        | 6.054            | 8.361            | -1.393           |
| <u>Navicula cincta</u>                              | 5.417            | 8.392            | -0.920           |
| <u>Navicula confervacea</u>                         | 8.045            | 7.287            | -5.669           |
| <u>Navicula confervacea</u> v.<br><u>perigrina</u>  | 5.125            | 8.692            | -0.573           |

Table 4 (Continued).

| Taxon   | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|---|------------------|------------------|------------------|
| <u>Navicula cryptocephala</u> v.<br><u>veneta</u> | 6.408            | 7.785            | -2.352           |
| <u>Navicula cuspidata</u>                         | 6.399            | 8.175            | -2.637           |
| <u>Navicula elginensis</u>                        | 10.287           | 5.505            | -1.590           |
| <u>Navicula explanta</u>                          | 5.162            | 8.433            | -0.705           |
| <u>Navicula globosa</u>                           | 2.057            | 3.772            | -1.584           |
| <u>Navicula graciloides</u>                       | 5.106            | 8.222            | -0.600           |
| <u>Navicula halophila</u>                         | 5.417            | 8.392            | -0.920           |
| <u>Navicula heufleri</u>                          | 5.914            | 8.436            | -2.123           |
| <u>Navicula laevissima</u>                        | 7.618            | 6.057            | -1.857           |
| <u>Navicula minima</u>                            | 4.729            | 7.850            | -0.074           |
| <u>Navicula mournei</u>                           | 4.638            | 7.901            | -0.209           |
| <u>Navicula mutica</u>                            | 6.351            | 7.790            | -1.646           |
| <u>Navicula oblonga</u>                           | 5.417            | 8.392            | -0.920           |
| <u>Navicula pseudoventralis</u>                   | 1.747            | 4.168            | -1.318           |
| <u>Navicula pupula</u>                            | 7.812            | 7.005            | -3.046           |
| <u>Navicula pupula</u> v.<br><u>rectangularis</u> | 4.953            | 7.383            | -0.193           |
| <u>Navicula radiosa</u>                           | 6.004            | 8.388            | -2.130           |
| <u>Navicula seminuloides</u>                      | 2.339            | 4.527            | -1.082           |
| <u>Navicula seminulum</u>                         | 5.417            | 8.392            | -0.920           |
| <u>Navicula skabitschewskyi</u>                   | 5.439            | 8.198            | -0.881           |
| <u>Navicula tantula</u>                           | 4.769            | 6.842            | 2.090            |

Table 4 (Continued).

| <u>Taxon</u>                                       | <u>x</u><br><u>coordinates</u> | <u>y</u><br><u>coordinates</u> | <u>z</u><br><u>coordinates</u> |
|--|--------------------------------|--------------------------------|--------------------------------|
| <u>Navicula tripunctata</u>                        | 5.417                          | 8.392                          | -0.920                         |
| <u>Navicula whittrockii</u> fo.<br><u>cruciata</u> | 6.736                          | 7.269                          | -1.929                         |
| <u>Neidium affine</u>                              | 5.877                          | 8.695                          | -1.187                         |
| <u>Neidium affine</u> v.<br><u>longiceps</u>       | 5.803                          | 8.496                          | -1.253                         |
| <u>Neidium affine</u> v.<br><u>undulatum</u>       | 5.901                          | 8.443                          | -1.309                         |
| <u>Neidium iridis</u>                              | 6.511                          | 8.114                          | -2.213                         |
| <u>Nitzschia amphibia</u>                          | 9.867                          | 1.056                          | -0.116                         |
| <u>Nitzschia commutata</u>                         | 5.417                          | 8.392                          | -0.920                         |
| <u>Opephora ansata</u>                             | 1.676                          | 5.027                          | -1.754                         |
| <u>Pinnularia appendiculata</u>                    | 5.840                          | 8.476                          | -1.981                         |
| <u>Pinnularia brebissonii</u>                      | 6.440                          | 7.686                          | -2.862                         |
| <u>Pinnularia brevicostata</u>                     | 7.052                          | 7.823                          | -3.101                         |
| <u>Pinnularia intermedia</u>                       | 6.589                          | 8.072                          | -1.970                         |
| <u>Pinnularia stomatophora</u>                     | 5.640                          | 8.584                          | -1.136                         |
| <u>Pinnularia streptoraphe</u>                     | 6.927                          | 7.890                          | -2.917                         |
| <u>Pinnularia stricta</u>                          | 5.793                          | 8.502                          | -1.242                         |
| <u>Pinnularia subcapitata</u>                      | 6.420                          | 8.164                          | -2.076                         |
| <u>Pinnularia viridis</u>                          | 6.459                          | 8.381                          | -2.336                         |
| <u>Rhopalodia gibba</u>                            | 5.720                          | 8.130                          | -1.459                         |
| <u>Rhopalodia gibberula</u> v.<br><u>protracta</u> | 5.640                          | 8.584                          | -1.136                         |
| <u>Stauroneis acuta</u>                            | 5.892                          | 8.448                          | -1.677                         |

Table 4 (Continued).

| Taxon                             | x<br>coordinates | y<br>coordinates | z<br>coordinates |
|-----------------------------------|------------------|------------------|------------------|
| <u>Stauroneis anceps</u>          | 7.133            | 7.779            | -3.560           |
| <u>Stauroneis phoenicenteron</u>  | 7.877            | 6.969            | -4.035           |
| <u>Stephanodiscus invisitatus</u> | 5.237            | 9.712            | 0.904            |
| <u>Tabellaria fenestrata</u>      | 5.162            | 8.433            | -0.705           |

Table 5. Radiocarbon age of sediment samples from Little Miller's Bay (L.M.B.) Lake West Okoboji and Arend's Kettle Hole (K.H.) Dickinson County, Iowa, determined by Isotopes, Inc.

| Isotopes Inc.<br>sample number | Sample              | Age in<br>years B.P. |
|--------------------------------|---------------------|----------------------|
| I-3617                         | L.M.B. 255-265 cm   | 2,460 $\pm$ 100      |
| I-1755                         | L.M.B. 575-585 cm   | 5,800 $\pm$ 130      |
| I-3618                         | L.M.B. 665-675 cm   | 8,670 $\pm$ 130      |
| I-1756                         | L.M.B. 1032-1042 cm | 12,700 $\pm$ 200     |
| I-3613                         | K.H. 270-280 cm     | 4,880 $\pm$ 110      |
| I-3614                         | K.H. 340-350 cm     | 9,100 $\pm$ 150      |
| I-3615                         | K.H. 490-500 cm     | 10,310 $\pm$ 180     |
| I-3616                         | K.H. 690-700 cm     | 12,400 $\pm$ 170     |

**APPENDIX B**













Figure 18 (Continued).

| Taxon | Little Miller's Bay site |      |       |       |       |       |       |       |       |       | Kattie Mole site |       |       |       |       |       |       |       |       |       | Occurrences<br>L.H.B. R.N. |       |       |       |       |       |       |       |       |       |       |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |      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      |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |         |    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 |         |         |         |         |         |         |         |         |         |         |         |         |
|-------|--------------------------|------|-------|-------|-------|-------|-------|-------|-------|-------|------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|--------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|       | 30.5                     | 91.5 | 122.0 | 152.5 | 183.0 | 213.5 | 244.0 | 274.5 | 305.0 | 335.5 | 366.0            | 396.5 | 427.0 | 457.5 | 488.0 | 518.5 | 549.0 | 579.5 | 610.0 | 671.0 |                            | 701.5 | 732.0 | 762.5 | 793.0 | 823.5 | 854.0 | 884.5 | 915.0 | 945.0 | 975.0 | 1006.5 | 1036.0 | 1066.5 | 1097.0 | 1127.5 | 1158.0 | 1188.5 | 1219.0 | 1249.5 | 1280.0 | 1310.5 | 1341.0 | 1371.5 | 1402.0 | 1432.5 | 1463.0 | 1493.5 | 1524.0 | 1554.5 | 1585.0 | 1615.5 | 1646.0 | 1676.5 | 1707.0 | 1737.5 | 1768.0 | 1798.5 | 1829.0 | 1859.5 | 1890.0 | 1920.5 | 1951.0 | 1981.5 | 2012.0 | 2042.5 | 2073.0 | 2103.5 | 2134.0 | 2164.5 | 2195.0 | 2225.5 | 2256.0 | 2286.5 | 2317.0 | 2347.5 | 2378.0 | 2408.5 | 2439.0 | 2469.5 | 2500.0 | 2530.5 | 2561.0 | 2591.5 | 2622.0 | 2652.5 | 2683.0 | 2713.5 | 2744.0 | 2774.5 | 2805.0 | 2835.5 | 2866.0 | 2896.5 | 2927.0 | 2957.5 | 2988.0 | 3018.5 | 3049.0 | 3079.5 | 3110.0 | 3140.5 | 3171.0 | 3201.5 | 3232.0 | 3262.5 | 3293.0 | 3323.5 | 3354.0 | 3384.5 | 3415.0 | 3445.5 | 3476.0 | 3506.5 | 3537.0 | 3567.5 | 3598.0 | 3628.5 | 3659.0 | 3689.5 | 3720.0 | 3750.5 | 3781.0 | 3811.5 | 3842.0 | 3872.5 | 3903.0 | 3933.5 | 3964.0 | 3994.5 | 4025.0 | 4055.5 | 4086.0 | 4116.5 | 4147.0 | 4177.5 | 4208.0 | 4238.5 | 4269.0 | 4299.5 | 4330.0 | 4360.5 | 4391.0 | 4421.5 | 4452.0 | 4482.5 | 4513.0 | 4543.5 | 4574.0 | 4604.5 | 4635.0 | 4665.5 | 4696.0 | 4726.5 | 4757.0 | 4787.5 | 4818.0 | 4848.5 | 4879.0 | 4909.5 | 4940.0 | 4970.5 | 5001.0 | 5031.5 | 5062.0 | 5092.5 | 5123.0 | 5153.5 | 5184.0 | 5214.5 | 5245.0 | 5275.5 | 5306.0 | 5336.5 | 5367.0 | 5397.5 | 5428.0 | 5458.5 | 5489.0 | 5519.5 | 5550.0 | 5580.5 | 5611.0 | 5641.5 | 5672.0 | 5702.5 | 5733.0 | 5763.5 | 5794.0 | 5824.5 | 5855.0 | 5885.5 | 5916.0 | 5946.5 | 5977.0 | 6007.5 | 6038.0 | 6068.5 | 6099.0 | 6129.5 | 6160.0 | 6190.5 | 6221.0 | 6251.5 | 6282.0 | 6312.5 | 6343.0 | 6373.5 | 6404.0 | 6434.5 | 6465.0 | 6495.5 | 6526.0 | 6556.5 | 6587.0 | 6617.5 | 6648.0 | 6678.5 | 6709.0 | 6739.5 | 6770.0 | 6800.5 | 6831.0 | 6861.5 | 6892.0 | 6922.5 | 6953.0 | 6983.5 | 7014.0 | 7044.5 | 7075.0 | 7105.5 | 7136.0 | 7166.5 | 7197.0 | 7227.5 | 7258.0 | 7288.5 | 7319.0 | 7349.5 | 7380.0 | 7410.5 | 7441.0 | 7471.5 | 7502.0 | 7532.5 | 7563.0 | 7593.5 | 7624.0 | 7654.5 | 7685.0 | 7715.5 | 7746.0 | 7776.5 | 7807.0 | 7837.5 | 7868.0 | 7898.5 | 7929.0 | 7959.5 | 7990.0 | 8020.5 | 8051.0 | 8081.5 | 8112.0 | 8142.5 | 8173.0 | 8203.5 | 8234.0 | 8264.5 | 8295.0 | 8325.5 | 8356.0 | 8386.5 | 8417.0 | 8447.5 | 8478.0 | 8508.5 | 8539.0 | 8569.5 | 8600.0 | 8630.5 | 8661.0 | 8691.5 | 8722.0 | 8752.5 | 8783.0 | 8813.5 | 8844.0 | 8874.5 | 8905.0 | 8935.5 | 8966.0 | 8996.5 | 9027.0 | 9057.5 | 9088.0 | 9118.5 | 9149.0 | 9179.5 | 9210.0 | 9240.5 | 9271.0 | 9301.5 | 9332.0 | 9362.5 | 9393.0 | 9423.5 | 9454.0 | 9484.5 | 9515.0 | 9545.5 | 9576.0 | 9606.5 | 9637.0 | 9667.5 | 9698.0 | 9728.5 | 9759.0 | 9789.5 | 9820.0 | 9850.5 | 9881.0 | 9911.5 | 9942.0 | 9972.5 | 10003.0 | 10033.5 | 10064.0 | 10094.5 | 10125.0 | 10155.5 | 10186.0 | 10216.5 | 10247.0 | 10277.5 | 10308.0 | 10338.5 | 10369.0 | 10399.5 | 10430.0 | 10460.5 | 10491.0 | 10521.5 | 10552.0 | 10582.5 | 10613.0 | 10643.5 | 10674.0 | 10704.5 | 10735.0 | 10765.5 | 10796.0 | 10826.5 | 10857.0 | 10887.5 | 10918.0 | 10948.5 | 10979.0 | 11009.5 | 11040.0 | 11070.5 | 11101.0 | 11131.5 | 11162.0 | 11192.5 | 11223.0 | 11253.5 | 11284.0 | 11314.5 | 11345.0 | 11375.5 | 11406.0 | 11436.5 | 11467.0 | 11497.5 | 11528.0 | 11558.5 | 11589.0 | 11619.5 | 11650.0 | 11680.5 | 11711.0 | 11741.5 | 11772.0 | 11802.5 | 11833.0 | 11863.5 | 11894.0 | 11924.5 | 11955.0 | 11985.5 | 12016.0 | 12046.5 | 12077.0 | 12107.5 | 12138.0 | 12168.5 | 12199.0 | 12229.5 | 12260.0 | 12290.5 | 12321.0 | 12351.5 | 12382.0 | 12412.5 | 12443.0 | 12473.5 | 12504.0 | 12534.5 | 12565.0 | 12595.5 | 12626.0 | 12656.5 | 12687.0 | 12717.5 | 12748.0 | 12778.5 | 12809.0 | 12839.5 | 12870.0 | 12900.5 | 12931.0 | 12961.5 | 12992.0 | 13022.5 | 13053.0 | 13083.5 | 13114.0 | 13144.5 | 13175.0 | 13205.5 | 13236.0 | 13266.5 | 13297.0 | 13327.5 | 13358.0 | 13388.5 | 13419.0 | 13449.5 | 13480.0 | 13510.5 | 13541.0 | 13571.5 | 13602.0 | 13632.5 | 13663.0 | 13693.5 | 13724.0 | 13754.5 | 13785.0 | 13815.5 | 13846.0 | 13876.5 | 13907.0 | 13937.5 | 13968.0 | 13998.5 | 14029.0 | 14059.5 | 14090.0 | 14120.5 | 14151.0 | 14181.5 | 14212.0 | 14242.5 | 14273.0 | 14303.5 | 14334.0 | 14364.5 | 14395.0 | 14425.5 | 14456.0 | 14486.5 | 14517.0 | 14547.5 | 14578.0 | 14608.5 | 14639.0 | 14669.5 | 14700.0 | 14730.5 | 14761.0 | 14791.5 | 14822.0 | 14852.5 | 14883.0 | 14913.5 | 14944.0 | 14974.5 | 15005.0 | 15035.5 | 15066.0 | 15096.5 | 15127.0 | 15157.5 | 15188.0 | 15218.5 | 15249.0 | 15279.5 | 15310.0 | 15340.5 | 15371.0 | 15401.5 | 15432.0 | 15462.5 | 15493.0 | 15523.5 | 15554.0 | 15584.5 | 15615.0 | 15645.5 | 15676.0 | 15706.5 | 15737.0 | 15767.5 | 15798.0 | 15828.5 | 15859.0 | 15889.5 | 15920.0 | 15950.5 | 15981.0 | 16011.5 | 16042.0 | 16072.5 | 16103.0 | 16133.5 | 16164.0 | 16194.5 | 16225.0 | 16255.5 | 16286.0 | 16316.5 | 16347.0 | 16377.5 | 16408.0 | 16438.5 | 16469.0 | 16499.5 | 16530.0 | 16560.5 | 16591.0 | 16621.5 | 16652.0 | 16682.5 | 16713.0 | 16743.5 | 16774.0 | 16804.5 | 16835.0 | 16865.5 | 16896.0 | 16926.5 | 16957.0 | 16987.5 | 17018.0 | 17048.5 | 17079.0 | 17109.5 | 17140.0 | 17170.5 | 17201.0 | 17231.5 | 17262.0 | 17292.5 | 17323.0 | 17353.5 | 17384.0 | 17414.5 | 17445.0 | 17475.5 | 17506.0 | 17536.5 | 17567.0 | 17597.5 | 17628.0 | 17658.5 | 17689.0 | 17719.5 | 17750.0 | 17780.5 | 17811.0 | 17841.5 | 17872.0 | 17902.5 | 17933.0 | 17963.5 | 17994.0 | 18024.5 | 18055.0 | 18085.5 | 18116.0 | 18146.5 | 18177.0 | 18207.5 | 18238.0 | 18268.5 | 18299.0 | 18329.5 | 18360.0 | 18390.5 | 18421.0 | 18451.5 | 18482.0 | 18512.5 | 18543.0 | 18573.5 | 18604.0 | 18634.5 | 18665.0 | 18695.5 | 18726.0 | 18756.5 | 18787.0 | 18817.5 | 18848.0 | 18878.5 | 18909.0 | 18939.5 | 18970.0 | 19000.5 | 19031.0 | 19061.5 | 19092.0 | 19122.5 | 19153.0 | 19183.5 | 19214.0 | 19244.5 | 19275.0 | 19305.5 | 19336.0 | 19366.5 | 19397.0 | 19427.5 | 19458.0 | 19488.5 | 19519.0 | 19549.5 | 19580.0 | 19610.5 | 19641.0 | 19671.5 | 19702.0 | 19732.5 | 19763.0 | 19793.5 | 19824.0 | 19854.5 | 19885.0 | 19915.5 | 19946.0 | 19976.5 | 20007.0 | 20037.5 | 20068.0 | 20098.5 | 20129.0 | 20159.5 | 20190.0 | 20220.5 | 20251.0 | 20281.5 | 20312.0 | 20342.5 | 20373.0 | 20403.5 | 20434.0 | 20464.5 | 20495.0 | 20525.5 | 20556.0 | 20586.5 | 20617.0 | 20647.5 | 20678.0 | 20708.5 | 20739.0 | 20769.5 | 20800.0 | 20830.5 | 20861.0 | 20891.5 | 20922.0 | 20952.5 | 20983.0 | 21013.5 | 21044.0 | 21074.5 | 21105.0 | 21135.5 | 21166.0 | 21196.5 | 21227.0 | 21257.5 | 21288.0 | 21318.5 | 21349.0 | 21379.5 | 21410.0 | 21440.5 | 21471.0 | 21501.5 | 21532.0 | 21562.5 | 21593.0 | 21623.5 | 21654.0 | 21684.5 | 21715.0 | 21745.5 | 21776.0 | 21806.5 | 21837.0 | 21867.5 | 21898.0 | 21928.5 | 21959.0 | 21989.5 | 22020.0 | 22050.5 | 22081.0 | 22111.5 | 22142.0 | 22172.5 | 22203.0 | 22233.5 | 22264.0 | 22294.5 | 22325.0 | 22355.5 | 22386.0 | 22416.5 | 22447.0 | 22477.5 | 22508.0 | 22538.5 | 22569.0 | 22599.5 | 22630.0 | 22660.5 | 22691.0 | 22721.5 | 22752.0 | 22782.5 | 22813.0 | 22843.5 | 22874.0 | 22904.5 | 22935.0 | 22965.5 | 22996.0 | 23026.5 | 23057.0 | 23087.5 | 23118.0 | 23148.5 | 23179.0 | 23209.5 | 23240.0 | 23270.5 | 23301.0 | 23331.5 | 23362.0 | 23392.5 | 23423.0 | 23453.5 | 23484.0 | 23514.5 | 23545.0 | 23575.5 | 23606.0 | 23636.5 | 23667.0 | 23697.5 | 23728.0 | 23758.5 | 23789.0 | 23819.5 | 23850.0 | 23880.5 | 23911.0 | 23941.5 | 23972.0 | 24002.5 | 24033.0 | 24063.5 | 24094.0 | 24124.5 | 24155.0 | 24185.5 | 24216.0 | 24246.5 | 24277.0 | 24307.5 | 24338.0 | 24368.5 | 24399.0 | 24429.5 | 24460.0 | 24490.5 | 24521.0 | 24551.5 | 24582.0 | 24612.5 | 24643.0 | 24673.5 | 24704.0 | 24734.5 | 24765.0 | 24795.5 | 24826.0 | 24856.5 | 24887.0 | 24917.5 | 24948.0 | 24978.5 | 25009.0 | 25039.5 | 25070.0 | 25100.5 | 25131.0 | 25161.5 | 25192.0 | 25222.5 | 25253.0 | 25283.5 | 25314.0 | 25344.5 | 25375.0 | 25405.5 | 25436.0 | 25466.5 | 25497.0 | 25527.5 | 25558.0 | 25588.5 | 25619.0 | 25649.5 | 25680.0 | 25710.5 | 25741.0 | 25771.5 | 25802.0 | 25832.5 | 25863.0 | 25893.5 | 25924.0 | 25954.5 | 25985.0 | 26015.5 | 26046.0 | 26076.5 | 26107.0 | 26137.5 | 26168.0 | 26198.5 | 26229.0 | 26259.5 | 26290.0 | 26320.5 | 26351.0 | 26381.5 | 26412.0 | 26442.5 | 26473.0 | 26503.5 | 26534.0 | 26564.5 | 26595.0 | 26625.5 | 26656.0 | 26686.5 | 26717.0 | 26747.5 | 26778.0 | 26808.5 | 26839.0 | 26869.5 | 26900.0 | 26930.5 | 26961.0 | 26991.5 | 27022.0 | 27052.5 | 27083.0 | 27113.5 | 27144.0 | 27174.5 | 27205.0 | 27235.5 | 27266.0 | 27296.5 | 27327.0 | 27357.5 | 27388.0 | 27418.5 | 27449.0 | 27479.5 | 27510.0 | 27540.5 | 27571.0 | 27601.5 | 27632.0 | 27662.5 | 27693.0 | 27723.5 | 27754.0 | 27784.5 | 27815.0 | 27845.5 | 27876.0 | 27906.5 | 27937.0 | 27967.5 | 27998.0 | 28028.5 | 28059.0 | 28089.5 | 28120.0 | 28150.5 | 28181.0 | 28211.5 | 28242.0 | 28272.5 | 28303.0 | 28333.5 | 28364.0 | 28394.5 | 28425.0 | 28455.5 | 28486.0 | 28516.5 | 28547.0 | 28577.5 | 28608.0 | 28638.5 | 28669.0 | 28699.5 | 28730.0 | 28760.5 | 28791.0 | 28821.5 | 28852.0 | 28882.5 | 28913.0 | 28943.5 | 28974.0 | 29004.5 | 29035.0 | 29065.5 | 29096.0 | 29126.5 | 29157.0 | 29187.5 | 29218.0 | 29248.5 | 29279.0 | 29309.5 | 29340.0 | 29370.5 | 29401.0 | 29431.5 | 29462.0 |





