CLEAR TECHNICAL REPORT NO. 76

ECOLOGICAL HISTORY OF SILVER LAKE, OHIO, THROUGH DIATOM ANALYSIS OF A SEDIMENT CORE

by

Cathy Lee Weiss
Environmental Biology Program

THE OHIO STATE UNIVERSITY
CENTER FOR LAKE ERIE AREA RESEARCH
COLUMBUS, OHIO

December 1977

PREFACE

The following document was prepared by Cathy Lee Weiss as partial requirement for a Master of Science Degree in the Environmental Biology Program, The Ohio State University. Research conducted for this thesis was partially supported by the Department of Botany and the Center for Lake Erie Area Research. Dr. Charles E. Herdendorf served as advisor; Drs. Clarence E. Taft and Emanuel D. Rudolph served as members of the reading and examination committee.

On behalf of the Center for Lake Erie Area Research, I am pleased that we are able to reproduce copies of this research report and make them available to other scientists.

Charles E. Herdendorf
Director

CLEAR TECHNICAL REPORT NO. 76

ECOLOGICAL HISTORY OF SILVER LAKE, OHIO, THROUGH DIATOM ANALYSIS OF A SEDIMENT CORE

by

Cathy Lee Weiss
Environmental Biology Program

THE OHIO STATE UNIVERSITY
CENTER FOR LAKE ERIE AREA RESEARCH
COLUMBUS, OHIO

December 1977

PREFACE

The following document was prepared by Cathy Lee Weiss as partial requirement for a Master of Science Degree in the Environmental Biology Program, The Ohio State University. Research conducted for this thesis was partially supported by the Department of Botany and the Center for Lake Erie Area Research. Dr. Charles E. Herdendorf served as advisor; Drs. Clarence E. Taft and Emanuel D. Rudolph served as members of the reading and examination committee.

On behalf of the Center for Lake Erie Area Research, I am pleased that we are able to reproduce copies of this research report and make them available to other scientists.

Charles E. Herdendorf
Director

ACKNOWLEDGEMENTS

Foremost I wish to extend my thanks to Dr. V. Ray Frederick for having secured the sediment core which was used in this diatom study. In addition, his assistance with the computer analysis of my diatom data was invaluable. I also wish to thank the members of my reading committee - the Drs. C.E. Herdendorf, C.E. Taft, and E.D. Rudolph - for their patient scrutiny of this thesis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This study of Silver Lake diatom sediments supplements earlier work by Ogden (1966) in pollen analysis and radiocarbon dating of select core samples, and the work of Frederick (1977) on the algae exclusive of the diatoms from a Silver Lake sediment core. An attempt has been made to formulate a climatic and ecological history of Silver Lake by analysing diatom data from fifty samples spaced evenly throughout a 7.35 meter sediment core.

Silver Lake, located in Logan County, Ohio, is a compound kettle lake formed in the Farmersville moraine approximately 11,000 to 14,000 years B.P., (before present), (Ogden 1966). Nearly seven miles southwest of the city of Bellefountaine, it lies at 1090 feet above MSL, adjacent to the highest elevation of the state, (Figure 1). The last of the glaciers to invade Ohio, the Wisconsin ice sheet flowed in two sections around this peak, forming the Miami and Scioto lobes which swept further south.

According to Ogden, and documented by Forsyth, (1961), Goldthwait (1959), and Sears (1930, 1941), at the retreat of the glacier an herbaceous flora with early postglacial trees predominated, (pollen zone 1). This period was followed by a reduction in spruce and fir, (zone 2), which later gave way to a deciduous forest, (zone 3). Zone 3 is further divided into four periods: 3a is

Figure 1. Map of Ohio showing location of Silver Lake in Logan County.

described by a more moist and warm climate, supportive of an oak-hickory stand with elm, beech, and walnut also evident; 3b is characterized by the most eastward extension of the prairie through Ohio, (Transeau 1935, 1941), having a warmer and drier climate than at present; 3c marks the return of the deciduous forest, including populations of oak, hickory, beech, maple, walnut, and ash; and finally the most recent period, zone 3d, signals the presence of man, in having high counts of *Ambrosia* and *Plantago* pollen indicative of forest clearance and the initiation of European-type agriculture.

PREVIOUS INVESTIGATIONS

The assessment of paleoclimate and lake paleoecology through diatom analysis has been made by many investigators. From the early 19th century, diatoms have been studied, their taxonomy improved, and the physical and chemical nature of their environment determined. Hustedt (1938, 1939) and Kolbe (1927) were among the earlier phycologists to study the relation between various ecological conditions and their associated diatom taxa, establishing halobian, current, and pH spectra by which the taxa were categorized. (The term "Taxa", as used herein, refers to the taxonomic classification of organisms to the level of species and variety.)

The halobian spectra, as defined by Kolbe (1927), classifies diatom taxa according to their degree of tolerance to salt. Oligohalobous forms are intolerant of salt concentrations greater than 5%, while mesohalobous taxa are present in brackish water and euryhalobous ones are truely marine. There are further sub-divisions of taxa within the oligohalobous category, including halophobic, or chloride-intolerant, taxa and halophilous taxa, which are tolerant of low chloride levels but occur most frequently in fresh water.

Hustedt (1938, 1939) devised the pH spectrum by which taxa may be categorized according to their pH tolerances. Alkalibiontic individuals are found at a pH above neutral, alkaliphilous forms may be sampled from waters of pH 7 or greater, indifferent taxa generally occur in neutral waters, acidophilous ones inhabit waters of pH 7 or less, and acidobiontic taxa show a greater occurrence in waters of pH $\leq$ 5.5 .

Although earlier studies were concerned with living representatives or surface sediment samples, more recent researchers have taken sediment cores several meters in length, enabling them to formulate hypotheses about the environment of the past. Hecky and Kilham (1973) concluded that sediment samples are generally more representative of a diatom population than are plankton samples, since seasonality and collecting net size may cause plankton samples to be misleading.

Studies of Lake Sallie, Minnesota, by Bradbury and Winter (1976) have shown that diatom valves which fall to the bottom of the water column are not redistributed by the current, but rather settle out in an area near that in which they lived. Therefore the "lake sediments potentially record a history of events that produced them", (pp. 1005). Edmondson (1974), studying the effects of domestic sewage input into, and diversion from, Lake Washington similarly concluded that a sediment core "is a diary of the deposition of particulate materials" into the lake. By examining diatoms in sediments, the ecological conditions of the past may be discovered. Birks (1976) and others agree that the present-day assemblages of certain species will be living under conditions similar to those which supported them thousands of years ago.

Pennington (1943), Round (1957, 1961), Haworth (1969), Pennington et al (1972) and Evans and Walker (1977) studied sediment cores from British lakes and ponds. They applied knowledge about the ecological tolerance of the diatoms sampled so that an ecological and climatic scheme of the lakes' past could be prepared. Pennington (1943) noted that diatoms could be "very sensitive indicators of variations in the environment", but caution should be taken since "any diatom may be over- or under-emphasized in counts due to [unequal] preservation of valves". Haworth (1969) acknowledged her concerns and continued by adding that only a minute area of lake bottom is sampled at any one time, thus inviting sampling bias.

Others, sampling in the United States, but conducting similar studies include Patrick (1936), Stoermer and Yang (1968), Stoermer, Taylor and Callender (1971) and Stoermer (1977). Diatom sediment core analyses undertaken elsewhere in the world include: Digerfeldt (1962), Bradbury (1971), Larson (1973), and Horie (#35, #37, and #46, 1975).

In addition to drawing conclusions about the past from ecological data pertaining to the taxa sampled, some researchers have made use of diatom ratios and indices to shed light on ecological histories. Duthie and Sreenivasa (1971) used Shannon's diversity and redundancy equations, (Shannon and Weaver 1964), to determine periods of eutrophy or oligotrophy in Lake Ontario. Patrick, in a study of Lago di Monterosi, Italy, (in Hutchinson 1970), and Koivo in Findland, (Koivo 1976), also used the diversity index to supplement other ecological information.

A eutrophic environment may be generally characterized as having high levels of organic enrichment, high species redundancy and low diversity, frequent algal blooms, and limited diurnal migrations of algal cells through the water column. An oligotrophic condition is just the reverse, exhibiting low levels of organics, reduced quantities of algae, high species diversity, and extensive diurnal algal migrations. A trophic condition showing characteristics midway between the two extremes is considered to be mesotrophic.

Stockner's ratio of Araphidineae to Centrales, commonly referred to as the A/C ratio, (Stockner 1971), enabled him to categorize the experimental lakes of northwestern Ontario into their trophic stages, as well as several Canadian and English lakes from earlier studies, (Stockner 1972). Realizing that the usefulness of the A/C ratio lies in the fact that Araphidineae and Centrales show "differential responses" to cultural lake enrichment, he noted that by "grouping species the interpretation is not subject to distortion by the presence or absence of any given species for undeterminable reasons", (Stockner and

Benson 1967, p. 529).

The Centrales/Pennales ratio, also referred to as the "diatom quatient" or C/P ratio, was designed by Nygaard (1949) as a measure of the trophic condition of a water mass. The C/P ratio has had widespread use, but must be considered with caution since, unlike Stockner, Nygaard perceives the Centrales as having a eutrophic tendency. The ecological characterization of those species contributing to the indices should be a deciding factor as to which index is the more accurate of the two for any particular study.

Another index designed by Nygaard (1956), the alpha index, is a means by which the numbers of taxa belonging to four of Hustedt's pH categories may be used to yield the pH of their surroundings. Merilä̈inen (1967) applied this formula to his study of 14 Finnish lakes, concluding that the accuracy of the index may be around one pH unit. A. del Prete (1977), examining three lakes in New York, also made use of this index and opts for its accuracy and usefulness.

MATERIALS, METHODS, AND STATISTICAL ANALYSES

The sediment core used in this study was taken from Silver Lake by V.R. Frederick using a modified Livingston Peat Sampler, (Livingston 1955). The exterior of the core was first stripped to avoid contamination, then subsamples were taken from the core with a cork borer. Fifty subsamples of approximately 1 cc each, from the sediment surface to 7.35 meters in 15 mm intervals, were preserved in 70% ethanol until diatom examination was commenced. From each of the subsamples 0.50 gm (wet weight) material was cleaned using 40 ml hydrogen peroxide (30%) at 20°C and several crystals of potassium dichromate. After 24 hours all organics had been entirely oxidized and the samples were decanted, rinsed with water, and resettled numerous times until no trace of oxidizing agent remained. Finally, to each drained sample, 10.0 ml material was added, the sediment thoroughly mixed, and 0.10 ml material transferred to a #1 (22 mm x 22 mm) coverslip. An even distribution of valves across the glass was attained by adding drops of distilled water until the entire area was wetted. The coverslip was dried over a warming tray then affixed with Hyrax mounting media, (refractive index = 1.64), to a slide. Two such slides were prepared for each sample.

Exceptions to the procedure as described above were the treatment of surface sediment sample Ø, for which

Table I. The total area of the slides viewed per level, the number of valves counted per sediment level, and the calculated numbers of valves for each 0.50 gm wet wt. sample.

Level #	sq. mm.	# valves in 0.50 gm.	# valves per level
Ø	2.34	10,416,650	500
1	3.82	6,410,250	"
2	8.21	2,941,150	"
3	3.87	6,250,000	"
4	4.91	4,901,960	"
5	4.72	5,102,040	"
6	2.56	9,615,384	"
7	2.12	11,363,636	"
8	9.68	2,500,000	"
9	1.93	12,500,000	"
10	2.25	10,869,565	"
11	2.11	11,363,636	"
12	3.51	6,944,444	"
13	3.01	8,064,516	"
14	2.92	8,333,333	"
15	6.35	8,787,878	"
16	7.61	3,164,556	"
17	1.17	20,833,333	"
18	3.35	7,142,856	"
19	3.91	6,250,000	"
20	4.01	6,097,560	"
21	4.46	5,434,782	"
22	1.33	67,857,142	"
23	4.01	6,097,560	"
24	2.27	10,869,565	"
25	4.66	5,208,333	"
26	3.53	6,944,444	"
27	1.40	67,857,142	"
28	1.49	66,666,666	"
29	1.49	66,666,666	"
30	5.02	4,807,692	"
31	1.64	14,705,882	"
32	2.86	8,333,333	"
33	4.91	4,901,960	"
34	1.98	12,500,000	"
35	7.78	3,125,000	"
36	20.16	1,201,923	"
37	37.80	641,025	"
38	10.80	75,892	17
39	10.80	53,571	12
40	10.80	174,107	39
41	10.80	156,250	35

Table I continued.

Level #	sq. mm.	#valves in 0.50 gm.	#valves per level
42	10.80	102,678	23
43	10.80	308,035	69
44	10.80	71,428	16
45	10.80	62,500	14
46	10.80	80,357	18
47	10.80	44,642	10
48	10.80	93,750	21
49	10.80	----	0

Level	Genera	Taxa
Ø	9	11
1	19	30
2	22	41
3	19	41
4	19	39
5	13	20
6	15	30
7	17	32
8	19	34
9	15	25
10	22	37
11	16	26
12	22	41
13	16	28
14	15	29
15	17	27
16	15	20
17	15	25
18	19	36
19	16	22
20	18	30
21	18	39
22	13	22
23	14	21
24	18	31
25	16	26
26	18	29
27	20	38
28	14	27
29	13	26
30	17	31
31	9	17
32	13	22
33	17	36
34	18	39
35	11	23
36	12	24
37	12	20
38	2	4
39	4	6
40	7	10
41	7	11
42	7	11
43	8	16
44	4	7
45	5	6
46	6	10
47	6	8
48	6	9
49	0	0

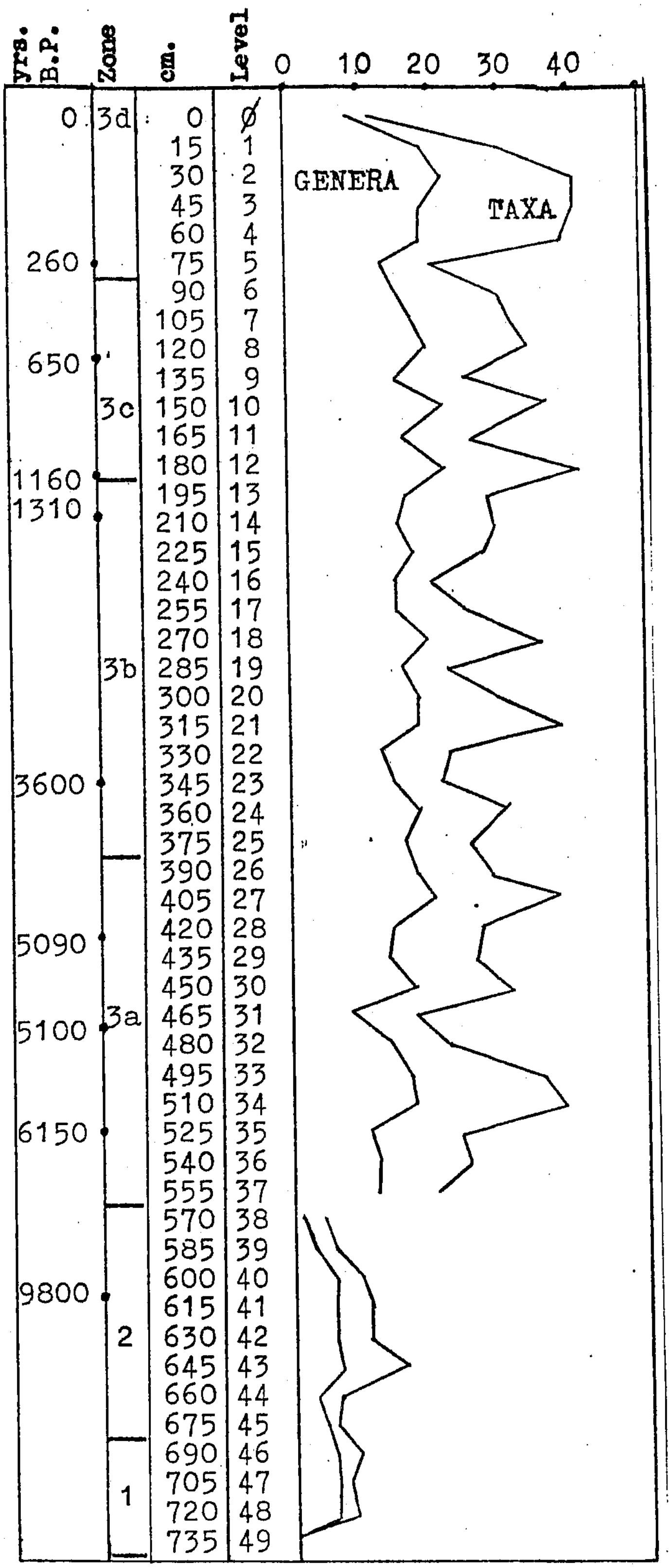

Figure 2. The total number of diatom taxa and the total number of diatom genera for each sediment level.

1.00 gm (wet wt.) material was cleaned and to which 20.0 ml water was added in the final step. For samples 8, 11 and 12 only 0.25 gm (wet wt.) material was cleaned and only 5.0 ml water was added to each for resuspension. The final dilution of the material on the slides from the original matter was therefore the same for all 50 samples.

For each slide representing sediment levels Ø through 37, 250 valves were identified to species, (or where appropriate, to specific variety), using Hansmann (1973), Huber-Pestalozzi <u>et al</u> (1942), Hustedt (1930), Patrick and Reimer (1966), and Weber (1971). The total area across the slides required to count 500 valves per level is recorded in Table I. In addition, the calculated number of valves present in each 0.50 gm. (wet wt.) sediment sample is given. Because of sparce populations of diatoms at levels 38 through 49, 10.80 sq mm was scanned per level. The total number of valves identified for these sediment samples is also included in Table I. Figure 2 contains the total numbers of genera and taxa for each level from the core.

Counts were made from random scans across each slide. Fragments of valves belonging to taxa having central areas were counted only when central areas were present. For taxa without central areas, the presence of at least half the valve was required before being included in the count. A Leitz Wetzlar DIALUX microscope with a Periplan-GF 10x ocular, oil immersion 100x/1.30 N.A. NPl objective, and a

Leitz Wetzlar GMBH light transformer was used for the study.

Percent organic and carbonate content of the sediment samples was determined by Frederick (1977) using the methods of Wetzel (1970), and appear in Figure 3. Computation of species diversity and species redundancy was executed according to Shannon and Weaver (1964), and is shown in Figure 4 for levels having valve counts of 500.

Figure 5 contains data about the alpha index and inferred pH for each sediment sample. Designed by Nygaard (1956), the alpha index is a method of determining the pH of the environment by substitution into the equation $pH = {}^{-}.81 \log\alpha + 6.63$. The alpha index is calculated for each level by dividing the sum of acid units by the total alkaline units. Species found to be tolerant of a wide range in pH or those most closely associated with pH 7, ("indifferent" species), are not taken into consideration in the formation of the alpha index. Division of the pH spectra into its five categories is according to Hustedt (1938). Ecological preferences for the diatom taxa encountered are included in Table II and were compiled from the following references: Bradbury (1971), Budde (1944), Duthie and Sreenivasa (1972), Foged (1948, 1954), Haworth (1972), Hutchinson (1970), Larson (1973), Lowe (1974), Nygaard (1956), Patrick and Reimer (1966, 1975), Pennington <u>et al</u> (1972), Round (1957, 1964), and Stoermer <u>et al</u> (1971).

The ratio of Araphidineae diatoms to Centrales, devised by Stockner (1971, 1972) and the ratio of Centrales to Pennales diatoms, (Nygaard 1949), are both measures of environmental conditions and are graphed in Figure 6. A third ratio, created by V.R. Frederick, (personal communication), divides the number of limnetic diatoms by littoral ones, thus serving as an indicator of water depth, (Figure 7).

Littoral organisms are those whose habitat is the photic zone along the sediment-water interface of a lake or stream. More specific sub-divisions of the littoral community include epilithic species, which live attached to a rock substrate, and epiphytic algae which exist attached to aquatic macrophytes. The limnetic group of algae are planktonic or free-floating, and drift with the movement of the water mass. As a general rule, centric diatoms belong to the limnetic group, while pennate diatoms are almost entirely littoral.

Statistical correlations between taxa and the parameters discussed above were computed using a Pearson product-moment program. Correlation coefficients were selected at the 95% level of significance.

Table II. Ecological tolerances of the diatom taxa.

Taxa	pH				Halobian				Habit			Trophic*		
	Ab	Ap	I	Ac	O	Hp	Hb	M	P	L	E	O	M	E
Achnanthes clevei var. *rostrata*		X			X									
A. exigua		X			X					X	X			X
A. exigua var. *heterovalva*		X	X		X						X	X	X	
A. flexella			X	X	X		X							
A. lanceolata var. *dubia*		X	X		X						X	X		X
A. linearis f. *curta*			X											
A. minutissima			X		X						X			X
Amphipleura pellucida		X			X			X			X			X
Amphora coffeaeformis	X							X			X			
A. delicatissima														
A. ovalis		X			X					X	X	X	X	
A. ovalis var. *pediculus*		X			X				X		X		X	X
Anomoeoneis sphaerophora var. *Güntheri*	X					X					X			
Asterionella formosa		X			X				X				X	X
Caloneis lepidula														
C. ventricosa		X	X		X								X	
Cocconeis pediculus		X	X		X						X	X	X	X
C. placentula var. *lineata*		X	X		X						X	X	X	X
Cyclotella antiqua				X			X		X					
C. bodanica			X	X					X			X	X	
C. comta		X	X		X				X			X	X	X
C. Kützingiana var. *radiosa*		X			X				X			X		

Table II continued.

Taxa	pH				Halobian				Habit			Trophic		
	Ab	Ap	I	Ac	O	Hp	Hb	M	P	L	E	O	M	E
Cyclotella Meneghiniana		X	X			X		X	X		X			X
C. stelligera		X			X				X					X
Cymbella affinis	X	X			X								X	
C. Ehrenbergii		X			X									
C. helvetica		X			X									
C. prostrata		X			X								X	
C. pusilla			X		X	X		X			X			
Denticula elegans		X			X						X			
Diploneis marginestriata			X		X									
Epithemia argus		X			X									
E. argus var. alpestris					X									
Eucocconeis flexella var. alpestris			X	X	X									
Eunotia arcus var. bidens		?	X	X			X					X		
E. maior				X	X						X	X		
E. parallela				X								X		
E. praerupta			X	X			X					X		
E. praerupta var. bidens			X	X			X					X		
Fragilaria construens		X			X				X		X	X	X	X
F. construens var. subsalina		X				X					X			
F. construens var. venter		X	X		X				X	X	X	X	X	X
F. crotonensis		X			X				X				X	X
F. gracillima												X		
F. leptostauron		X	X		X		X				X			
F. vaucheriae		X			X				X		X			
Gomphonema acuminatum var. coronata		X	X		X							X	X	

Table II continued.

Taxa	pH				Halobian				Habit			Trophic		
	Ab	Ap	I	Ac	O	Hp	Hb	M	P	L	E	O	M	E
<u>Gomphonema</u> <u>angustatum</u>		X	X		X						X	X	X	X
<u>G</u>. <u>angustatum</u> var. <u>producta</u>		X	X		X					X		X		
<u>G</u>. <u>constrictum</u>		X	X		X						X	X	X	X
<u>G</u>. <u>longiceps</u> f. <u>gracilis</u>		X			X									
<u>Gyrosigma</u> <u>strigilis</u>								X				X		
<u>Hantzschia</u> <u>amphioxys</u>		X			X			X		X	X		X	X
<u>Mastogloia</u> <u>Grevillei</u>										X	X			
<u>M</u>. <u>smithii</u>		X			X			X			X			
<u>M</u>. <u>smithii</u> var. <u>amphicephala</u>		X			X	X								
<u>M</u>. <u>smithii</u> var. <u>lacustris</u>	X	X			X	X					X			
<u>Melosira</u> <u>granulata</u> var. <u>angustissima</u>		X			X				X				X	X
<u>M</u>. <u>italica</u>		X	X		X		X		X	X	X		X	X
<u>Navicula</u> <u>accomoda</u>		X			X						X			
<u>N</u>. <u>atomus</u>		X	X		X						X			
<u>N</u>. <u>crucigera</u>														
<u>N</u>. <u>cryptocephala</u>		X	X		X			?			X		X	X
<u>N</u>. <u>elginensis</u>		X			X			X						
<u>N</u>. <u>halophila</u>		X						X			X		X	
<u>N</u>. <u>laevissima</u>			X								X			
<u>N</u>. <u>pupula</u> var. <u>mutata</u>			X		X						X			X
<u>N</u>. <u>pupula</u> var. <u>rectangularis</u>		X	X		X						X		X	X
<u>N</u>. <u>radiosa</u>			X		X			X			X		X	
<u>N</u>. <u>Rotaeana</u>				X	X									
<u>N</u>. <u>salinarum</u> var. <u>intermedia</u>		X			X			X			X		X	X

Table II continued.

Taxa	pH Ab	Ap	I	Ac	Halobian O	Hp	Hb	M	Habit P	L	E	Trophic O	M	E
Navicula scutelloides	X				X						X			X
N. subocculta														
N. tridentula							X							
Nedium iridis var. ampliatum			X		X		X				X			
N. productum			X		X									
Nitzschia acuta	X				X									
N. angustata var. acuta			X		X							X		
N. denticula		X			X						X			X
N. frustulum		X			X	X	X	X	X	X	X			X
N. ignorata														X
N. linearis		X			X						X			X
Opephora Martyii	X	X	X		X					X	X	X	X	X
O. swartzii					X			X						
Pinnularia biceps			X		X									
P. divergens			X											
P. flexuosa				X										
P. lata				X										
P. microstauron			X	X	X						X	X	X	
P. nodosa			X	X	X									
Rhopalodia gibba	X	X			X					X	X		X	X
Stauroneis anceps f. gracilis			X	X	X						X	X	X	X
S. anceps f. linearis			X		X									X
S. phoenicenteron f. gracilis			X		X						X			
Stephanodiscus astraea	X				X				X					X

Taxa	pH Ab	pH Ap	pH I	pH Ac	Halobian O	Halobian Hp	Halobian Hb	Halobian M	Habit P	Habit L	Habit E	Trophic O	Trophic M	Trophic E
<u>Stephanodiscus</u> <u>astraea</u> var. <u>minutula</u>	X	X			X				X					X
<u>S</u>. <u>tenuis</u>									X					X
<u>Surirella</u> <u>biseriata</u> var. <u>constricta</u>					X									
<u>S</u>. <u>linearis</u>			X		X									
<u>S</u>. <u>linearis</u> var. <u>constricta</u>			X		X									
<u>S</u>. <u>ovata</u>		X			X						X			X
<u>Synedra</u> <u>amphicephala</u>					X									
<u>S</u>. <u>cyclopum</u>											X			
<u>S</u>. <u>ulna</u> var. <u>longissima</u>		X			X						X			X
<u>Tabellaria</u> <u>fenestrata</u>			X	X			X		X		X	X	X	X

*Definition of symbols:

<u>pH Spectrum</u>: Ab= Alkalibiontic, (pH>7); Ap= Alkaliphilous, (pH≥7); I= Indifferent, (pH≈7); Ac= Acidophilous, (pH≤7)

<u>Halobian Spectrum</u>: O= Oligohalobous, (salt<5%); Hp= Halophilous, (salt 1-5%); Hb= Halophobous, (salt≈0%); M= Mesohalobous, (salt 5-20%)

<u>Habitat</u>: P= Planktonic, (free-floating); L= Littoral, (sediment-water interface); E= Epiphytic, (attached to vegetation)

<u>Trophic Spectrum</u>: O= Oligotrophic, (nutrient-poor); M= Mesotrophic; E= Eutrophic, (nutrient-rich)

Level	% Organic	% Carbonate
1	15.01	10.85
2	32.74	17.36
3	23.24	24.69
4	40.21	17.24
5	65.40	4.99
6	59.18	4.32
7	22.22	23.77
8	29.93	7.74
9	38.12	14.72
10	35.45	4.89
11	26.62	19.51
12	21.71	13.61
13	30.14	15.83
14	25.14	13.42
15	36.66	15.10
16	58.55	4.63
17	36.88	10.09
18	38.47	5.81
19	41.12	7.67
20	34.96	6.86
21	33.94	7.54
22	44.24	5.51
23	37.25	5.52
24	35.54	6.53
25	26.60	7.27
26	20.67	16.53
27	30.30	5.11
28	23.38	17.36
29	43.71	2.31
30	55.28	2.11
31	49.36	2.71
32	26.65	2.02
33	15.13	10.02
34	11.52	17.72
35	16.63	2.98
36	11.17	5.90
37	10.87	4.15
38	10.12	3.85
39	8.84	4.62
40	8.63	5.01
41	7.15	6.33
42	6.64	7.02
43	4.37	11.16
44	4.98	5.97
45	5.51	5.46
46	4.24	5.98
47	6.75	5.84
48	2.92	6.98
49	2.50	8.11

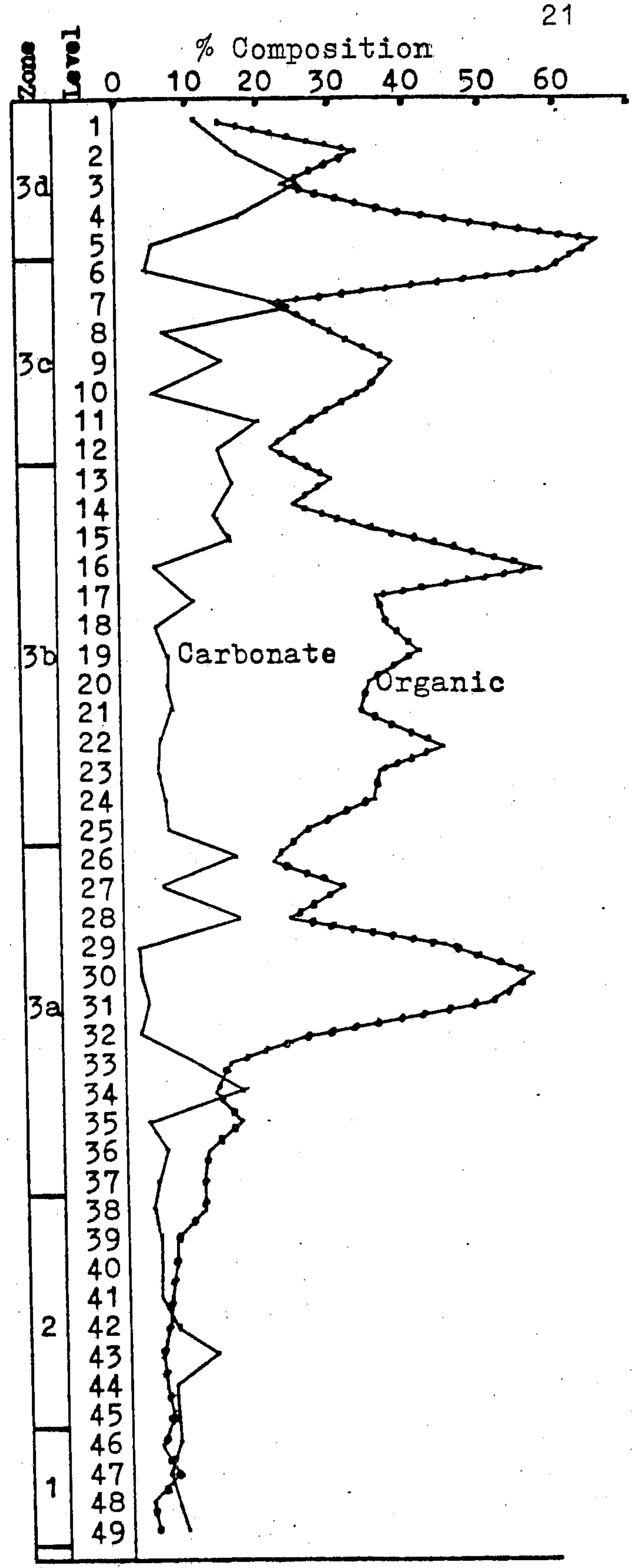

Figure 3. Organic and carbonate content of each level.

Level	Diversity	Redundancy
Ø	1.1431	0.5568
1	2.7762	0.2092
2	3.0215	0.2204
3	3.2316	0.1536
4	2.6030	0.3402
5	1.1495	0.6782
6	2.1394	0.4228
7	1.6103	0.6099
8	2.1087	0.4644
9	1.4770	0.6129
10	2.7279	0.2854
11	1.9577	0.4486
12	2.5670	0.3653
13	2.0292	0.4426
14	2.0527	0.4349
15	2.0339	0.4319
16	1.5140	0.5443
17	1.1447	0.7218
18	2.0955	0.4718
19	1.2638	0.6451
20	1.8464	0.5195
21	2.3829	0.4107
22	1.0959	0.7228
23	1.4534	0.5772
24	2.0223	0.4701
25	1.9791	0.4413
26	1.7771	0.5364
27	2.4900	0.3694
28	2.0837	0.4146
29	1.9573	0.4487
30	1.9873	0.4816
31	1.2043	0.6258
32	1.8301	0.4527
33	2.4600	0.3652
34	1.6412	0.6430
35	2.0652	0.3797
36	2.4102	0.2697
37	2.0462	0.3488

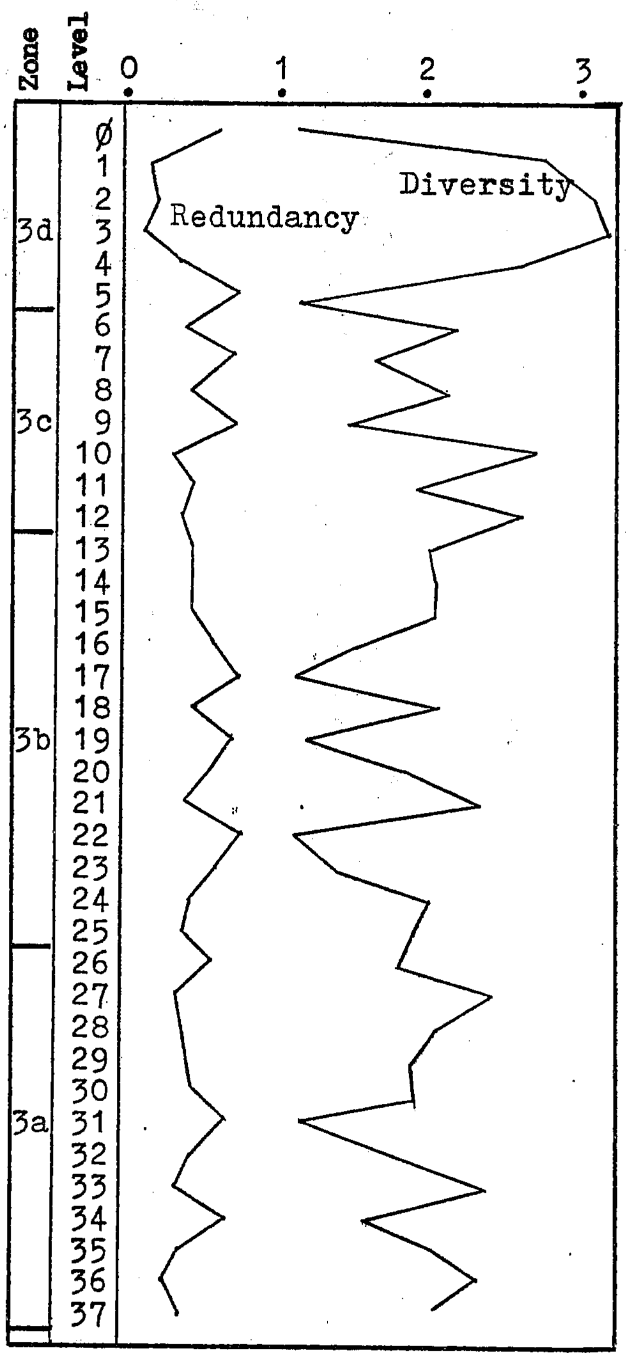

Figure 4. Diatom taxa diversity and redundancy values for levels Ø through 37. Insufficient data available for analysis of levels 38 through 49.

Level	α Index	pH
Ø	0.013	8.158
1	0.050	7.683
2	0.040	7.764
3	0.078	7.529
4	0.010	8.268
5	0.008	8.343
6	0.008	8.322
7	0.064	7.597
8	0.106	7.418
9	0.028	7.893
10	0.091	7.473
11	0.073	7.551
12	0.161	7.272
13	0.047	7.706
14	0.036	7.801
15	0.041	7.758
16	0.007	8.389
17	0.095	7.457
18	0.046	7.713
19	0.026	7.921
20	0.040	7.760
21	0.035	7.814
22	0.009	8.286
23	0.019	8.022
24	0.060	7.617
25	0.012	8.177
26	0.018	8.052
27	0.011	8.222
28	0.020	8.012
29	0.027	7.902
30	0.009	8.274
31	not calculated	
32	0.010	8.258
33	0.109	7.409
34	0.201	7.194

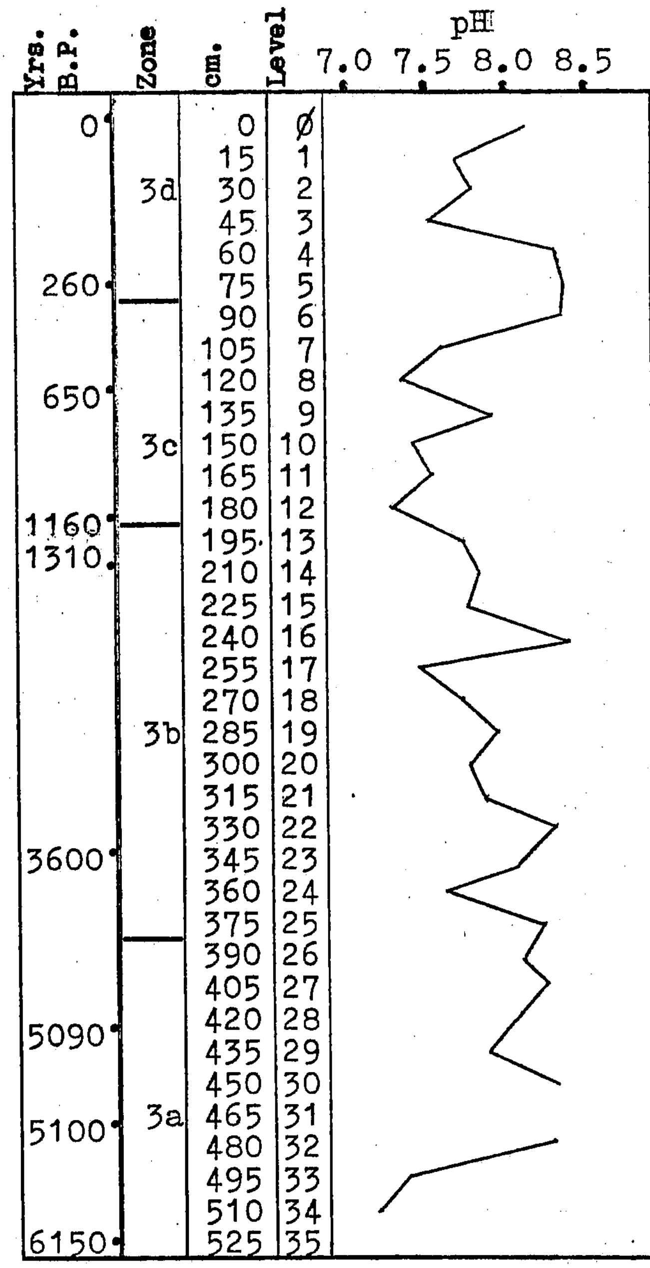

Figure 5. Alpha index and inferred pH for levels Ø through 34.

Level	A/C Ratio	C/P Ratio
Ø	0.328	2.650
1	1.024	0.506
2	0.428	1.167
3	0.736	0.222
4	2.111	0.276
5	6.078	0.147
6	3.050	0.250
7	0.058	5.024
8	2.015	0.355
9	2.385	0.370
10	3.971	0.163
11	0.595	0.938
12	0.548	0.916
13	0.167	1.577
14	0.548	1.000
15	0.374	0.799
16	0.820	0.730
17	0.043	3.854
18	0.919	0.587
19	1.630	0.529
20	0.610	1.008
21	2.495	0.272
22	2.563	0.312
23	2.690	0.292
24	1.314	0.538
25	2.309	0.326
26	0.889	0.825
27	0.434	1.212
28	0.935	0.866
29	2.719	0.319
30	27.385	0.027
31	7.904	0.116
32	19.550	0.042
33	0.602	0.672
34	0.101	2.788

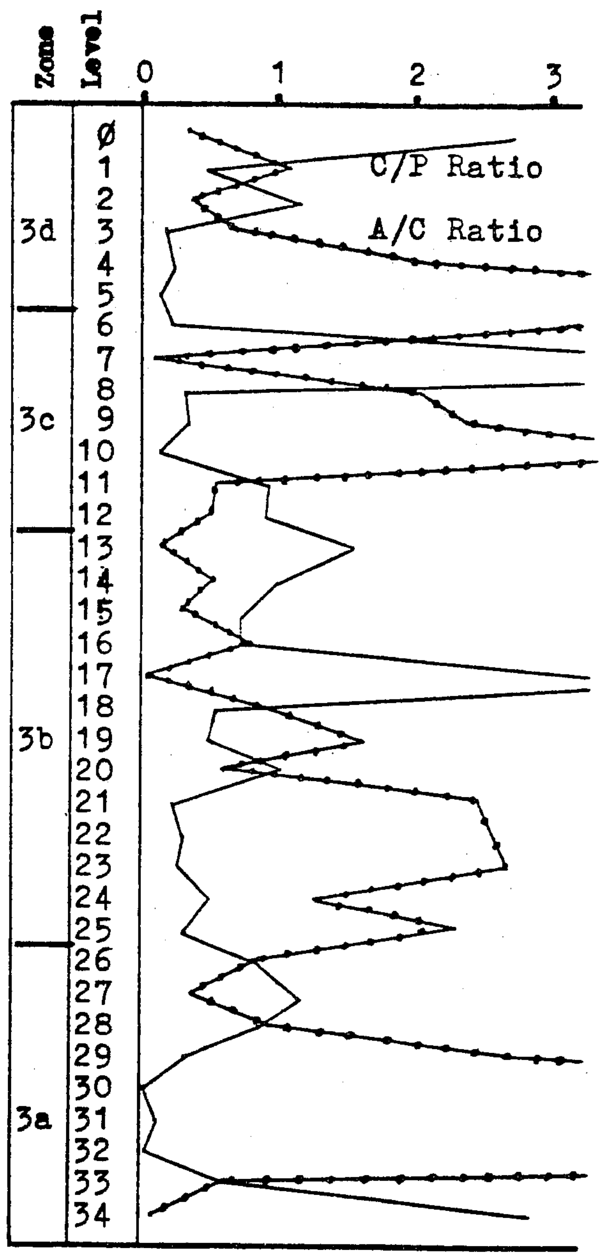

Figure 6. Ratio of Araphidineae to Centrales and ratio of Centrales to Pennales, based on the numbers of individuals per level.

Level	LD indiv	LD taxa
Ø	26.778	1.750
1	2.125	0.500
2	1.463	0.464
3	0.462	0.281
4	2.049	0.444
5	9.638	0.667
6	4.263	0.429
7	7.475	0.455
8	3.762	0.478
9	10.628	0.471
10	2.289	0.370
11	3.386	0.529
12	2.846	0.323
13	2.497	0.400
14	3.425	0.556
15	1.564	0.500
16	3.310	0.429
17	4.814	0.389
18	2.448	0.385
19	10.111	0.467
20	4.208	0.429
21	2.969	0.300
22	5.579	0.467
23	5.024	0.500
24	4.263	0.550
25	4.376	0.300
26	5.849	0.381
27	3.673	0.520
28	8.804	0.800
29	9.000	0.857
30	2.817	0.409
31	12.514	0.889
32	4.618	0.692
33	1.809	0.333
34	4.263	0.393

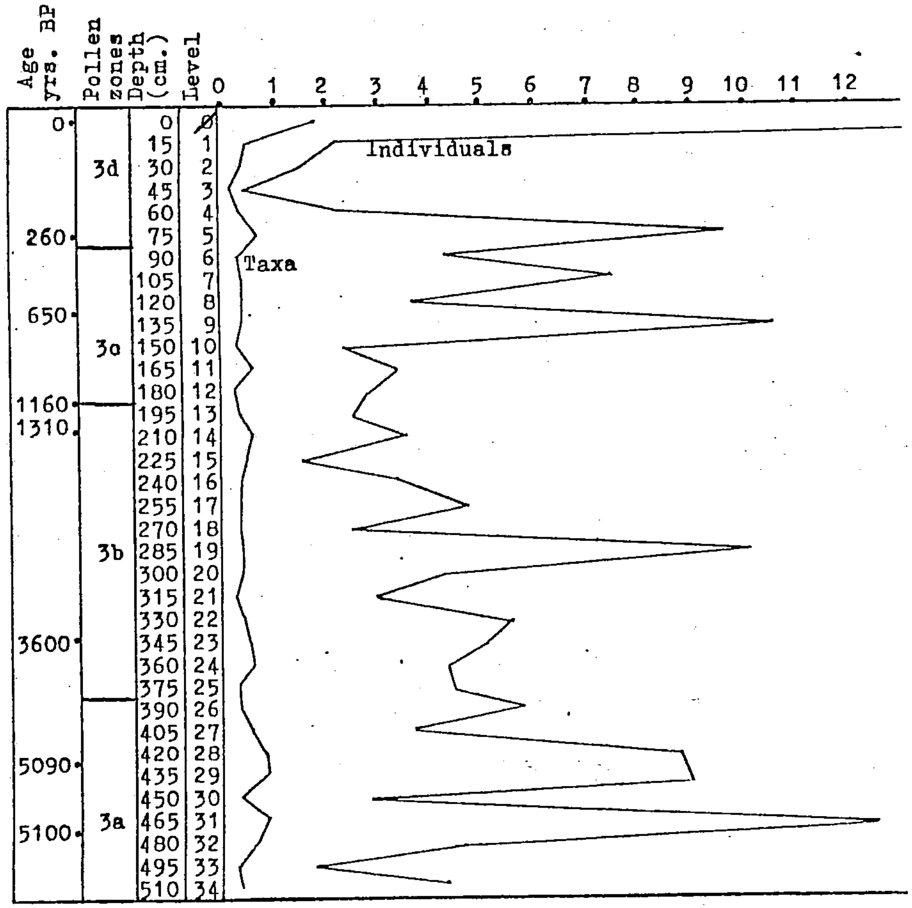

Figure 7. Diatom littoral development index using numbers of taxa and numbers of individuals for levels Ø through 34.

RESULTS AND DISCUSSION

From the 50 subsamples within the core, 105 diatom taxa from 35 genera were identified, (see Appendix A). Beginning at 7.35 meters in glacial till and continuing upward through the 5.70 meter level approximately four thousand years later, 280 individuals representing 34 taxa and 16 genera were counted, (Appendix B). Of these, 3 taxa were found to occur exclusively in this lower portion of the core: *Anomoeoneis sphaerophora* var. *Güntheri*, *Cymbella prostrata*, and *Opephora swartzii*. Two of the 3 are considered alkaliphilous, while the third is alkalibiontic. This lends support to the hypothesis that Silver Lake, lying in limestone bedrock, had fairly alkaline beginnings. *Fragilaria construens*, *F. construens* var. *subsalina*, and *F. construens* var. *venter*, the most dominant taxa from the 7.35 through 5.70 meter depths, are also considered alkaliphilous, and may be found living planktonically or in the littoral zone.

Pollen zones 1 and 2 occur entirely within these lower sediment depths. The level of organics began to increase during this period, carbonate content peaked then showed a decline, (Figure 3), and the postglacial spruce and fir were replaced by oak and herbaceous vegetation. A hypothesis that the lake was rather shallow during this time, owing to the porous nature of glacial till and a less humid climate during zone 2 is suggested. Frederick (1977) identified the shallow-water alga Chara from these zones, lending encouragement to this theory. Also, Hutchinson (1973) and Koivo (1976) hypothesized the existence of oligotrophic lake conditions for initial postglacial periods, owing to the low temperatures and the great erosion of glacial till acting to bury organic matter.

If Silver Lake were as alkaline as has been suggested, it would serve as an explanation for the relative paucity of diatoms observed. At approximately pH 8.3 silicon dioxide returns to solution, thus permitting few valves to be preserved, (Kendall 1969). Hecky and Kilham (1973) determined that as the level of organic matter in the sediment rises, the preservation of diatom valves in highly alkaline lakes is enhanced. A rise in percent content of organics at sample 38 from the low levels encountered before that is predictably accompanied by an increase in the number of diatom frustules after level 38. Previous to this depth the percent content of organics in the sediments are at the lowest levels recorded for the core, and that coupled with high pH values would result in poor diatom valve preservation. In addition, Frey (1969) and Bradbury and Winter (1976) noticed that dissolution of frustules occurs more readily in littoral zones, or in the entire water columns of lakes less than 25 meters in depth, such as Silver Lake.

Two unlikely alternatives to this explanation are that either silica or calcium carbonate is limiting. The first prospect, that silica may be limiting to their growth, (as it is if concentrations are as low as 0.5 mg/l (Pearsall 1932)), is eliminated because sand and undissolved silica are abundant in the lower levels (Table III). The second alternative has been rejected since the limestone-lain lake would certainly meet the required 3.0 mg/l minimum of calcium carbonate for the support of diatom growth, (Pearsall 1932). Finally, the frustules could have been destroyed by other organisms. The amphipods Hyalella and Crangonyx are capable of crushing diatoms into tiny fragments, (Edmondson 1975), and the macro-invertebrate Mysis relicta harvests sinking diatom cells, (Stoermer and Yang 1968). The inadequacy of this hypothesis is twofold: the core depth selectivity; and the nearly total destruction of frustules inhabiting only the lower sediment levels.

For the remaining samples Ø through 37, 500 valves were identified from each level. Andrews (1972) suggested that it is sufficient to count only 200 valves when attempting to determine "biostratigraphy". Ritchie and Koivo (1975) counted 200 valves from a Glacial Lake Agassiz core then compared the ecological relative frequencies to counts of greater than 200. They found the two counts to be comparable, even though a considerable number of additional taxa were added after 200 valves were identified.

Table III. Description of sediment as illustrated by 25 levels at 30 centimeter intervals, (Frederick, 1977).

Core depth (cm)	Sediment
0 - 76	Yellow-brown marly gyttja
76 - 198	Banded dark gray-brown marly gyttja
198 - 290	Light gray marly gyttja
290 - 351	Dark gray-brown marly gyttja
351 - 411	Banded dark gray-brown gyttja
411 - 442	Gray-brown gyttja
442 - 564	Dark gray-brown gyttja
564 - 686	Light gray-brown gyttja
686 - 716	Banded dark gray-brown gyttja with wood fragments
716 - 747	Gray-brown gyttja with sand and wood fragments

As a precaution against counting too few valves, each sediment sample's taxa was subjected to Preston's (1948) octave curve. Ideally, according to Patrick (1954), the curve mode should lie in the third or fourth octave in order to properly represent the population. In 9 of the 38 samples the mode fell in the second octave, while the other samples were safely within the third octave or greater.

The assumption is that the core was essentially undisturbed and that samples accurately represent the sediment levels from which they were taken. Mixing of shallow sediments may occur as a result of the activities of diving birds, carp, or burrowing invertebrates. Stockner and Lund (1970) located chironomids at sediment depths of 1 meter, but the invertebrates were found to occur only occasionally lower than 15 cm. They concluded that had the chironomids stirred the sedimants significantly it would be evident by stratigraphy destruction, which was not a problem in this study. (See Table III.)

Sediment samples 37 through 26 lie within pollen zone 3a. Centric diatoms are essentially absent from the core from its beginning until level 34. One *Melosira italica* and 3 *Cyclotella bodanica* valves are the only representatives from the centrics at lower depths. Correlation analysis indicates that the centrics are negatively associated with alkaline conditions, again supporting the theory that initially Silver Lake was very alkaline. At level 34 the centrics, almost entirely composed of <u>Cyclotella bodanica</u>, (Figure 8), reached a peak in abundance which was surpassed only twice thereafter (Figure 9). This peak corresponds to a significant increase in percent carbonate and the lowest calculated inferred pH for the core of 7.19.

Level 31 corresponds to a period of heavy precipitation approximately 5,100 years B.P. A postulate is entertained that the lake bottom became sealed with primarily allochthanous sediment at this time, causing water depths to increase substantially. The sediment deposition rate increased markedly at this time (Figure 10) and the number of valves in 0.50 gm of sediment reached the highest value recorded up to that level. Kendall (1969) recorded peaks in sedimentation rates for Lake Victoria, Tanzania, Jih-Yueh Tan, Taiwan, and Rodgers Lake, Connecticut coincident with that for Silver Lake. The littoral development index potentially indicates periods of high and low water level, being dependent upon the numbers of littoral and limnetic diatoms present at each sediment level (Figure 7). At level 31 the index rises sharply, surpassed only by the surface sediment sample, suggesting an increase in water depth and proportionately fewer littoral diatoms.

Percent organics showed a rapid increase at sample 31, the level of carbonates decreased, species diversity dropped dramatically, and the Araphidineae, primarily <u>Fragilaria</u>

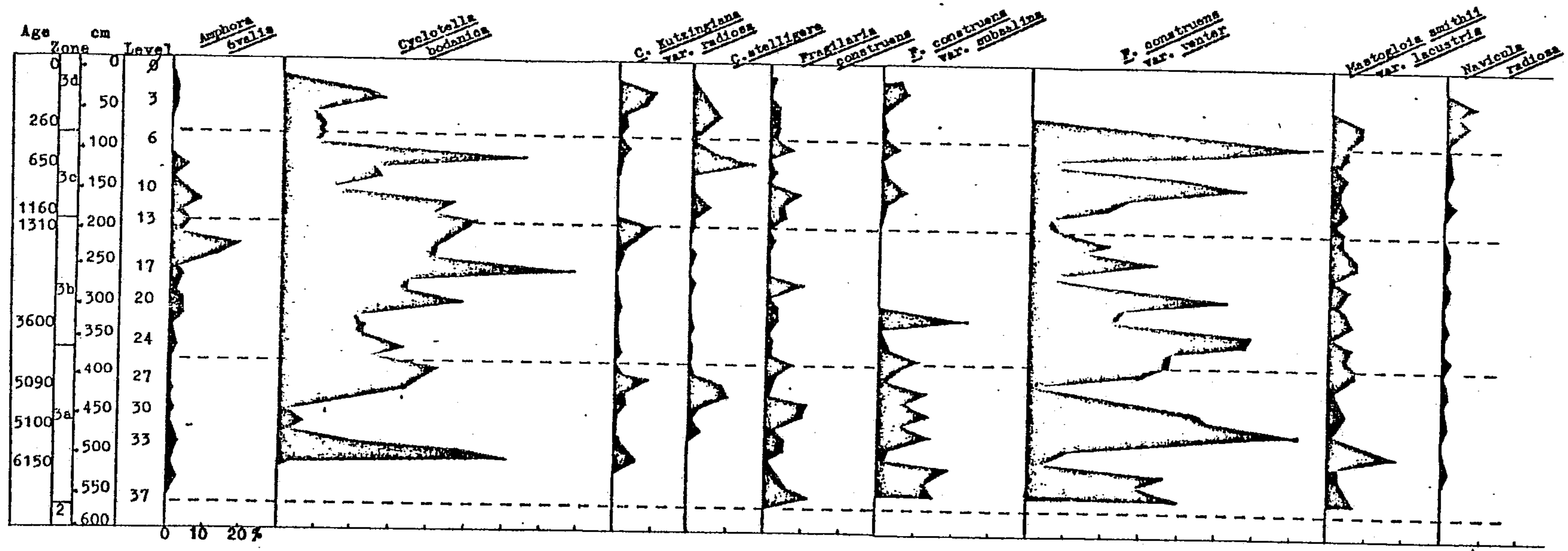

Figure 8. Percentage frequency per level of selected diatom taxa for levels Ø through 37.

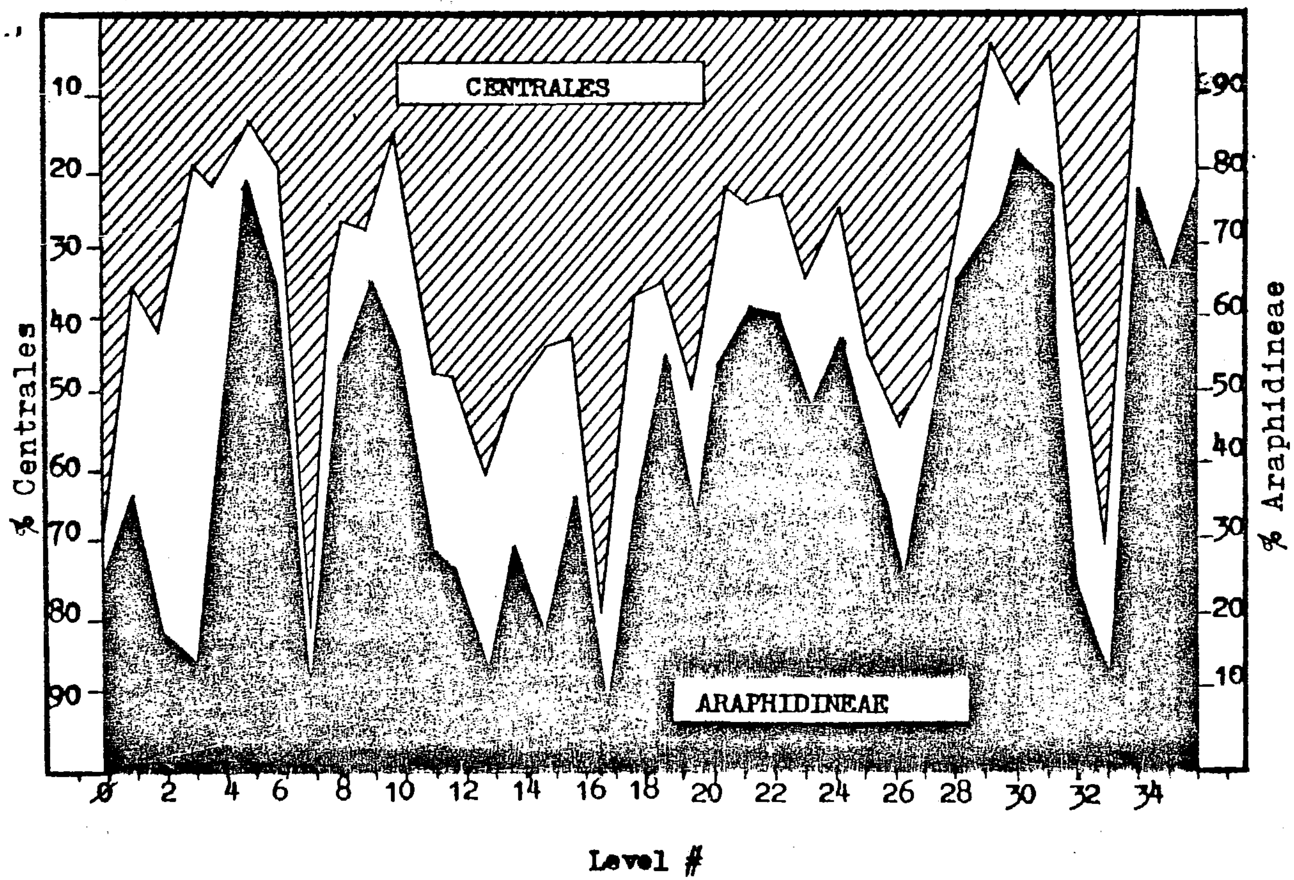

Figure 9. Percentage of Centric and Araphidineae diatoms per level. The balance may be attributed to Biraphidineae primarily, although some Monoraphidineae and Raphidoidineae occur.

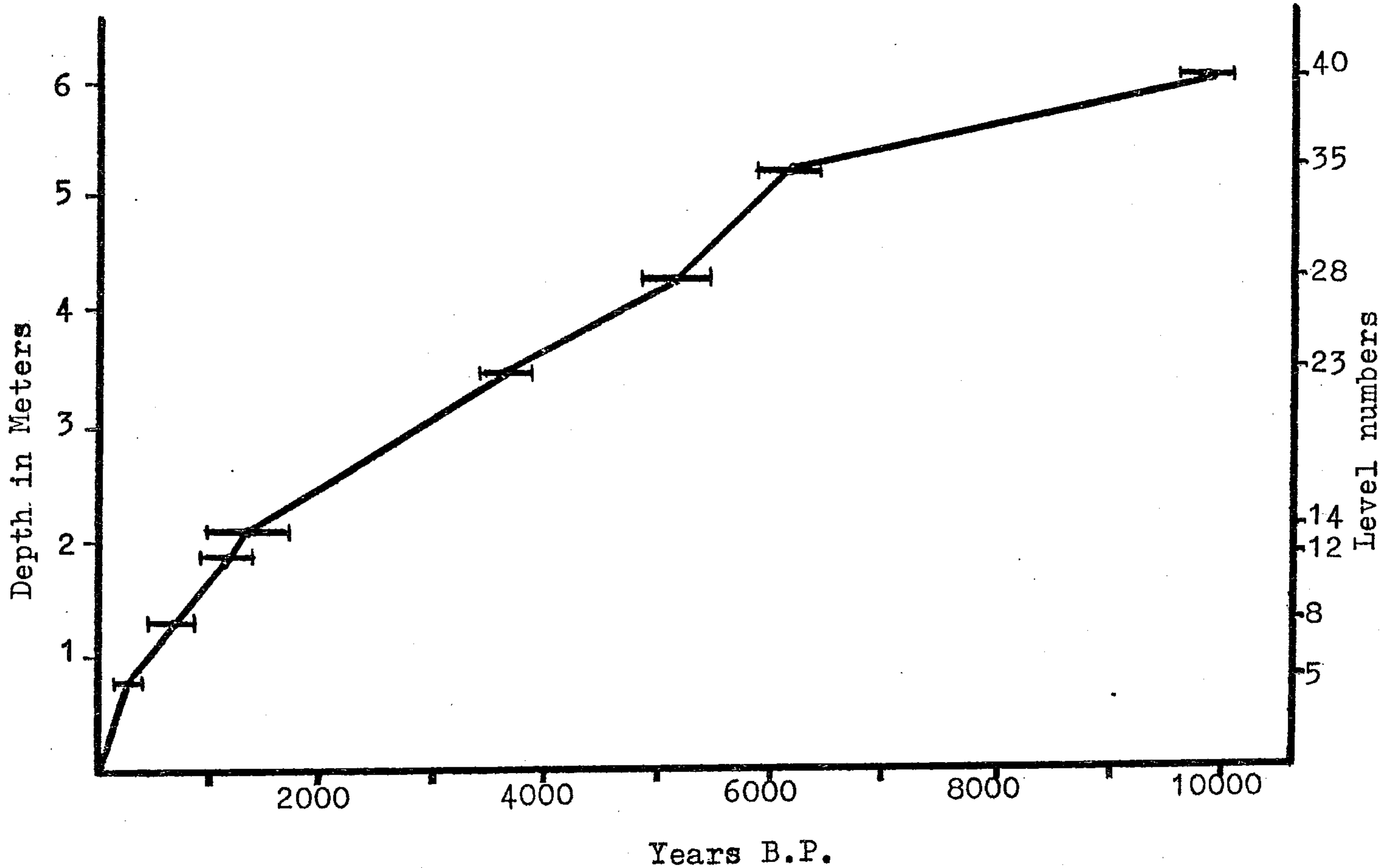

Figure.10. Sediment deposition rates for Silver Lake with standard errors in years. Data from Ogden (1966), chart from Frederick (1977).

construens var. venter, reached their greatest abundance of any time throughout the core. Percent organics and percent carbonates are generally negatively correlated at all times. Wetzel (1970) considers the cause of this relationship to be the absorbent quality of particulate calcium carbonate towards certain dissolved organic compounds, which further reduces the level of organics by inhibiting their regeneration by microbial action. A drop in species diversity and the proliferation of Araphidineae are generally thought to be indicative of eutrophication. Frederick's results substantiate this in the lack of Desmidaceae, indicators of oligotrophic conditions, and the complementary rise in eutrophic Cyanophyta and Chlorococcales species.

The pH could not be calculated at this level since acidic species, necessary for the computation of the alpha index, were absent from the sample. However, one may infer that the pH was 8.0 or greater from the presence of only alkaline species and the pH of adjacent samples.

Continuing upward, the diversity index increased to a maximum for the zone at level 27, the percent organics declined, Cyclotella species peaked for a second time, and Fragilaria species, (most notably F. construens var. venter), were rare. These conditions, when analyzed as a whole, signify a period of oligotrophy, which is supported by values from the A/C ratio. This condition is not unexpected since the rise in water level and reduction in precipitation would cause a dilution of available nutrients.

The lower portion of pollen zone 3b is characterized by an increasing percentage of centric diatoms, reaching a climax at sediment level 17, a reduction in Araphidineae to a record minimum at that level, and a peak in organics at level 16. The pH is calculated to be at its zenith at level 16 - nearly 8.4. The estimated number of valves in 0.50 gm reaches a minimum for the zone also at level 16, which is likely to be the result of the association of high pH and increased dissolution of silicon dioxide.

The remaining levels of zone 3b show a decrease in the content of organics, a corresponding increase in percent carbonate, a reduction in Araphidineae following their momentary rise at level 16, and an increase in centrics after their reduction at level 16. Species diversity also increased following the period of environmental stress imposed by the high pH. _Amphora ovalis_ attained its maximum representation during level 16 when the pH is thought to have been so high. Perhaps their valves are more resistant to dissolution at high pH levels, causing their over-representation at level 16.

The highlights of zone 3c, encompassing sediment samples 12 through 6, occur at levels 7 and 6. At 1.05 meters there was a drop in organic content, shadowed by a reduction in _Fragilaria construens_ var. _venter_ and an increase in Cyclotella bodanica. Appropriately, the A/C ratio is seen to drop and a period of oligotrophy is generally prevailing. This is accompanied by a fairly healthy species diversity and low levels of taxa indicative of eutrophic conditions, such as Mastogloia smithii var. lacustris. As one approaches level 6, a reversal in ecological conditions takes place. Oligotrophy is replaced by increasing eutrophy and the associated indicators react accordingly. The A/C ratio climbs above 3.0 and the level of organics begins to rise. (An A/C ratio below 1.0 is considered to represent oligotrophy while one above 2.0 signals a eutrophic potential, according to Stockner (1971).)

Sediment sample 5, belonging to the most recent pollen zone, 3d, contains taxa indicative of highly eutrophic conditions. At this time, approximately 260 years B.P., European agricultural practices became established in the area immediately surrounding Silver Lake. Forest clearance, documented via pollen analysis as an increase in Ambrosia and Plantago, brought about increased water run-off and erosion, contributing to the lake's enrichment. The littoral development index shows a rise in limnetic taxa at that time, suggesting an increase in water depth brought about by increased land runoff. Organics then contributed more to the sediment than at any other time in the history of Silver Lake, the species diversity index reached a minimum, and sediment deposition increased to a rate as of yet unparalleled. The pH also rose, perhaps a reaction to the increased contribution of alkaline soil to the lake, or possibly a result of increased algal photosynthesis. Asterionella, commonly occurring in conjunction with forest clearance, (Hutchinson 1973), predictably appeared at level 5 and was found in increasing quantities up to the surface sediment sample.

At level 3 the carbonate content rose, indicative of active tillage of the watershed, (Wetzel 1970). Also at this time the contribution by the Biraphidineae reaches a maximum of 55.6%, primarily attributable to increases in Cymbella species, Epithemia argus, (10.4%), and Navicula species, (most notably Navicula radiosa).

From level 3 to the present time the lake has gradually become less eutrophic. A note of caution must accompany the interpretation of the A/C ratio of the surface sediment sample, however. Since the centric diatoms consist wholly of Stephanodiscus tenuis and Melosira granulata var. angustissima at sample Ø, and since both are indicators of eutrophy, the intent of the index is unfulfilled. Since the C/P ratio inherently considers centrics to be tolerant of eutrophic conditions, this is the more accurate ratio for this level. At all other times throughout the core the majority of the centrics are intolerant of enrichment, and therefore the A/C ratio is the more useful.

SUMMARY AND CONCLUSIONS

Early postglacial data concerning Silver Lake suggest that, due to the porous nature of glacial till, it was a shallow lake with a fairly alkaline pH and few diatom taxa. The level of organics is very low, and because of the rapid erosion of till, sedimented organics were quickly covered and inhibited from becoming resuspended. Like most postglacial lakes, Silver Lake was probably oligotrophic in character initially, as exemplified by sample 34 at 5.10 meters.

Approximately 5,100 years B.P., at level 31 in the core, an increase in world-wide precipitation caused a significant change in the ecology of Silver Lake. As the forest evolved to deciduous vegetation from a primarily coniferous one, allochthanous nutrient matter contributed to the eutrophication of Silver Lake. The porous lake bed probably became sealed and the sediment deposition rate rose substantially. The depth of the water column undoubtedly increased, which is indicated by the diatom littoral development index. As the period of intense precipitation declined, the degree of eutrophy subsided until an oligotrophic environment prevailed, beginning at sample level 27, 4.05 meters from the sediment surface.

For a brief period at 2.40 meters, (sample level 16), the percent composition of centric diatoms decreased, the numbers of Araphidineae valves increased, percent organics peaked, and the inferred pH reached the greatest alkaline value calculated for any sample level within the core. Thereafter until sample level 5, the lake resumed an oligotrophic character.

Nearly 260 years ago, represented by level 5, the area surrounding Silver Lake was cleared of its woody vegetation and cultivated by the early Ohio colonists. The effects of deforestation and active tillage of the watershed are manifested as an increase in sediment deposition, a rise in the level of organics, reduced diatom species diversity, and indications of a condition of extreme eutrophication. From this depth, at 0.75 meters to the surface sediment sample, the degree of enrichment has declined. Currently, over 90% of the watershed is being cultivated (Ogden 1966).

By careful analysis of the diatom communities from a Silver Lake sediment core, and correlated physical data about the sediments, it has been possible to infer the ecological and climatic conditions which prevailed throughout the lake's history. The results from this examination correlate well with the pollen and radiocarbon data of Ogden (1966) and the non-diatom algal data prepared by Frederick (1977). A summary of the highlights and conclusions from these three studies may be seen in Table IV.

Table IV. Summary of Silver Lake paleoecology and paleoclimate as proposed by the present diatom study, the non-diatom algal study by Frederick (1977), and the pollen analysis and radiocarbon dating by Ogden (1966). Pollen zones according to Ogden.

Pollen Zone	Age Yrs. B.P.	Depth cm.	Sample no.	Diatom Analysis: Highlights	Diatom Analysis: Conclusions	Non-diatom Algal Analysis: Highlights	Non-diatom Algal Analysis: Conclusions	Pollen and Radiocarbon Analysis: Highlights	Pollen and Radiocarbon Analysis: Conclusions
3d	260 level 5	15 to 76	1-5	High A/C ratio and littoral development; low diversity followed by max. diversity then low again; high pH; *Asterionella* present; Biraphidineae maximum.	eutrophic but becoming less so towards top of zone	High carbonates midway; organics max.; Desmids decline; Cyanophyta and Chlorococcales dominant; *Phacotus* max.; low diversity; compound quotient high.	eutrophic	Sedimentation rate max.; oak decline; *Ambrosia* and *Plantago* max.	European type agriculture at level 5, 260 yrs. B.P.
3c	650 level 8 1160 level 12	76 to 195	6-12	High species diversity; Centrics max.; low A/C ratio; high diversity and littoral development; lower pH; *Cyclotella stelligera* max.	oligotrophic	Cyanophyta and Chlorococcales declined; Desmids abundant; high organics; low compound quotient; carbonates increased then decreased; high diversity.	oligotrophic	Reduced non-arboreal; rise in beech, oak, maple, ash, elm, and walnut.	cooler, moist; bottom of zone 1160 yrs. B.P.; level 8 is 650 yrs. B.P.
3b	1310 level 14 3600 level 23	195 to 381	13-25	Inferred pH max. at level 16; low A/C ratio; *Cyclotella bodanica* and *Amphora ovalis* max. at level 17; fluxuating diversity.	Generally oligotrophic very alkaline	Cyanophyta and Desmids high; low Chlorococcales; diversity high; compound quotient low; organics and carbonates high.	oligotrophic	Prairie; hickory max.; beech min.	warm, dry; top of zone 1310 yrs. B.P.; level 23 is 3600 yrs. B.P.
3a	5100 level 31	381 to 564	26-37	Lowest inferred pH at level 34; centrics replaced by Araphidineae in dominance at level 31 then return to dominance; diversity low and littoral development and redundancy high at level 31.	alkaline, eutrophic phase at level 31	Reduced *Botryococcus* at end of zone; Chlorococcales and Cyanophyta abundant; diversity max. at top of zone; compound quotient max. at level 31, then min.; organics high then low; low carbonates.	eutrophic phase at level 31, then oligotrophic; lake basin filled	No spruce, fir or pine; oak, hickory, beech, walnut, and elm increase; increased sedimentation rate.	warm, moist, high precipitation at 5100 yrs. B.P., (level 31)
2	9800 level 41	564 to 686	38-45	Few taxa; very alkaline pH; dominant taxa: *Fragilaria construens*, *F. construens* var. *subsalina*, and *F. construens* var. *venter*.	shallow, alkaline and oligotrophic	Chlorococcales abundant; much *Botryococcus*; some Desmidaceae; organics high; carbonates peaked then declined; high diversity and compound quotient.	shallow oligotrophic	Oak abundant; spruce decline; non-arboreal increase.	warming; radiocarbon date: 9800 yrs. B.P. at level 41
1		686 to 747	46-49	↓	↓	*Chara* abundant; low organics; high carbonates; Cyanophyta dominant; compound quotient high then low; low diversity index.	shallow eutrophic	Spruce, fir, sedge and grass.	cool and moist

LITERATURE CITED

Andrews, G.W. 1972. Some fallacies of quantitative diatom paleontology. Nova Hedwigia 39: 285-295.

Birks, H.J.B. 1976. Late Wisconsin vegetational history at Wolf Creek, central Minnesota. Ecol. Monogr. 46: 395-429.

Birks, H., M.C. Whiteside, D.M. Stark and R.C. Bright. 1976. Recent paleolimnology of three lakes in northwestern Minnesota. Quat. Res. 6: 249-272.

Bradbury, J.P. 1971. Paleolimnology of Lake Texcoco, Mexico - evidence from diatoms. Limnol. Oceanogr. 16: 180-200.

Bradbury, J.P. and T.C. Winter. 1976. Areal distribution and stratigraphy of diatoms in the sediments of Lake Sallie, Minnesota. Ecology 57: 1005-1014.

Budde, H. 1944. Die Benthale Algenflora, die Entwicklungsgeschichte der Gewasser und die Seentypen in Naturschutzgebeit. Arch. Hydrobiol. 39: 189-293.

del Prete, A. 1977. Diatoms in Honnelaga, Woodhull and Seventh Lakes. Paper presented at annual meeting of Amer. Soc. Limnol. Oceanogr., Ann Arbor, June 20-27. State U. N.Y., Oswego. Typescript copy. 15p.

Digerfeldt, G. 1962. The postglacial development of Lake Trummen. Folia Limnol. Scand. 16: 1-104.

Duthie, H.C. and M.R. Sreenivasa. 1972. Evidence for the eutrophication of Lake Ontario from the sedimentary diatom succession. Proc. 14th Conf. Great Lakes Res., Int. Assoc. Great Lakes Res., pp. 1-13.

Edmondson, W.T. 1974. The sedimentary record of the eutrophication of Lake Washington. Proc. Nat. Acad. Sci. 71: 5093-5095.

_______________ 1975. Microstratification of Lake Washington sediments. Verh. Internat. Verein Limnol. 19: 770-775.

Evans, G.H. and R. Walker. 1977. The late quaternary history of the diatom flora of Llyn Clyd and Llyn Glas, two small oligotrophic high mountain tarns in Snowdonia (Wales). New Phytol. 78: 221-236.

Foged, N. 1948. Diatoms in water-courses in Funen. Dansk. Bot. Arkiv 12(nos. 5,6,9,12), var. pps.

Foged, N. 1954. On the diatom flora of some Funen lakes. Folia Limnol. Scand. 6: 7-81.

Forsyth, J.L. 1961. Dating Ohio's glaciers. Ohio Div. Geol. Survey, Info. Circ. 30, Columbus, Ohio. 9p.

Frederick, V.R. 1977. The environmental significance of the algal floras from three central Ohio sediment profiles. Doctoral Dissertation, The Ohio State University, Columbus, 91p.

Frey, D.G. 1969. Evidence for eutrophication from remains of organisms in sediments. pp. 594-613. In: Eutrophication: Causes, Consequences, Correctives. National Academy of Science, Washington, D.C.

Goldthwait, R.P. 1959. Scenes in Ohio during the last ice age. Ohio J. Sci. 59: 193-216.

Hansmann, E.W. 1973. Diatoms of the streams of eastern Connecticut. State Geological and Natural History Survey of Conn., Dept. Env. Protection Bull. 106.

Haworth, E.Y. 1969. The diatoms in a sediment core from Blea Tarn, Langdale. J. Ecol. 57: 429-439.

__________ 1972. Diatom succession in a core from Pickerel Lake, northwestern South Dakota. Geol. Soc. Amer., Bull. 83: 157-172.

Hecky, R.E. and P. Kilham. 1973. Diatoms in alkaline, saline lakes: ecology and geochemical implications. Limnol. Oceanogr. 18: 53-71.

Horie, S., ed. 1975. Paleolimnology of Lake Biwa and the Japanese pleistocene. Contribution on the Paleolimnology of Lake Biwa and the Japanese Pleistocene. 3(85):

- #35. Shinobu Mori. Vertical distribution of diatoms in core samples from Lake Biwa. pp. 368-391.
- #37. N.N. Davidova and A.A. Kurochkina. Late glacial and postglacial paleolimnology of Lake Onega. pp. 409-419.
- #46. W.Pennington. Climatic changes in Britain, as interpreted from lake sediments between 15,000 and 10,000 years ago. pp. 536-569.

Huber-Pestalozzi, G. and F. Hustedt. 1942. Die Kieselagen, In: A. Thienemann. Das Phytoplankton des Susswassers, Die Binnengewässer. Band XVI, Tiel II, Hälfte II.

Hustedt, F. 1930. Bacillariophyta. pp. 1-466. In: A. Pascher, Die Susswasser - Flora Mitteleuropas.

_____ 1938. Systematische und Ökologische Untersuchungen Über die Diatomeen-flora von Java, Bali, und Sumatra. Arch. Hydrobiol. Supple. 15: 131-506.

_____ 1939. Systematische un Ökologische: Java, Bali und Sumatra. Arch. Hydrobiol. Suppl. 16: 1-155, 274-384.

Hutchinson, G.E., ed. 1970. Ianula: an account of the history and development of the Lago di Monterosi, Latium, Italy. Trans. Amer. Phil. Soc. 60: 178p.

_____ 1973. Eutrophication. Amer. Sci. 61: 269-279.

Kendall, R.L. 1969. An ecological history of the Lake Victoria basin. Ecol. Monogr. 39: 121-176.

Koivo, L.K. 1976. Species diversity in postglacial diatom lake communities of Finland. Paleogeogr., Paleoclim., Paleoecol. 19: 165-190.

Kolbe, R.W. 1927. Zur Ökologie, Morphologie und Systematik der Brackwasser-diatomeen. Die Kieselalngen des Sperenberger Salzebiets Pflanzenforschung, Heft 7: I-IV, pp. 1-146.

Larson, D.D. 1973. Paleoecological investigations of diatoms in a core from Kerguelen Island, southeast Indian Ocean. Master Thesis, The Ohio State University, Columbus, 70p.

Livingston, D.A. 1955. A lightweight piston sampler for lake deposits. Ecology 36: 137-139.

Lowe, R.L. 1974. Environmental requirements and pollution tolerance of freshwater diatoms. Env. Protection Agency, Bull. 670/4-74-005, 334p.

Meriläinen, J. 1967, The diatom flora and the hydrogen-ion concentration of the water. Annal. Bot. Fenn. 4: 51-58.

Nygaard, G. 1949. Hydrobiological studies of some Danish ponds and lakes. II. The quotient hypothesis and some new or little known phytoplankton organisms. Kgl. Danske Videnskab. Selskab., Biol. Skrifter 7: 1-293.

Nygaard, G. 1956. Ancient and recent flora of diatoms and Chryophyceae in Lake Gribsø. Folia Limnol. Scand. 8: 32-94.

Ogden, J.G. 1966. Forest history of Ohio. I. Radiocarbon dates and pollen stratigraphy of Silver Lake, Logan County, Ohio. Ohio J. Sci. 66: 387-400.

Patrick, R. 1936. Some diatoms of Great Salt Lake. Bull. Torrey Bot. Club. 63: 157-166.

__________, M.H. Hohn and J.H. Wallace. 1954. A new method for determining the pattern of the diatom flora. Notulae Naturae, Acad. Nat. Sci. Phila. 259: 1-12.

__________, and C.W. Reimer. 1966. The diatoms of the United States. Vol. I. Acad. Nat. Sci. Phila., Monogr. No. 13, 213p.

__________________ 1975. The diatoms of the United States. Vol. II. Acad. Nat. Sci. Phila., Monogr. No. 13.

Pearsall, W.H. 1932. Phytoplankton in the English Lakes. II. The composition of the phytoplankton in relation to dissolved substances. J. Ecol. 20: 241-262.

Pennington, W. 1943. Lake sediments: The bottom deposits of the north basin of Windermere with special reference to the diatom succession. New Phytol. 42: 1-27.

__________, E.Y. Haworth, A.P. Bonny and J.P. Lishman. 1972. Lake sediments in northern Scotland. Phil. Trans., Royal Soc. Lond. 264: 191-294.

Preston, F.W. 1948. The commoness and rarity of species. Ecology 29: 254-283.

Ritchie, J.C. and L.K. Koivo. 1975. Postglacial diatom stratigraphy in relation to the recession of Glacial Lake Agassiz. Quat. Res. 5: 529-540.

Round, F.E. 1957. The late-glacial and post-glacial diatom succession in the Kentmere Valley deposit. New Phytol. 56: 98-126.

__________ 1961. The diatoms of a core from Esthwaite Water. New Phytol. 60: 43-59.

__________ 1964. The ecology of benthic algae. pp. 138-184. In: D.F. Jackson, ed., Algae and Man. Plenum Press, N.Y.

Sears, P.B. 1930. A record of post-glacial climate in northern Ohio. Ohio J. Sci. 30: 205-217.

__________ 1941. Postglacial vegetation in the Erie-Ohio area. Ohio J. Sci. 41: 225-234.

Shannon, C.E. and W. Weaver. 1964. <u>The Mathematical Theory of Communication</u>. Univer. Ill. Press, Urbana. 125p.

Stockner, J.G. 1971. Preliminary characterization of lakes in the experimental lakes area, northwestern Ontario, using diatom occurrences in the sediments. J. Fish. Res. Bd. Canada 28: 265-275.

__________ 1972. Paleolimnology as a means of assesing eutrophication. Verh. Internat. Verein Limnol. 18: 1018.

__________, and W.W. Benson. 1967. The succession of diatom assemblages in the recent sediments of Lake Washington. Limnol. Oceanogr. 12: 513-532.

__________ and J.W.G. Lund. 1970. Live algae in postglacial lake deposits. Limnol. Oceanogr. 15: 41-58.

Stoermer, E.F. and J.J. Yang. 1968. Preliminary report of the fossil diatom flora from Lake Huron sediments. Proc. 11th Conf. Great Lakes Res., Int. Assoc. Great Lakes Res., pp. 253-267.

__________, S.M. Taylor, and E. Callender. 1971. Paleoecological interpretation of the holocene diatom succession in Devil's Lake, North Dakota. Trans. Amer. Micros. Soc. 90: 195-206.

__________ 1977. Post-pleistocene diatom succession in Douglas Lake, Mich. J. Phycol. 13: 73-80.

Transeau, E.N. 1935. The prairie peninsula. Ecology 16: 423-437.

__________ 1941. Prehistoric factors in the development of the vegetation of Ohio. Ohio J. Sci. 41: 207-211.

Weber, C.I. 1971. A guide to the common diatoms at water pollution surveillance system stations. USEPA, Cinci., Ohio. 101p.

Wetzel, R.G. 1970. Recent and postglacial production rates of a marl lake. Limnol. Oceanogr. 15: 491-503.

APPENDICES

Appendix A. List of diatom taxa.

Achnanthes clevei var. rostrata Hust.
A. exigua Grun.
A. exigua var. heterovalva Krasske
A. flexella (Kütz.) Brun
A. lanceolata var. dubia Grun.
A. linearis f. curta H.L.Sm.
A. minutissima Kutz.

Amphipleura pellucida Kütz.

Amphora coffeaeformis Agardh
A. delicatissima Krasske
A. ovalis Kütz.
A. ovalis var. pediculus Kütz.

Anomoeoneis sphaerophora var. Güntheri O.Müller

Asterionella formosa Hass.

Caloneis lepidula (Grun.) Cleve.
C. ventricosa (Ehr.) Meist.

Cocconeis pediculus Ehr.
C. placentula var. lineata (Ehr.) Cleve.

Cyclotella antiqua W.Sm.
C. bodanica Eulenst.
C. comta (Ehr.) Kütz.
C. Kützingiana Thwaites var. radiosa Fricke
C. Meneghiniana Kütz.
C. stelligera Cleve. and Grun.

Cymbella affinis Kütz.
C. Ehrenbergii Kütz.
C. helvetica Kütz.
C. prostrata (Berkeley) Cleve.
C. pusilla Grun.

Denticula elegans Kütz.

Diploneis marginestriata Hust.

Epithemia argus Kütz.
E. argus var. alpestris Grun.

Eucocconeis flexella (Kütz.) var. alpestris Brun

Eunotia arcus var. bidens Grun.
E. maior (W.Sm.) Rabh.
E. parallela Ehr.

Eunotia praerupta Ehr.
E. praerupta var. bidens (Ehr.) Grun.

Fragilaria construens (Ehr.) Grun.
F. construens var. subsalina Hust.
F. construens var. venter (Ehr.) Grun.
F. crotonensis Kitton
F. gracillima Mayer
F. leptostauron (Ehr.) Hust.
F. vaucheriae (Kütz.) Peters.

Gomphonema acuminatum var. coronata (Ehr.) W.Sm.
G. angustatum (Kütz.) Rabh.
G. angustatum var. producta Grun.
G. constrictum Ehr.
G. longiceps f. gracilis Hust.

Gyrosigma strigilis (W.Sm.) Cleve.

Hantzschia amphioxys (Ehr.) Grun.

Mastogloia Grevillei W.Sm.
M. smithii Thwaites ex W.Sm.
M. smithii var. amphicephala Grun.
M. smithii var. lacustris Grun.

Melosira granulata var. angustissima Müll.
M. italica (Ehr.) Kütz.

Navicula accomoda Hust.
N. atomis (Kütz.) Grun.
N. crucigera (W.Sm.) Cleve.
N. cryptocephala Kütz.
N. elginensis (Greg.) Ralfs
N. halophila (Grun.) Cleve.
N. laevissima Kütz.
N. pupula var. mutata (Krasske) Hust.
N. pupula var. rectangularis (Greg.) Grun.
N. radiosa Kütz.
N. Rotaeana (Rabh.) Grun.
N. salinarum var. intermedia (Grun.) Cleve.
N. scutelloides W.Sm. ex Greg.
N. subocculta Hust.
N. tridentula Krasske

Nedium iridis var. ampliatum (Ehr.) Cleve.
N. productum (W.Sm.) Cleve.

Nitzschia acuta Hantzsch
N. angustata var. acuta Grun.
N. denticula Grun.
N. frustulum (Kütz.) Grun.
N. ignorata Krasske
N. linearis W.Sm.

Opephora Martyi Héribaud
O. swartzii (Grun.) Petit

Pinnularia biceps Greg.
P. divergens W.Sm.
P. flexuosa Cleve.
P. lata (Bréb.) Rabh.
P. microstauron (Ehr.) Cleve.
P. nodosa (Ehr.) W.Sm.

Rhopalodia gibba (Ehr.) O.Müll.

Stauroneis anceps f. *gracilis* Rabh.
S. anceps f. *linearis* (Ehr.) Hust.
S. phoenicenteron f. *gracilis* (Ehr.) Hust.

Stephanodiscus astraea (Ehr.) Grun.
S. astraea var. *minutula* (Kütz.) Grun.
S. tenuis Hust.

Surirella biseriata var. *constricta* Grun.
S. linearis W.Sm.
S. linearis var. *constricta* (Ehr.) Grun.
S. ovata Kütz.

Synedra amphicephala Kütz.
S. cyclopum Brutschi
S. ulna var. *longissima* (W.Sm.) Brun

Tabellaria fenestrata (Lyngb.) Kütz.

Appendix B. Percentage of occurrence for diatom taxa at each sediment level Ø through 37. Total number of taxa are given for sediment levels 38 through 48. No diatom valves were identified at level 49.

Taxa	Level Ø	1	2	3	4	5	6	7	8	9	10
Achnanthes clevei var. rostrata											
A. exigua			.4	2.8							2.4
A. exigua var. heterovalva				2.6	.4	.2	1.4	.2	.6	.4	2.2
A. flexella		.4						.2		.4	
A. lanceolata var. dubia				2.6	1.0		.2			.2	2.8
A. linearis f. curta		3.2	2.0	2.6	.4						.2
A. minutissima	1.6	.4	1.4		.2						
Amphipleura pellucida											
Amphora coffeaeformis											
A. delicatissima											
A. ovalis		1.6	1.2	.4					4.0	.4	2.2
A. ovalis var. pediculus									.4		
Anomoeoneis sphaerophora var. Güntheri											

Taxa	Level Ø	1	2	3	4	5	6	7	8	9	10
Asterionella formosa	7.0	5.6	2.4		2.4	1.0			.4		
Caloneis lepidula				.4				.4	.8		.2
C. ventricosa				1.4	.6						
Cocconeis pediculus											
C. placentula var. *lineata*							.4	.2			1.8
Cyclotella antiqua											
C. bodanica		21.0	27.6	9.0	10.6	10.4	9.2	65.2	25.4	26.8	13.2
C. comta				.6	5.0	2.0	2.8	.2			
C. Kützingiana var. *radiosa*		9.2	7.4	2.0	2.0	.4	3.2	1.2	.4		
C. Meneghiniana		.2	.8								
C. stelligera		3.0	4.8	6.6	4.0		4.8	16.4	.4	.2	.8
Cymbella affinis	.4	.4	1.6	1.6			.4				
C. Ehrenbergii					.4	.4	1.2	.6	1.0	.2	
C. helvetica		4.0	3.2	7.6	2.8		1.4	2.4	.6		.4
C. prostrata											
C. pusilla		2.4	1.8	2.2	1.2		.8	2.8	.2		

Taxa	Level	Ø	1	2	3	4	5	6	7	8	9	10
Denticula elegans			1.2	.4		1.4						.6
Diploneis marginestriata				.4		.2			.2			
Epithemia argus					10.4	4.6	.6	1.0	.6	.4	1.4	.4
E. argus var. *alpestris*			.8	2.8								
Eucocconeis flexella var. *alpestris*			.4									
Eunotia arcus var. *bidens*												
E. maior			.4		1.8	1.0		.8	.4	.2	.2	.4
E. parallela		.4					.2		.8	.2	.2	1.0
E. praerupta												
E. praerupta var. *bidens*												
Fragilaria construens		.2		2.2	2.2	2.4	1.0	6.2		2.0		8.4
F. construens var. *subsalina*		5.2	6.8	3.2		1.0		5.2		1.4	3.2	7.4
F. construens var. *venter*						36.4	73.6	48.6	2.2	38.6	57.6	27.2
F. crotonensis		11.2	8.6	.2	.2	.2						

Taxa	Level Ø	1	2	3	4	5	6	7	8	9	10
Fragilaria gracillima								.4			.2
F. leptostauron											
F. vaucheriae		4.6	2.4	7.2	.6			.4	.4	.8	1.6
Gomphonema acuminatum var. coronata									.2		
G. angustatum	1.2		4.2	4.8	1.4	.8	.8	2.4	2.0	.6	4.4
G. angustatum var. producta		2.2	.6								
G. constrictum				.2							
G. longiceps f. gracilis			3.2								.4
Gyrosigma strigilis			.6	.2	1.2		.2			.2	.6
Hantzschia amphioxys											
Mastogloia Grevillei											
M. smithii		1.2	2.2	.6	1.0	.4	.6				
M. smithii var. amphicephala		1.4		2.6				.2	.2		
M. smithii var. lacustris				7.0	7.8	4.4	4.0	1.8	4.0	2.2	2.2

Taxa / Level	∅	1	2	3	4	5	6	7	8	9	10
Melosira granulata var. angustissima	3.4										
M. italica			.2								
Navicula accomoda			.8	2.4	.8		.6	.6	.4		.2
N. atomus				.8		.4	1.8			.2	
N. crucigera											
N. cryptocephala			.8		.4		.6	.4	1.2	.4	.8
N. elginensis				1.2	.2						
N. halophila											
N. laevissima			1.4	1.8	.6	.2	.6	.2		.4	1.4
N. pupula var. mutata			1.6	.4	.2						.4
N. pupula var. rectangularis											
N. radiosa		8.4	2.0	5.0	1.4	.4	.6	1.4	.4		2.0
N. Rotaeana											
N. salinarum var. intermedia											
N. scutelloides											
N. subocculta											

Taxa	Level ∅	1	2	3	4	5	6	7	8	9	10
Navicula tridentula				.4							
Nedium iridis var. *ampliatum*			.6	1.0	.4	.8	.2	.4	2.4	.8	.2
N. productum											
Nitzschia acuta			.8	.4	.4			.6		.4	
N. angustata var. *acuta*		1.4	1.2		.4						
N. denticula			.4					.6	.6	.2	.4
N. frustulum											
N. ignorata		.4									
N. linearis											
Opephora Martyi											
O. swartzii											
Pinnularia biceps											
P. divergens			.2	.4	1.8		1.2	.4	.4		1.2
P. flexuosa		.8	1.2	.4							
P. lata											
P. microstauron				1.0		.6			.2		

Taxa	Level Ø	1	2	3	4	5	6	7	8	9	10
Pinnularia nodosa											
Rhopalodia gibba		.4	1.6	.8	.4		.2		.4		1.2
Stauroneis anceps f. gracilis											
S. anceps f. linearis			2.0	.2							
S. phoenicenteron f. gracilis		.6							.2		.2
Stephanodiscus astraea											
S. astraea var. minutula			.8								
S. tenuis	69.2	.2									
Surirella biseriata var. constricta											.2
S. linearis											
S. linearis var. constricta											
S. ovata											
Synedra amphicephala					.4	.4	.2	.2	.2	.2	1.0
S. cyclopum											
S. ulna var. longissima	.2	8.8	6.4	2.2	2.2	1.8	.8	1.4	2.2	1.2	4.0
Tabellaria fenestrata			1.0	1.6				.2	7.6	1.4	5.8

Taxa	Level	11	12	13	14	15	16	17	18	19	20	21
Achnanthes clevei var. rostrata												
A. exigua		.4	.8									
A. exigua var. heterovalva					.2				1.8		.4	.4
A. flexella		.8	1.8	1.4	.2	1.0	.2	1.2		.2	.8	1.2
A. lanceolata var. dubia									.2			.4
A. linearis f. curta				.4					.2			.6
A. minutissima			1.2									.6
Amphipleura pellucida			.4	.4								
Amphora coffeaeformis												
A. delicatissima												
A. ovalis		7.8	2.2	4.6	2.4	18.4	11.8	1.8	3.0	1.8	2.2	2.8
A. ovalis var. pediculus												
Anomoeoneis sphaerophora var. Güntheri												

Taxa Level	11	12	13	14	15	16	17	18	19	20	21
Asterionella formosa										.4	
Caloneis lepidula										.4	
C. ventricosa											
Cocconeis pediculus						.4		.4			
C. placentula var. lineata		.2									
Cyclotella antiqua							.2				
C. bodanica	46.0	39.0	51.6	45.2	41.8	40.6	78.4	35.8	33.8	48.6	20.2
C. comta				.4			.8				
C. Kützingiana var. radiosa			9.2	4.4	2.0	1.4		.4	.8	1.4	.6
C. Meneghiniana											
C. stelligera	2.4	.4	.4		.6			.8		.2	.6
Cymbella affinis		.8				.4					.4
C. Ehrenbergii	1.2	1.2	.8		.4	.6		.2		.2	.2
C. helvetica	.6	1.2	.6	.8	1.4		.8	.8	.4	.4	1.0
C. prostrata											
C. pusilla	1.0	1.2		2.0		2.0			.2	1.2	.2

Taxa / Level	11	12	13	14	15	16	17	18	19	20	21
Denticula elegans	.4	1.6	2.2	1.2	1.0	.2	1.8	.8	.6	.4	.4
Diploneis marginestriata											
Epithemia argus	1.2	1.2	1.8		1.4	.2		.6		.2	
E. argus var. alpestris											
Eucocconeis flexella var. alpestris											
Eunotia arcus var. bidens		.2									
E. maior		.2	.2		.6	.4	.2	1.2	.2	.2	.8
E. parallela											
E. praerupta								.6		.2	
E. praerupta var. bidens								.6			
Fragilaria construens	4.2	4.4		2.0	.6			9.8	.6	2.4	2.4
F. construens var. subsalina	1.2	.2									23.4
F. construens var. venter	20.0	5.6	7.0	20.0	13.2	34.0	1.2	19.2	52.6	24.8	23.4
F. crotonensis							.2				

Taxa / Level	11	12	13	14	15	16	17	18	19	20	21
Fragilaria gracillima	.8	1.6	.2	1.0		.2	.4	.2			
F. leptostauron											
F. vaucheriae	.2	3.0	2.0	.2	.6			.4		.4	.6
Gomphonema acuminatum var. coronata		.4									
G. angustatum	.2	1.4	2.0	3.2	2.6	.6	3.0	5.2	.4	5.2	3.0
G. angustatum var. producta											
G. constrictum											.4
G. longiceps f. gracilis		.6	.4	.6			1.6	1.4			.8
Gyrosigma strigilis	.2	.4		.6					.2		.6
Hantzschia amphioxys											
Mastogloia Grevillei											
M. smithii		.4									
M. smithii var. amphicephala											
M. smithii var. lacustris	3.8	1.4	2.8	3.0	6.8	7.2	.8	5.2	3.0	4.8	6.4

Taxa / Level	11	12	13	14	15	16	17	18	19	20	21
Melosira granulata var. angustissima											
M. italica		8.4									
Navicula accomoda		.4	1.0	.6	.4		.6	2.2	.4		.4
N. atomus		.2		.2							
N. crucigera											
N. cryptocephala	1.0	2.8	1.8	.2				.8		.4	
N. elginensis						.2		.4			.8
N. halophila			.2	1.0	.4		.8		.2	.2	.4
N. laevissima	.4	.2									
N. pupula var. mutata			.4								.2
N. pupula var. rectangularis			1.6	1.0	1.0	.2	.2	.6	.2	.2	.8
N. radiosa				.6	.6		.6	.4			.2
N. Rotaeana								.2	.8		
N. salinarum var. intermedia											
N. scutelloides											
N. subocculta											

Taxa / Level	11	12	13	14	15	16	17	18	19	20	21
<u>Navicula</u> <u>tridentula</u>											
<u>Nedium</u> <u>iridis</u> var. <u>ampliatum</u>	.2		.2	.4	.4	.2		.8	.2		.2
<u>N</u>. <u>productum</u>											
<u>Nitzschia</u> <u>acuta</u>											.2
<u>N</u>. <u>angustata</u> var. <u>acuta</u>											
<u>N</u>. <u>denticula</u>		.2					.4			.4	
<u>N</u>. <u>frustulum</u>											
<u>N</u>. <u>ignorata</u>											
<u>N</u>. <u>linearis</u>											
<u>Opephora</u> <u>Martyi</u>				.6	.4			.8	1.0		
<u>O</u>. <u>swartzii</u>											
<u>Pinnularia</u> <u>biceps</u>			4.0	3.2	.8		.2	.2	.2	1.6	.6
<u>P</u>. <u>divergens</u>	1.6	.4	1.8	1.2	.8	.6	.6	.2		1.4	.4
<u>P</u>. <u>flexuosa</u>										.2	
<u>P</u>. <u>lata</u>					.8						.2
<u>P</u>. <u>microstauron</u>	1.6	1.4									

Taxa	Level 11	12	13	14	15	16	17	18	19	20	21
Pinnularia nodosa											
Rhopalodia gibba		.8					.4	.8			
Stauroneis anceps f. gracilis											
S. anceps f. linearis	.4	.2									
S. phoenicenteron f. gracilis		.2			.2		.2				.2
Stephanodiscus astraea						.2					
S. astraea var. minutula											
S. tenuis											
Surirella biseriata var. constricta											
S. linearis											
S. linearis var. constricta		.2						.2		.6	.4
S. ovata											
Synedra amphicephala											
S. cyclopum											
S. ulna var. longissima	.6	6.4	.4	1.8	1.0	.4	1.6	2.6	1.4	1.4	2.4
Tabellaria fenestrata	1.8	5.0	.6	1.8	.8			1.0	.8	1.2	1.2

Taxa	Level 22	23	24	25	26	27	28	29	30	31	32
Achnanthes clevei var. rostrata											
A. exigua											
A. exigua var. heterovalva	.2	.4		1.2	.2		.2	.6	1.0	1.0	1.0
A. flexella	.4	1.8	1.2	1.0	.4		.4	1.0	.8		.8
A. lanceolata var. dubia			.2	.4			.6		1.4		
A. linearis f. curta				.2	.4	.2		.2	.4		
A. minutissima			.4				.2		.4	.4	
Amphipleura pellucida											.2
Amphora coffeaeformis						.4					
A. delicatissima									.2		
A. ovalis	.6	1.0	1.8	.6	.2	.2	.6	.2	1.4	.2	1.4
A. ovalis var. pediculus								.8	1.0	2.2	
Anomoeoneis sphaerophora var. Güntheri											

Taxa	Level	22	23	24	25	26	27	28	29	30	31	32
Asterionella formosa							11.0	1.2				
Caloneis lepidula				.2								
C. ventricosa												
Cocconeis pediculus						.2	.2					
C. placentula var. lineata												
Cyclotella antiqua												.4
C. bodanica		22.4	21.8	32.2	24.6	42.4	37.8	33.0	17.8	1.0	6.2	2.4
C. comta												
C. Kützingiana var. radiosa		.6	.4	1.8		1.4	8.2	3.0	2.4	.2	.6	1.2
C. Meneghiniana												
C. stelligera		.8	.4	1.0		1.4	8.8	10.4	4.0	.6	3.6	
Cymbella affinis												
C. Ehrenbergii		.4	.6	.6	.8	.6	1.8	.2		.6		.4
C. helvetica				1.0		.4	1.6	.2	.4	.2		
C. prostrata												
C. pusilla		.4		1.2	.4	1.2	2.8	1.0	.2	.4		

Taxa / Level	22	23	24	25	26	27	28	29	30	31	32
Denticula elegans	.2	.6	.8		.4	.8			.6		
Diploneis marginestriata		.2					.2				
Epithemia argus		.4	.4	1.8	.2	.6			.2		
E. argus var. alpestris											
Eucocconeis flexella var. alpestris											
Eunotia arcus var. bidens											
E. maior	.2										
E. parallela											
E. praerupta			1.6	.2	.2	.2					
E. praerupta var. bidens											
Fragilaria construens	.2	1.0	1.0	7.4	2.4	1.8	.6	10.0	8.8	2.0	5.0
F. construens var. subsalina		1.6	3.6	10.0	5.8	1.8	12.2	6.8	12.6	6.0	13.0
F. construens var. venter	59.4	57.8	37.2	36.6	30.6	1.8	24.2	44.0	49.4	72.6	47.0
F. crotonensis						.4					

Taxa	Level 22	23	24	25	26	27	28	29	30	31	32
Fragilaria gracillima			.2			.4	.4	.2			
F. leptostauron											11.8
F. vaucheriae			.2			2.2		1.0		.2	.4
Gomphonema acuminatum var. coronata											
G. angustatum	.6	2.2	1.4	1.0	1.0	2.0	3.0	1.0	.8	.4	
G. angustatum var. producta											
G. constrictum	.2									.2	
G. longiceps f. gracilis	.2			.2		1.6					.2
Gyrosigma strigilis				.8	.4	.2		.2	.2	.2	1.4
Hantzschia amphioxys									.4		
Mastogloia Grevillei											
M. smithii											
M. smithii var. amphicephala											
M. smithii var. lacustris	1.0	7.2	4.2	7.6	6.6	1.8	2.6	4.4	3.6	1.8	9.4

Taxa	Level 22	23	24	25	26	27	28	29	30	31	32
Melosira granulata var. angustissima											
M. italica									.8		
Navicula accomoda											
N. atomus		.4		.6	.4	.2			1.2		
N. crucigera											
N. cryptocephala				.4	.2		.2				.6
N. elginensis	.2										.2
N. halophila		.8		.6		1.6	.8				
N. laevissima	.2							.2			
N. pupula var. mutata					.4	.6		.2			
N. pupula var. rectangularis	.2		.8			1.0			8.0		.4
N. radiosa			1.4		.4	1.6	.2	.4	.8		
N. Rotaeana											
N. salinarum var. intermedia										1.0	
N. scutelloides											
N. subocculta											

Taxa / Level	22	23	24	25	26	27	28	29	30	31	32
<u>Navicula</u> <u>tridentula</u>											
<u>Nedium</u> <u>iridis</u> var. <u>ampliatum</u>		.2	.2					.2			.2
<u>N</u>. <u>productum</u>											
<u>Nitzschia</u> <u>acuta</u>				.2		.8					
<u>N</u>. <u>angustata</u> var. <u>acuta</u>											
<u>N</u>. <u>denticula</u>											
<u>N</u>. <u>frustulum</u>											
<u>N</u>. <u>ignorata</u>											
<u>N</u>. <u>linearis</u>						.2					
<u>Opephora</u> <u>Martyi</u>	.6	.4	1.6	2.6	.6		2.0	1.4	.2	1.4	1.0
<u>O</u>. <u>swartzii</u>											
<u>Pinnularia</u> <u>biceps</u>	.2	.6	.6						2.4		.2
<u>P</u>. <u>divergens</u>			.4	.2		.4	.2				
<u>P</u>. <u>flexuosa</u>		.2	.2			.2					
<u>P</u>. <u>lata</u>				.2							
<u>P</u>. <u>microstauron</u>											

Taxa / Level	22	23	24	25	26	27	28	29	30	31	32
Pinnularia nodosa											
Rhopalodia gibba					.2						
Stauroneis anceps f. gracilis											
S. anceps f. linearis					.4						
S. phoenicenteron f. gracilis		.4				.2			.4		
Stephanodiscus astraea											
S. astraea var. minutula											
S. tenuis											
Surirella biseriata var. constricta											
S. linearis											
S. linearis var. constricta				.2	.2	.2					
S. ovata											
Synedra amphicephala											
S. cyclopum						2.0	.6	.2			
S. ulna var. longissima	.8		.4	.2		2.2	1.2	.6			
Tabellaria fenestrata			1.8		.8	.2	1.0	1.6	.2		

Taxa	Level 33	34	35	36	37	38	39	40	41	42	43
Achnanthes clevei var. rostrata		.4	.4								
A. exigua											
A. exigua var. heterovalva	.2	.8	4.4	8.6	3.0			2			4
A. flexella	.2										
A. lanceolata var. dubia	2.0	.6	2.6	10.8	1.0			1	5		9
A. linearis f. curta		.2									1
A. minutissima											
Amphipleura pellucida											
Amphora coffeaeformis	.2										
A. delicatissima	.8	.2	.8	1.4	.6						5
A. ovalis	1.8	.8	.6	2.0							
A. ovalis var. pediculus	1.4	1.6	.8	.8	1.4						1
Anomoeoneis sphaerophora var. Güntheri											2

Taxa / Level	33	34	35	36	37	38	39	40	41	42	43
Asterionella formosa											
Caloneis lepidula	1.0										
C. ventricosa											
Cocconeis pediculus									1		1
C. placentula var. lineata											
Cyclotella antiqua	14.0	6.4									
C. bodanica	23.8	61.6	.4	.2							
C. comta											
C. Kützingiana var. radiosa	2.4	5.4									
C. Meneghiniana											
C. stelligera											
Cymbella affinis				.2							
C. Ehrenbergii		.8									
C. helvetica	1.6	.4									
C. prostrata											
C. pusilla		.4						2			

Taxa Level	33	34	35	36	37	38	39	40	41	42	43
Denticula elegans									1		1
Diploneis marginestriata	.2	.8	1.2	.2							
Epithemia argus	.4				.6			1		2	
E. argus var. *alpestris*											
Eucocconeis flexella var. *alpestris*											
Eunotia arcus var. *bidens*											
E. maior		.2									
E. parallela											
E. praerupta		.4									
E. praerupta var. *bidens*											
Fragilaria construens	4.0		2.4	5.6	11.6	6		8	1	1	2
F. construens var. *subsalina*	2.2	1.6	18.4	13.0	14.6	2	3	7	10	2	6
F. construens var. *venter*	13.2	4.2	37.4	28.8	40.0	7	1	9	14	4	9
F. crotonensis											

Taxa / Level	33	34	35	36	37	38	39	40	41	42	43
Fragilaria gracillima											
F. leptostauron	.4	.4	14.8	3.8	8.6					1	
F. vaucheriae		.2									
Gomphonema acuminatum var. coronata											
G. angustatum		.4			1.0						
G. angustatum var. producta											
G. constrictum											
G. longiceps f. gracilis					.6						
Gyrosigma strigilis	2.0	1.0	1.8	2.2	2.0		1			1	
Hantzschia amphioxys									1	1	
Mastogloia Grevillei		1.0	.2								
M. smithii		1.4	.4	1.8							
M. smithii var. amphicephala											
M. smithii var. lacustris	18.6	2.8	3.0	4.4	6.8			1			

Taxa	Level 33	34	35	36	37	38	39	40	41	42	43
Melosira granulata var. *angustissima*											
M. italica											
Navicula accomoda											2
N. atomus		.4	.6	1.4							
N. crucigera				.2							
N. cryptocephala	.2										
N. elginensis									1	2	
N. halophila	.2	.2							1	1	3
N. laevissima							1				
N. pupula var. *mutata*											
N. pupula var. *rectangularis*											
N. radiosa	.6	1.0									
N. Rotaeana											
N. salinarum var. *intermedia*	.8	.2	.4	1.2	.4	2	6	5	1		
N. scutelloides	.6	1.2	5.0	1.6	.8						
N. subocculta	.2		.2	1.2	.6						

Taxa	Level 33	34	35	36	37	38	39	40	41	42	43
Navicula tridentula											
Nedium iridis var. ampliatum											
N. productum	.4										
Nitzschia acuta		.2									
N. angustata var. acuta					.6						
N. denticula	.2		.2	.2						1	
N. frustulum	.2			.4							
N. ignorata											
N. linearis											
Opephora Martyi	3.4	.6	3.8	9.0	4.4		3	3	4	2	10
O. swartzii											12
Pinnularia biceps	.2			1.0							
P. divergens	.6	.6									
P. flexuosa											
P. lata	.2										
P. microstauron											

Taxa / Level	33	34	35	36	37	38	39	40	41	42	43
Pinnularia nodosa		.2									
Rhopalodia gibba		.6									
Stauroneis anceps f. gracilis					.4						1
S. anceps f. linearis											
S. phoenicenteron f. gracilis											
Stephanodiscus astraea											
S. astraea var. minutula											
S. tenuis		.2									
Surirella biseriata var. constricta											
S. linearis		.2									
S. linearis var. constricta	.4										
S. ovata	.4										
Synedra amphicephala											
S. cyclopum											
S. ulna var. longissima		.2									
Tabellaria fenestrata	1.0	.2	.2		1.0						

Taxa / Level	44	45	46	47	48	49
Achnanthes clevei var. *rostrata*						
A. exigua						
A. exigua var. *heterovalva*				1		
A. flexella						
A. lanceolata var. *dubia*		1				
A. linearis f. *curta*						
A. minutissima						
Amphipleura pellucida						
Amphora coffeaeformis						
A. delicatissima						
A. ovalis						
A. ovalis var. *pediculus*		1				
Anomoeoneis sphaerophora var. *Güntheri*					1	

Taxa	Level 44	45	46	47	48	49
Asterionella formosa						
Caloneis lepidula						
C. ventricosa						
Cocconeis pediculus						
C. placentula var. *lineata*				1		
Cyclotella antiqua						
C. bodanica						
C. comta						
C. Kützingiana var. *radiosa*						
C. Meneghiniana						
C. stelligera						
Cymbella affinis						
C. Ehrenbergii						
C. helvetica					1	
C. prostrata			2			
C. pusilla				2		

Taxa / Level	44	45	46	47	48	49
Denticula elegans		1	2			
Diploneis marginestriata						
Epithemia argus						
E. argus var. alpestris						
Eucocconeis flexella var. alpestris						
Eunotia arcus var. bidens						
E. maior						
E. parallela						
E. praerupta						
E. praerupta var. bidens						
Fragilaria construens			3	1	1	
F. construens var. subsalina	8				4	
F. construens var. venter	1	12	2	1	4	
F. crotonensis						

Taxa	Level 44	45	46	47	48	49
Fragilaria gracillima						
F. leptostauron						
F. vaucheriae						
Gomphonema acuminatum var. coronata						
G. angustatum						
G. angustatum var. producta						
G. constrictum						
G. longiceps f. gracilis						
Gyrosigma strigilis					1	
Hantzschia amphioxys	1		1			
Mastogloia Grevillei						
M. smithii						
M. smithii var. amphicephala						
M. smithii var. lacustris						

Taxa	Level 44	45	46	47	48	49
Melosira granulata var. angustissima						
M. italica				1		
Navicula accomoda						
N. atomus			1	1		
N. crucigera						
N. cryptocephala						
N. elginensis						
N. halophila	1					
N. laevissima						
N. pupula var. mutata	2		1	2		
N. pupula var. rectangularis						
N. radiosa			2			
N. Rotaeana						
N. salinarum var. intermedia	1					
N. scutelloides						
N. subocculta						

Taxa Level	44	45	46	47	48	49
Navicula tridentula						
Nedium iridis var. ampliatum						
N. productum						
Nitzschia acuta						
N. angustata var. acuta						
N. denticula						
N. frustulum					1	
N. ignorata						
N. linearis						
Opephora Martyi	3	2	2		4	
O. swartzii		3	2		4	
Pinnularia biceps						
P. divergens						
P. flexuosa						
P. lata						
P. microstauron						

Taxa	Level 44	45	46	47	48	49
Pinnularia nodosa						
Rhopalodia gibba						
Stauroneis anceps f. *gracilis*						
S. anceps f. *linearis*						
S. phoenicenteron f. *gracilis*						
Stephanodiscus astraea						
S. astraea var. *minutula*						
S. tenuis						
Surirella biseriata var. *constricta*						
S. linearis						
S. linearis var. *constricta*						
S. ovata						
Synedra amphicephala						
S. cyclopum						
S. ulna var. *longissima*						
Tabellaria fenestrata						