THE CONTRIBUTION OF DIATOMS TO THE SEDIMENTS OF CRYSTAL LAKE, VILAS COUNTY, WISCONSIN.

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ABSTRACT. Examination of top, middle, and bottom samples from six-foot cores taken at eight representative stations showed a surprising horizontal differentiation in diatom flora in a lake of such small size and regular features as Crystal Lake, Vilas County, Wisconsin, together with some likewise interesting stratigraphic differences. A study of the former indicated that ecological factors played an important part in determination of local species of diatoms, while a study of the latter offered interesting suggestions with regard to physico-chemical changes in the lake water during the course of its geological history, which changes though probably very slight were sufficient to induce a change in the diatom flora at various periods, and probable conditions at different stages are suggested. The lake has been since its origin, a favorable environment for diatom growth as is indicated by the great diversity of species and their abundant contribution to the sediments, though probably at no time has productivity been rich. The sediments have been built up largely by a slow steady bottom growth, relatively slower than most lakes, due to the nutrient low waters. The presence of diatoms proved a good indicator in determining the thickness of the sediments, which were thin compared to other lakes of the region. The lake has probably changed little since its basin was formed.

ACKNOWLEDGMENT.

THE writer is indebted to Dr. W. H. Twenhofel of the Department of Geology of the University of Wisconsin for the interesting opportunity to coöperate in a study of the sediments of Crystal Lake, Vilas County, Wisconsin, and for portions of his samples upon which the present study is based. Sampling was done and preliminary examination made in August 1937, with facilities and accommodations provided at the Trout Lake Limnological Laboratory of the University of Wisconsin and the Wisconsin Geological and Natural History Survey, at the invitation of Dr. E. A. Birge and Dr. Chancey Juday. The work was initiated and planned by Doctor Twen-

hofel, and samples collected by him and Mr. Broughton were distributed among several investigators for special studies.

INTRODUCTION.

Crystal Lake, Vilas County, Wisconsin, is a small, nearly round lake, about half a mile in diameter, four miles east of the southern end of Trout Lake and in the south-central part of the county. The lake lies in a saucer-shaped basin of fine, light-colored to white, quartz sand, with gradually sloping sandy beach all around, and with sandy shores sloping gently away from the lake on all sides. On the north side it is separated only a few hundreds yards from Big Muskellunge Lake, by a strip of flat land carrying a main highway; on the south the shore reaches back to a flat, wooded, slightly-boggy country.

Crystal Lake is unique in being one of the clearest, most colorless lakes in the world. Its waters contain a low amount of dissolved substance, support a very light plankton, and are relatively meager in life in general. It has no inlet or outlet but is fed by springs and seepage waters. It is locally said that the waters are so similar to distilled water as to be safe for use in storage batteries. Because of these extreme characteristics, and also because of its small size and simple regular shape which make it easy to study, it has become one of the best studied lakes known.

As Drs. Juday and Birge point out (Juday and Birge, 1932, p. 449) Crystal Lake "is an outstanding example of this type of lake (Oligotrophic)," that is, one in which a good supply of dissolved oxygen is found in the deeper waters at all seasons. The paucity of plankton and lack of inflowing organic residues keep decomposition low and do not use up the available oxygen. With a scarcity of basic elements and a poor phytoplankton, a fair supply of free CO_2 exists, maintaining a moderately low hydrogen-ion concentration. The figures in the accompanying table, taken from analyses by Birge and Juday (Card catalogue), will give some idea of these relationships, and, compared with those of Trout Lake, given as an example of a medium hard water lake, will indicate clearly the softness and the poverty stricken nature of the Crystal Lake waters. These relations will be referred to later in explaining some of the conditions of diatom deposition in formation of the sediments.

Doctor Twenhofel selected Crystal Lake for this series of studies, because he wished to learn the nature of the sediments in a type of very soft water lake, and yet not of the bog type, for comparison with other kinds of lakes with less marked conditions. The small size of the lake, and the simple, uniform, and apparently stable conditions of its environment, led the writer at the outset to the somewhat logical assumption that a rather uniform and monotonous diatom flora might be expected throughout the sediments, changing little with time and varying little in different areas of the small lake basin. Brief progress, however, in the course of examination of the samples, served to disillusion the mind entirely of this idea, and the choice of this lake proved particularly fortunate, and fruitful of interesting results with respect to the part played by the diatoms, a statement of which will be attempted in the following discussion.

METHOD.

Thirty-one samples were collected from eight stations in Crystal Lake, by Doctor Twenhofel and Mr. Broughton, as mentioned in the list of descriptions of samples. Sampling was done from a heavy raft. From each station a six-foot vertical core of the bottom was taken, using a brass tube six feet long and three inches in diameter, with a weight to force it into the mud. Inside this tube which was slightly constricted at the bottom was placed a close fitting galvanized iron tube, slit for its entire length on one side. When the sampler full of material was raised the inner tube could be taken out and the slit edges spread apart to remove samples. Since the extent of penetration of the sampler and the degree of compaction of the sediment were somewhat uncertain it was considered adequate for the present preliminary purpose to take a sample from the bottom, middle, and top of each core (sample not taken from bottom of core, station No. 5). An additional surface sample was taken from each station with an Ekman dredge to serve as a control. For the purpose of this study samples were preserved in formalin. Superficial study was made of each crude sample, and a detailed analysis of the diatom content was made on portions cleaned and prepared in routine manner. Relative abundance of each species was stated on the basis of five arbitrary categories ranging from very scarce, to frequent, to very common, as seen in the table of species at the end of the paper.

Table I. (Water Analyses—Representative figures from card catalogue by Birge and Juday.) Figures represent Milligrams of substance per liter of water.

CRYSTAL LAKE.
(August 20, 1929.)

Depth (Meters)	Surface	5	10	15	20 (Bottom)
Plankton	0.46	0.61	0.52	0.64	0.65
Carbon dioxide (Free)	0.5	0.5	0.75	2.75	4.0
Oxygen	8.68	8.73	10.8	9.58	8.36
Phosphorus (Total)	0.011	0.011	0.012	0.035	0.018
Nitrogen (Total)	0.011	0.011	0.007	0.008	0.009
Silica	None	None	None	Trace	Trace
Hydrogen ion Conc.	6.0	6.0	6.0	5.8	5.4
Conductivity	9.0	9.0	9.1	9.8	10.5
Color	0	0	0	0	6

TROUT LAKE.
Northern Part.
(August 7, 1929.)

Depth (Meters)	Surface	10	15	20	26
Plankton	0.66	0.70	0.60	0.40	1.06
Carbon dioxide (Free)	0.00	1.75	4.25	5.25	9.00
Oxygen	8.62	9.4	7.58	6.10	2.6
Phosphorus (Total)	0.012	0.012	0.014	0.017	0.050
Nitrogen (Total)	0.028	0.030	0.032	0.057	0.063
Silica	6.0	6.0	6.0	6.4	8.0
Hydrogen ion Conc.	7.8	7.6	7.0	6.9	6.7
Conductivity	73	72	72	73	75
Color	6	8	8	8	10

RESULTS AND CONCLUSIONS.

As indicated in the introduction, a much greater diversity was found in the diatom flora of the sediments than had been anticipated in so small and uniform a lake basin. The appended table lists 23 genera and 85 species of diatoms, with three or four varieties. Varietal differences were in general ignored as being of dubious value and not pertinent to the present study, or this list might have been very appreciably extended. Crystal Lake proved to be distinctly different from other lakes of the region being studied by the writer, not only in this impressive diversity of the diatom content of its sediments, but also in the kinds of diatoms found. It may be said that more commonly the deep water sediments of the lakes are quite homogeneous and consist of two or three, or at most a very few characteristic species. It is notable that the species known to contribute most largely to such sediments, namely, *Melosira granulata, Stephanodiscus niagarae,* and *Fragilaria harrissonii* were conspicuously rare in all of the Crystal Lake sediments. The reasons for the distinctively different character of the Crystal Lake sediments in the above respects are not explainable in the light of our present knowledge, but they can doubtless be assigned to the softness and generally meager nutrient content of the water. In spite of the implication of a less favorable nutrient supply, it is evident from the study of the sediments that, throughout its history, Crystal Lake has provided a healthy environment for diatom growth within the limitations of the nutrient supply, and that diatoms have been a chief contributor to the sediments. Because of the restricted productivity suggested by these facts, the rate of accumulation of the sediments has been slow, the evidence for which will be discussed later.

Not only is the diversity of diatom flora generally impressive, but more specifically, a definite biological stratification was exhibited by the diatoms, suggestive of changes of climatic or hydrologic conditions during the life history of the lake, and also a conspicuous localized distribution was found depending on environmental factors in different areas of the lake bottom, quite in contrast to the uniformity expected in so simple a lake basin.

The uncertainty of the exact relationship of the levels of the different samples, due to the difficulties of sampling at these depths, does not warrant a fine correlation between corresponding samples at the different stations, but stratigraphically the following general points are clear. It is evident from the table that a much more heterogeneous diatom flora is present in the bottom of core samples than in the upper layers, indicating that a more diverse flora existed in the earlier and newer stages of the lake, when the bottom was cleaner and less clogged with sediments, the water was perhaps less acid, and probably richer seepage waters fed the lake. These points are supported by the greater profusion of growth, the presence of larger and heavier diatom forms, and of such species as *Melosira arenaria* and *Campylodiscus hibernicus* not found at all in the upper sediments. The presence of these in abundance in bottom of core sample No. 7, might on the other hand indicate the pres-

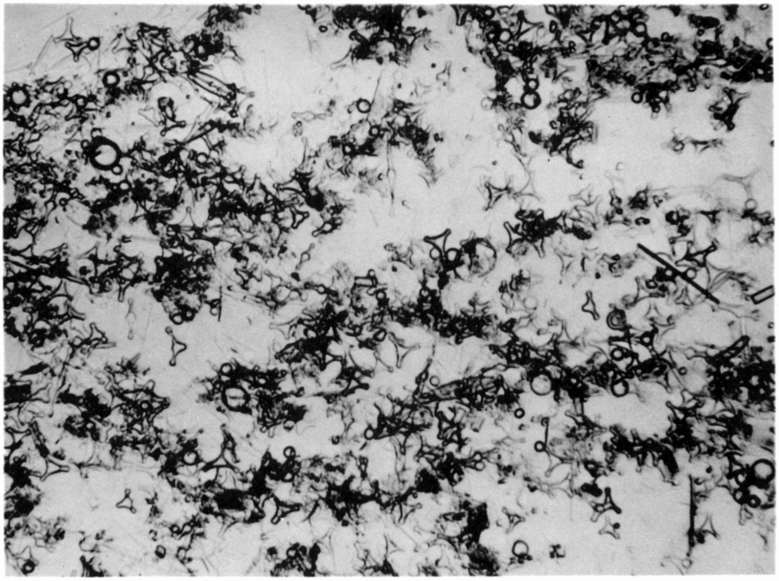

Fig. 1.

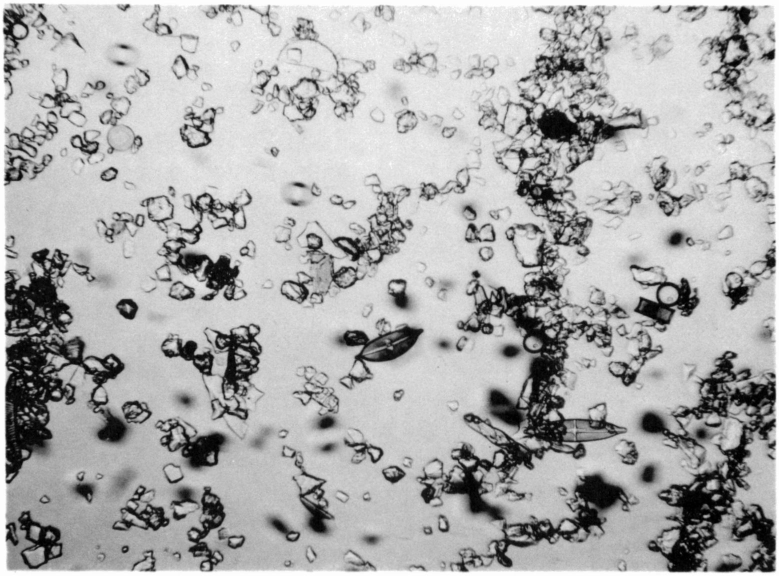

Fig. 2.

Fig. 1. Sample 2. Traverse 2. Middle of Core. Triangular and irregular forms of *Fragilaria construens* in abundance. X 240.

Fig. 2. Sample No. 7. Bottom of Core. Diatoms infrequent and various; much sand. X 143.

ence of a spring at this place; however, that is purely conjecture.

The tremendous dominance or practically pure composition of several middle of core samples by *Fragilaria construens* and varieties is most unusual and most interesting, and is the most striking evidence of a biological stratification due to changing conditions. It shows that there must have been a considerable period at some time in the history of the lake when its waters "bloomed" for many successive years exclusively with this form. The presence in these particular samples of a high preponderance of mutant and abnormal forms of this species is also strongly suggestive of a radical transition stage in the history of the lake when conditions were not always too favorable, though this is in itself a variable species which may partially account for these mutants. The liking of this species for shallower water leads to the very tentative surmise that the level of the lake may have been lower at the time. This material is so very interesting from a diatom standpoint that it has seemed desirable to give a photographic illustration of it (Plate 1, Fig. 1).

A still more limited and critical flora occupies the surface sediment of the lake bottom. In it the frequent occurence of such forms as *Navicula iridis*, various species of *Stauroneis*, and *Eunotia robusta* in considerable numbers, species which tolerate or thrive in the very soft and highly acid waters of bogs, is fair evidence that the surface sediments are being formed under conditions of a more acid environment than prevailed when the diverse acid intolerant diatom population of the lower sediments occupied the freshly formed lake basin. Organic decomposition in the recent sediments, and less ready access to highly deficient lime-bearing seepage waters are probably responsible for a somewhat lower hydrogen ion concentration at the present day. The abundance of heavier shelled forms in the lower sediments is indicative of a richer silica supply in the newly formed lake basin, probable lower temperature, and more alkaline seepage waters.

Mention should be made here of the great abundance of pine and other pollen so intimately associated with the diatoms as a chief component of much of these sediments, though it does not exactly deserve discussion under this subject. In some of the samples, particularly of the middle and upper core sediments, such pollen comprises more than 50 per cent of the mass of the sediment. It is very resistant and materially affects the physical appearance of the muds; its partial and slow decomposition may contribute to the acidity of the waters. Its much greater sparsity in the lower sediments suggests a less dense stand of forest in the region at the time they were being deposited. Its resistance and the good state of its preservation even in the lower sediments supports the above cause, rather than that of its disappearance from these layers through decomposition. The lesser concentration of pollen in the lower sediments serves to accentuate the richness of diatoms, which, however, is real also.

The most impressive observation of the localized distribution of diatoms at a particular period within the confines of this small lake basin is shown by the top of core in Sample No. 8, which is strikingly dominated by *Eunotia*, and mainly one species. In this mud also is to be found an abundance of fibers and fragments of moss. This particular sample very obviously shows a typical epiphytic environment, where the sampler struck a localized bed of moss bearing a dense encrustation of the typically epiphytic diatom, *Eunotia*. Some other samples show this localization in less marked degree, and other differences in the surface diatom flora as well as color differences between the samples furnish further observation of such localization. Doubtless this obtains for the underlying sediments too, but cannot be ascertained because of uncertainty of correlation of given levels of sampling. It would appear that the adjustments which function in the maintenance of these small local differences under apparently most uniform conditions constitute a problem of high complexity, the delicacy of solution of which can hardly be over-estimated.

The abundance and homogeneity of *Fragilaria construens* in a few middle of core samples suggest the probability of profuse and uniform deposition of this form during the period when it flourished, and that if it had been possible to secure middle of core samples all at the same corresponding level distribution of this form would have been found more equal in all. Conversely it seems that the difference of samples with respect to this form is a criterion of the lack of stratigraphic correlation of the samples. It should be borne in mind that a difference of a few years, with possible slight fluctuating water conditions, might well bring about a complete change in the diatom flora, and be represented by a very slight difference in level in a sediment being laid down so slowly as it is logical to assume this lake sediment has been.

Despite emphasis on the diversity of certain few of the samples and the clear evidence of biological stratification, the superficial differences in the diatom content of the various samples are not so great; rather they suggest a fairly stable history for the lake, with a constant but slow rate of deposition. Apparently at no period in the history of the lake, unless it be that during the "blooming" of *Fragilaria construens*, has diatom growth been exceptionally prolific.

As suggested by the fact that the type of diatoms chiefly composing parts of the sediment where biological stratification is evident, are either shallow water epiphytes or more often plankton forms, it would seem that the bottom flora has been more constant, and stratification has been contributed to largely by plankton or exotic forms living in the upper waters more subject to fluctuation. Dominance of the sediments in general by an essentially epiphytic and bottom type of diatoms indicates that they have been built up from the bottom to a much greater extent than they have resulted from plankton deposition, which is the less common mode of deposition in a lake of this depth. This is most conspicuously associated, again, with the practical absence of such forms as *Melosira granulata* and *Stephanodiscus niagarae*. These facts suggest again, that throughout most of its history, the upper waters of the lake have been poor in necessary nutrient and supported a meager plankton, and that these conditions have been quite stable.

One of the useful observations in connection with this study relates to the thickness of the sediment. Complete absence of diatoms in the bottom of the core at some stations, and large or considerable quantities of sand in most of the others, suggest that in most instances the sampler has completely or nearly penetrated the entire organic sediment of the lake bottom. In samples No. 2, 3, 4, and 7 penetration does not appear to be complete, yet the presence of sand indicates it approaches the bottom; in the others it seems to have penetrated. The line of demarcation is fairly sharp, and thus the diatoms, which doubtless occupied the lake shortly after the formation of its basin, serve as a good criterion for determining the base of the sediment as their shells are permanent and positive evidence of the beginning of life in such an environment. Allowing for compaction of the sample and penetration of the sampler somewhat beyond its length, Doctor Twenhofel has estimated the maximum thickness of the sediment to be about three meters. It is interesting to note that this doubtless conservative figure is probably much less than for many other lakes in the region, for which there is some evidence to show that sediments may run from six to nine meters or more in thickness. These general facts correlate again with the poverty stricken nature of Crystal Lake waters and a slow rate of deposition.

If three meters is a correct figure and the lake has occupied its basin for 10,000 years as some geologists maintain, deposition may be considered to have been at the rate of about an inch in a hundred years, or about one-fourth of a millimeter a year. If the period of 20,000 years accepted by others is taken, rate of deposition has been correspondingly even less, which figures, though very hypothetical, may be suggestively helpful.

A perhaps apt conclusion which may be drawn from the study of a simple environment such as this, where most possible variable factors would seem to have been minimized or eliminated, is that of the very elementary state of our knowledge concerning specific environmental requirements of individual diatom species. It is obvious to the writer that previous more or less arbitrary conclusions as to specific diatom requirements need to be reconsidered. Apparently in this, and in all, environments a delicately adjusted and very complex set of factors operate in those naturally selective processes whereby one species of diatom and associated organisms gain dominance in a localized area, as is shown in the case of *Eunotia* above discussed. Our knowledge of the functioning of these is certainly far from precise. Determination of factors controlling such slight differences in species distribution in very restricted and localized areas will require much greater refinement of limnological technique and coördination than has yet been attempted.

The local distribution of *Eunotia* here, depending upon the moss on which it grows as a substrate, in an environment which would apparently otherwise be equally suited to other types of diatoms, indicates how such a purely ecological factor as this moss distribution, which of course, in turn is dependent on still

Fig. 1.

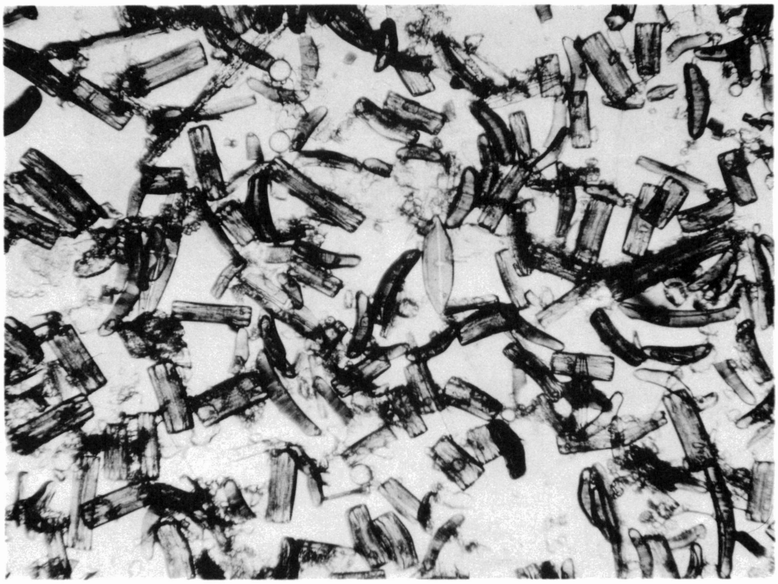

Fig. 2.

Fig. 1. Sample No. 6. Top of Core. Miscellaneous bottom diatoms in fine mud sediment. X 136.

Fig. 2. Sample No. 8. Top of Core. Almost pure *Eunotia* in mud containing moss fragments. Typical epiphytic environment. X 143.

other complex circumstances, may play an important part in the diatom distribution and deposition in a sediment.

The localization of this form, and the practical absence of fine sand from the surface sediments tends to show that dynamic water movements have affected the sedimentation process little, and that there has been practically no shift or horizontal transport of sediments in this small lake basin.

The generalization may be made that throughout its history Crystal Lake has supported a very diversified diatom flora rather characteristic of somewhat shallower lakes than this. It would seem that the clarity of the water and richer nutrient near the bottom may have been responsible for this condition, and it appears also that this clearness of the water may have maintained throughout the history of the lake.

SUMMARY.

1. Crystal Lake, a small, oval, clear, soft-water lake, exhibits an unexpected diversity both in biological stratification and in horizontal distribution of diatoms, in its sediments.

2. The profuse diatom flora of the sediments is very different in character from that of most lakes of the region.

3. An environment conducive to diatom production, fairly stable and constant, with few marked fluctuations obtained throughout the history of the lake.

4. Diatoms and pine pollen are chief contributors to the sediments.

5. Sediments show that a more profuse diatom population lived in the earlier history of the lake in the clean sandy basin, under probably more neutral conditions, lower temperature, and richer inflowing seepage waters.

6. Larger shelled forms in this earlier sediment suggest richer nutrient waters, with higher silica content.

7. A period of rich "blooming" of *Fragilaria construens* occurred as a marked change during a later part of the lake's history.

8. Acid tolerant diatoms indicate a change toward greater acidity in the upper sediments.

9. Preponderance of bottom-living and epiphytic diatoms throughout show that the sediments have been built up from the bottom more than from planktonic deposition from above.

10. Forms typical to deep water sediments, like *Melosira* and *Stephanodiscus* are conspicuously scarce.

11. Local growths of *Eunotia* on moss beds illustrate the importance of certain environmental circumstances in controlling horizontal distribution of diatom species, depending on purely ecological association.

12. Complete penetration of the sediment mass was attained in a few instances, with the diatoms serving as a good criterion of the line of demarcation.

13. The sediment mass is thinner than in most lakes, showing a poor nutrient condition, with a smaller annual increment of deposition.

14. The rate of deposition is estimated to be one-fourth to one-eighth of a millimeter per year.

15. Localization shows that dynamic water movements influenced deposition in this small lake but little; no signs of shift or transport of surface diatoms are evident.

16. More precise studies of specific ecological factors, controlling local distribution of diatoms, with more cautious assignment of causes, are badly needed.

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General Description of Samples.

A. Top of Cores.

No. 1. Traverse 2. (650 feet from North Shore; depth 15.5 meters.)—Considerable pine and other pollen, plant debris and crustacean parts, no sand, diatoms plentiful and various with *Navicula iridis* var. *amphigomphus* Pfitzer dominating.

No. 2. Traverse 2. (800 feet from North Shore; depth 16 meters.)—Pollen and moss fragments abundant, crustacean tests plentiful, practically no sand, diatoms plentiful, *Eunotia* and epiphytic forms dominating.

No. 3. (1000 feet from North Shore, 750 feet from East Shore; depth 19 meters.)—Mainly pollen, no sand, some crustacean remains, diatoms plentiful.

No. 4. (900 feet from North Shore, 600 feet from East Shore; depth 20¼ meters, deepest point in lake.)—Much pollen, some crustacean parts, no sand, diatoms plentiful, *Navicula iridis* dominant.

No. 5. (900 feet from North Shore, 400 feet from East Shore; depth 16 meters.)—Many moss fragments, much pollen, no sand, diatoms plentiful, various. Epiphytic environment, but not as dense and typical as No. 8. *Eunotia* dominant.

No. 6. (1500 feet from West Shore, 1200 feet from East Shore, 600 feet from South Shore; depth 18 meters.)—Considerable pollen, no sand, plenty of diatoms. Top of core much darker in color than bottom.

No. 7. (900 feet from North Shore, 1050 feet from West Shore, 870 feet from South Shore; depth 18 meters.)—Much pollen, no sand, some crustacean parts, spicules, diatoms plentiful. *Navicula appendiculata* particularly abundant.

No. 8. (630 feet from North Shore, 750 feet from West Shore, 900 feet from South Shore; depth 14.5 meters.)—Much moss fragment, much pollen, diatoms abundant, with *Eunotia* dominant. Typical epiphytic environment.

(Station locations and general depths for the Middle of Core and Bottom of Core samples are, of course, the same as in the corresponding numbers above, hence, are not repeated with the descriptions of these samples given below.)

B. Middle of Cores.

No. 1. Traverse 2.—Quantities of pine pollen dominate this sample. No sand. Remains of Crustaceans. Diatoms plentiful and various, similar to top of core. Plant debris common.

No. 2. Traverse 2.—Much pollen, crustacean tests, no sand, diatoms abundant and various. *Fragilaria construens* dominating, with *Navicula Iridis* also very numerous.

No. 3. Mainly pine and other pollen, crustacean remains, no sand, diatoms plentiful, various. *Fragilaria construens* abundant.

No. 4. Mainly pine and other pollen, crustacean remains, no sand, diatoms plentiful and various; *Fragilaria construens* var. very abundant.

No. 5. Relatively little pollen, crustacean remains or plant debris; considerable sand and silt; diatoms few. This sample is more like bottom of cores of most of the stations.

No. 6. Relatively little pollen or plant debris, some crustacean remains; much sand; diatoms very few.

No. 7. Considerable pollen, plant debris and crustacean remains; very little sand, diatoms plentiful but not abundant. Felt-like masses of excreta. This sample resembles bottom of core more than the top.

No. 8. Much moss fragment, considerable pollen; sand prevalent; diatoms fairly plentiful, *Eunotia* dominant. This is a typical epiphytic environment, as in No. 8, top of core.

C. Bottom of Cores.

No. 1. Traverse 2.—Mostly sand, some pine pollen, some crustacean remains, some spicules, very few diatoms.

No. 2. Traverse 2.—Considerable sand, pollen, crustacean tests, spicules, diatoms plentiful and various.

No. 3. Considerable pollen, crustacean remains, excreta, some sand, diatoms plentiful and various.

No. 4. Considerable pollen, crustacean remains, much plant debris, some sand, diatoms plentiful and various. Sampler apparently did not penetrate sediment here at this deepest point.

No. 5. No bottom of core sample for this number.

No. 6. Light brown, very fine sand, and sticky; very little pollen, no crustacean remains; no diatoms. Apparently practically complete penetration of mud.

No. 7. Much sand, some crustacean remains and some pollen; diatoms plentiful and various, *Navicula mesolepta* and *N. appendiculata* dominating. *Melosira arenaria* and *Campylodiscus hibernicus* occur in this sample in considerable numbers and differentiating it from all other samples taken in the lake.

No. 8. Light brown in color, fine sand and clay; no pollen or diatoms. This sample appears to have completely penetrated the lake sediment.

TABLE II.

DIATOMS OF CRYSTAL LAKE, VILAS CO., WISCONSIN.

Position in Core	Top								Middle								Bottom							
Core	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Achnanthes calcar Cleve																			S					
Amphora ovalis						S	S				F				F			F	F	F			F	
" " var. libyca (Ehr.) Cleve																S			F	F				
Campylodiscus hibernicus Ehr.																							C	
Cocconeis diminuta Pant.													S			F			C	C			C	
Cyclotella comta (Ehr.) Kütz.	F					VC	C		S	S	S			S	F		S	C	VC	C			C	
Cymbella cistula (Hempr.) Kirchn.															F				F	F				
" cymbiformis (Ag.? Kütz.) V. H.						F	S			S								F	F	F			F	
" delicatula Kütz.																		S						
" ehrenbergii Kütz																				F				
" gastroides Kütz.																				S			F	
" naviculiformis Auersw.					F	F				S	S				F			F	F	F				
" ventricosa Kütz.	F		F		F	F	S			S	F	S	S		F	F			C	C				
Epithemia argus Kütz.											S				S	F			F	S			F	
" sorex Kütz.																			S				S	
" turgida (Ehr). Kütz.																				S			F	
" zebra (Ehr.) Kütz.																				VS			VS	
Eunotia arcus Ehr.							S											F	S					
" gracilis (Ehr.) Rab.																		S		F				
" major (W. Sm.) Rab.	C	C			C			VC		S						*VC*								
" monodon Ehr.	C	VC		C	*VC*			*VC*	S			S	S	S		*VC*		S						
" pectinalis (Kütz.) Rab.	F	S	C		C	S		C			S		S		S	F								
" robusta Ralfs	S							C		S						C				F				
" septentrionalis Oestrup																			S					

TABLE II—(Continued).

Position in Core	Top								Middle								Bottom							
Core	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Fragilaria binodis Ehr.																				S				
" construens (Ehr.) Grun..					F	F				*C*	*C*	*VC*	S	F										
" harrissonii W. Sm.																		S	S	S			F	
" mutablis (W. Sm.) Grun.													F						F	F			C	
" pinnata Ehr.													S	S					C	F			F	
Frustulia rhomboides (Ehr.) De T.	VS			S																			F	
Gomphenema acuminatum Ehr....							S								S									
" constrictum Ehr.						S	S											S	S	S				
" constrictum var. capitata (Ehr.) Cleve.						S	S			S		S			S	S		S	S	S				
Gomphonema olivaceum (Lyngb.) Kütz.						S									S			F	F	F				
Hantzschia amphioxys (Ehr.) Grun.							S			F								S	S	S				
Melosira arenaria Moore																							C	
" granulata (Ehr.) Ralfs.	S	S		S	S		S			S	F	S			S	S		F	S	S				
" italica (Ehr.) Kütz.																				F				
Navicula (Neidium) affine Ehr. var. amphirhynchus (Ehr.) Cleve.						F													F					
" (Neidium) amphigomphus Pfitzer	*VC*	S																						
" ambigua Ehr.							S																	
" anglica Ralfs						F	F					S	S	S	S			F	F	F			C	
" appendiculata Kütz.	C		F	F	C	F			F	C	F	F			C		S		C					VC
" bacillum Ehr.	F		F		F						F	F			F			F		F				
" cuspidata Kütz.						S									S				S	S				

TABLE II—(Continued).

Position in Core	Top								Middle								Bottom							
Core	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Navicula dicephala (Ehr.) W. Sm.																			S					
" (Neidium) dilatatum Ehr.	F																							
" elliptica Kütz.			F				F		S	S	S	S						S	F					
" gastrum Ehr.																				S				
" (Neidium) hitchcockii Ehr.	S				F		F		F	F		S			S			F	F				F	
" instabilis A. S.																		F						
" (Pinnularia) interrupta W. Sm.					S	S	S																	
" (Neidium) iridis Ehr.	C	S	C	VC	C	C	S	F	C	C	F	S			S	VC				C				
" (Neidium) iridis var. ampliata Ehr.						S				F						C								
" major Kütz.	F		F	C			F		S	S	S				F			F	F	F				
" mesolepta Ehr.			C			*VC*	F			C	F	F	S	S	C			C	C	C			*VC*	
" mesolepta var. angusta Cleve.						F				C					F			F	F	F			C	
" nobilis Ehr.																		S						
" (Diploneis) ovalis Hilse.																		F		F				
" (Neidium) producta W. Sm.																				S				
" (Diploneis) puella Schumann						S	S				F				F				F	F				
" pupula Kütz.			C	F	C	C	F				F							C	C	C			C	
" radiosa Kütz.						F	F			F		S			F			F	F	F			C	
" (Caloneis) silicula Ehr.					F	F			S						S			F	F	F				
" subtilissima Cleve.			*VC*	C				F								C								
" viridis Nitzsch	F										S													

TABLE II—(Concluded).

Position in Core	Top								Middle								Bottom							
Core	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Nitzschia gracilis Hantzsch																		S						
" palea (Kütz.) W. Sm. ..					F	S	S								S	S								
Opephora martyi Herib																			S					
Pleurosigma acuminatum (Kütz.) Grun.																				S			S	
" spencerii (Quek.) W. Sm.																				S				
Rhopalodia gibba (Ehr.) O. Müll.	S																S			S			F	
" gibberula (Ehr.) O. Müll.																				S				
Stauroneis acuta W. Sm.														S					S	S			S	
" alabamae var. rostata Hust.	F									F		S						F						
" anceps Ehr. (and varieties)	C	S	C	C	C	C	F	F		F	F	S			F	F		C	F	C			VC	
" phoenicenteron Ehr.		S	S		F		S	S	S	F	S	S			S	S				S				
Stephanodiscus Niagarae Ehr. ...																							VS	
Surirella elegans Ehr.	S																						C	
" tenera Greg.	S		S		F				S	*VC*	F	S			S			S					F	
Synedra delicastissima W. Sm.....																				S				
" ulna Ehr.						VS									S				S					
Tabellaria fenestrata (Lyngb.) Kütz.	S		S	S		F				F	F		S			S		S						
" flocculosa (Roth) Kütz...	S		F	S	F	F	F		S	C	F		S			S			F	F				
" " " " var.					F	F			S	C	F													

VS—very scarce. C—common.
S—scarce. VC—very common.
F—frequent. *VC*—dominant.