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M. R. SREENIVASA AND H. C. DUTHIE

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The postglacial diatom history of Sunfish Lake, southwestern Ontario

M. R. SREENIVASA AND H. C. DUTHIE
Department of Biology, University of Waterloo, Waterloo, Ontario
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An investigation was made of the diatom stratigraphy in a sediment core from Sunfish Lake, a small (8.3 ha), deep (20 m), meromictic lake in southwestern Ontario. About 340 diatom species and varieties distributed among 37 genera were identified from the sediments; however, only 16 taxa had more than 2% representation in any sample. On the whole, the number of individuals and diversity of the samples increase over the postglacial period. Diatoms first appear in pollen zone A and consist mainly of the littoral forms *Cymbella diluviana*, *Fragilaria lapponica*, and *F. construens* var. *venter*. It is suggested that these taxa are typical of early postglacial lacustrine sediments in northeastern North America. *Cyclotella bodanica* first appears in zone B and is dominant in most samples throughout the core. It is euplanktonic and typical of subalpine, circumneutral, oligotrophic lakes. In C_2, when the climate was possibly warmer and drier than present, there is evidence for a lower lake level: *C. bodanica* is temporarily replaced in importance in the sediments by *C. kuetzingiana* and the proportion of littoral and epiphytic diatoms increases. *Cyclotella bodanica* regains its former importance in C_3 sediments with the possible return to a cooler, wetter climate. About 850 years before present (B.P.) the lake evidently became eutrophic. *Cyclotella bodanica* declines and there is an increase in the proportion of several species typical of a higher trophic level, e.g., *Stephanodiscus hantzschii*, *Cyclotella glomerata*, and several *Synedra* spp. The cause is unknown. The lake probably became meromictic about 140 B.P. at a time when the forest was cleared and agriculture began in the watershed.

SREENIVASA, M. R., et H. C. DUTHIE. 1973. The postglacial diatom history of Sunfish Lake, southwestern Ontario. Can J. Bot. **51**: 1599–1609.

Les auteurs ont étudié la stratigraphie des diatomées dans une carotte sédimentaire provenant du lac Sunfish, un lac méromictique de faible superficie (8.3 ha) et profond (20 m) du sud-ouest de l'Ontario. Environ 340 espèces et variétés de diatomées, appartenant à 37 genres, ont été identifiées dans les sédiments; cependant, seulement 16 taxons étaient représentés à une fréquence de plus de 2% dans les échantillons. En général, le nombre d'individus et la diversité des échantillons augmentent au cours de la période post-glaciaire. Les diatomées apparaissent pour la première fois dans la zone pollinique A et comprennent surtout les formes littorales suivantes: *Cymbella diluviana*, *Fragilaria lapponica* et *F. construens* var. *venter*. Les auteurs émettent l'opinion que ces taxons sont typiques des sédiments lacustres du début de la période post-glaciaire au nord-est de l'Amérique du Nord. *Cyclotella bodanica* apparaît d'abord dans la zone B et est dominant dans presque tous les échantillons dans toute la carotte. C'est une espèce euplanctonique typique des lacs oligotrophes, sub-alpins, et à pH voisin de la neutralité. Dans la zone C_2, au moment où le climat était possiblement plus chaud et plus sec qu'actuellement, il y a des indications que le niveau du lac a baissé: *C. bodanica* perd temporairement de l'importance pour être remplacé par *C. kuetzingiana* et la proportion des diatomées littorales et épiphytiques augmente. *Cyclotella bodanica* retrouve son importance dans les sédiments de la zone C_3, possiblement avec le retour d'un climat plus frais et plus humide. Il y a environ 850 ans, le lac devint clairement eutrophe. *Cyclotella bodanica* diminue et il y a une augmentation dans la proportion de plusieurs espèces typiques d'un niveau tropique plus élevé, par exemple, *Stephanodiscus hantzschii*, *Cyclotella glomerata* et plusieurs espèces de *Synedra*. La cause de ce changement est inconnue. Le lac devint probablement méromictique il y a environ 140 ans, au moment où la forêt fut coupée et où l'agriculture débuta dans le bassin.

[Traduit par le journal]

Introduction

This paper is a report on the diatom stratigraphy in a sediment core from Sunfish Lake, a small but relatively deep meromictic lake in southwestern Ontario. The primary objective of the study was to describe the development of the diatom flora over the postglacial period and to examine any relationships between the diatom assemblages and regional postglacial climatic and vegetational changes. Another objective was to determine, if possible, the antiquity of meromixis and any influence this may have had on the diatoms.

Few studies of a similar nature have been carried out in Ontario. Duthie and Mannada Rani (1967) identified over 200 species of diatom from Pleistocene interglacial beds at Toronto, and Stockner (1971) described the diatom stratigraphy in sediment cores from shield lakes in northwestern Ontario. Tippett (1964) described diatoms from the sediments of two eastern Ontario lakes but did not give a complete analysis. Duthie and Sreenivasa (1971) showed evidence for the eutrophication of Lake Ontario from the sedimentary diatom stratigraphy. Relevant studies from other parts of glaciated northeastern North America are referred to elsewhere in this paper.

Sunfish Lake (Fig. 1) is one of a series of kettles on a large irregular kamy sand deposit extensively capped by silty till known as the Waterloo Interlobate Moraine (Chapman and Putnam 1966). It is probably the oldest moraine in southern Ontario. The elevation of the lake is 365 m. It has an area of 8.3 ha, a maximum depth of 20 m, and a volume development ratio of 1.56. It is moderately alkaline; the surface waters are usually pH 8.0–8.5 and the alkalinity is about 100 mg/liter $CaCO_3$. The chemocline is at about 13 m and the underlying monimolimnion is anaerobic and contains large amounts of sulfide. The physical and chemical limnology is more fully described in Duthie and Carter (1970). The lake is moderately productive and usually contains large populations of phytoplankton and zooplankton (Duthie and Carter 1970). Because of the steep nature of the basin the littoral is narrow and mostly free of aquatic plants except for patches of *Chara* sp. The lake bottom is a black sulfide sapropel.

Materials and Methods

The diatom analysis was done on a 495-cm-long continuous core section collected by means of a Mackereth piston corer from near the deepest point in the lake (Fig. 1). The core was immediately transported to the laboratory horizontally in sections of about 1 m and stored at 4°C.

The core was sampled at intervals of 10 cm. Five grams of dried material were cleaned with strong acid, washed in distilled water, and equal subsamples were dried on a cover glass and mounted in Hyrax for microscopic examination. Three transects per slide were counted and totalled. The resulting counts of frustules per sample are thus semiquantitative in that they are directly comparable but are not expressed on a volumetric or areal basis. The method is sufficient to detect qualitative changes in the diatom flora between samples and to compare the relative abundance of individual species. Diversity (H) and redundancy (R) values were calculated according to Pielou (1966).

The pollen data were kindly supplied by Mr. B. A. Sreenivasa but the present authors assume responsibility for interpretation.

The percentage moisture and inorganic and organic carbon were determined at frequent intervals in the core.

Sedimentology and Correlation

A description of the core is given in Fig. 2. The basal portion of the core consists of sand and silty clay, which is characteristic of late glacial lacustrine sediments, probably deposited as a result of erosion from the unconsolidated terrain. Overlying the sand and silty clay is gyttja which in places is visibly pigmented. Much of the gyttja, except the older deposits, is finely varved. The upper 40 cm of the core is a sticky black sapropel.

The postglacial vegetational history deduced from pollen analysis has been divided into six stages (Fig. 2) consistent with interpretations from other sites in southwestern Ontario (Anderson 1971). A radiocarbon determination of 10 500 ± 220 B.P. was obtained at 360 cm at the base of pollen zone B where *Pinus* pollen replaces *Picea* in relative importance. Anderson (1971) at

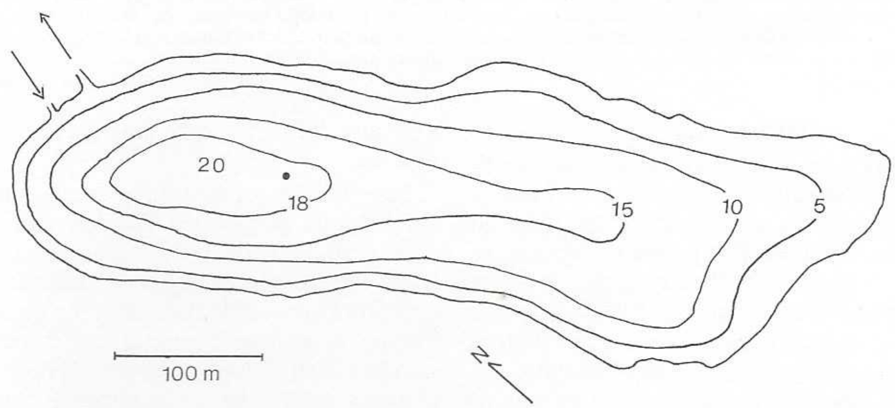

FIG. 1. Hydrographic map of Sunfish Lake showing position of sampling station (●). Depths in meters.

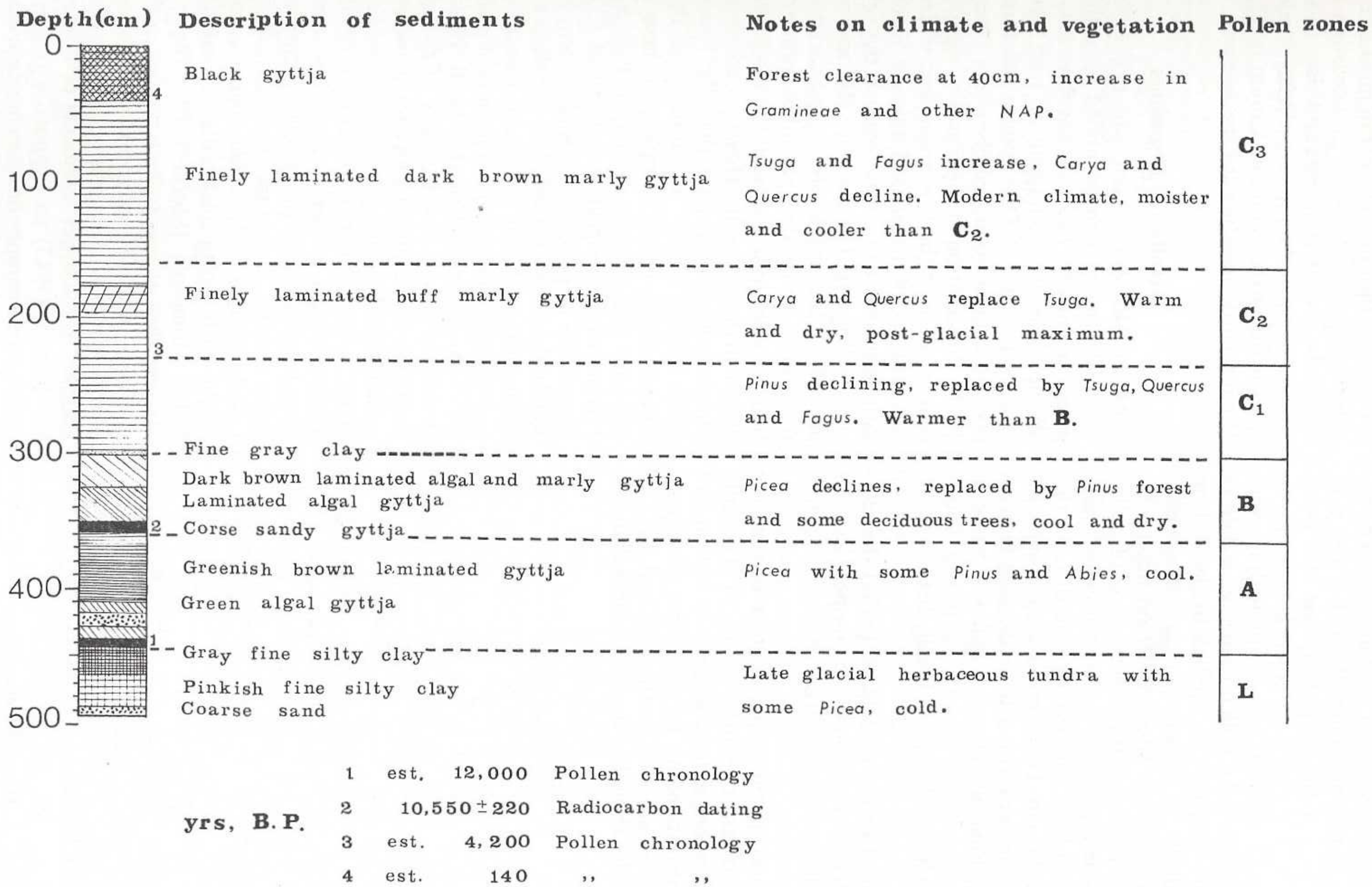

FIG. 2. Description of a sediment core from Sunfish Lake with notes on climate and vegetation.

Ballycroy Bog, 83 km NE of Sunfish Lake, obtained a radiocarbon date of 4220 ± 130 B.P. near the base of the C_2 pollen zone at a point where *Quercus* pollen is of equal importance to the declining *Tsuga*. By correlation with the very similar Sunfish Lake pollen sequence, a date of about 4200 B.P. may be applied to the 220-cm level. Similarly, as a result of radiocarbon determinations at several sites, Anderson obtained a date of about 12 000 B.P. for the base of pollen zone A, where *Picea* forests first became established in southern Ontario. In Sunfish Lake this is at about 445 cm. The base of the black sapropel at 40 cm coincides with a large increase in grass and other nonarboreal pollen and a decrease in arboreal pollen typical of forest clearance. This is reputed to have taken place locally between 1830 and 1840.

Over most of the postglacial period the sedimentation rate was around 0.5 mm per year, but in the most recent sediments, 0–40 cm, it averages 2.8 mm per year.

In general, the moisture content of the core increases toward the surface (Fig. 3). The only major exceptions are the minima at 430 cm and 355 cm corresponding to sand and silt layers. Carbonate is generally between 5 and 10% in most samples though it declines to less than 5% at the top of the core. The pH in most of the core is between 7.3 and 7.4. Organic carbon is very low in the deeper sediments and rises to a maximum of 8.9% at the top of C_1. After a minimum in C_2 it rises to a second maximum of 12.2% at 75 cm then declines toward the surface.

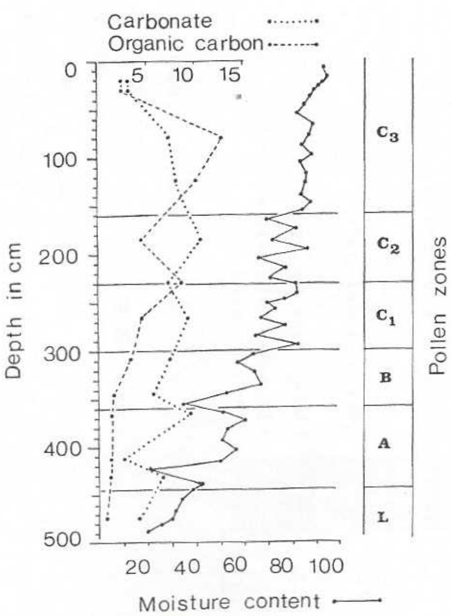

FIG. 3. Moisture content, organic and inorganic carbon in a core from Sunfish Lake.

Results and Discussion

About 340 species and varieties distributed among 37 genera were identified from the postglacial sediments (Table 1). The flora is typically alkaliphilous to circumneutral with very few acidophilous taxa. Descriptions of three new taxa have been published elsewhere (Sreenivasa 1971). Preservation of the frustules was good except in some of the lower samples, where there was evidence of mechanical damage. Counts per sample tended to increase toward the sediment surface (Fig. 4). The diversity (H) and redundancy (R) of the samples show great variation over the profile, being strongly influenced by variations in *Cyclotella bodanica*, the most abundant diatom in the sediments. However, the uppermost samples are more diverse than the lower ones. Only 16 taxa had at any time more than 2% representation in any sample and these are the only ones considered in this paper (Figs. 5 and 6).

Diatoms first appear at a depth of 400 cm in the middle of pollen zone A. Between 400 and 360 cm the counts are very low, consisting mainly of the littoral forms *Fragilaria construens* var. *venter* (Ehr.) Grun., *F. lapponica* Grun., and *Cymbella diluviana* (Krasske) M.-B. Florin, and at 400 cm only, a few frustules of the plankter *Cyclotella kuetzingiana* Thwaites. *Cymbella diluviana* and *F. construens* var. *venter* were abundant in the lower sediments of Linsley Pond, Connecticut (Patrick 1943), and they were also abundant in three postglacial sediment cores from the St. Lawrence lowlands studied by Lasalle (1966). *Cymbella diluviana* was also found in the early postglacial sediments of Kirchner Lake, Minnesota (Florin 1970). These littoral diatoms thus appear to be typical of early postglacial lacustrine sediments in northeastern North America. The preponderance of littoral diatoms in the lower sediments of Linsley Pond led Patrick (1943) to support a theory of increased transparency or lower water levels during deposition. However, Vallentyne and Swabey (1955) favored increased secondary deposition

TABLE 1

The diatom flora (species)

Achnanthes Bory
clevei Grun.
conspicua May
duthii sp. nov.
exigua Grun.
var. *heterovalvata* Krasske.
flexella (Kz.) Brun
var. *arctica* (Lagst.) A. Cl.
grimmei Krasske
lanceolata var. *abbreviata* Reimer.
var. *dubia* Grun.
var. *elliptica* Schulz.
var. *genuina* May.
var. *rostrata* (Ostrup) Hust.
lapponica var. *fennica* A. Cl.
linearis var. *pusilla* f. *exilis* A. Cl.
maxima var. *genuina* A. Cl.
microcephala (Kz.) Grun.
minuta (Cl.) A. Cl.
minutissima (Kz.) Grun.
nodosa A. Cl.
perigalli Brun & Hér
undulatus sp. nov.

Amphipleura Kuetzing.
pellucida (Ehr.) Kz.

Amphiprora Ehrenberg.
ornata Bailey

Amphora Ehrenberg.
coffaeiformis var. *borealis* (Kz.) Cl.
libyca Ehr.
ovalis Kz.
pediculus var. *minor* Grun.
perpusilla Grun.

Anomoeoneis Pfitzer.
sphaerophora (Ehr.) Pfitz.
vitrea (Grun.) var. *vitrea* Pat & Reimer

Astrionella Hassall.
formosa Hassall.

Caloneis Cleve
alpestris (Grun.) Cl
bacillum (Grun.) *Mereschk.*
lewisii Patr
procera Östrup
silicula subsp. *limosa* var. *genuina* Cl.
var. *truncata* (Grun.) May.
subsp. *ventricosa* var. *truncatula* (Grun.) May.
trochus var. *linearis* f. *fasciata* (Hust.) May.
f. *typica* May.
ventricosa var. *alpina* (Cl.) Pat.

Cocconeis Ehrenberg.
disculus (Schum.) Cl
var. *diminuta* Pant. A. Cl.
pediculus Ehr.
var. *baltica* (J. Dannf.) A. Cl.
placentula Ehr.

Cyclotella Kuetzing.
antiqua W. Sm
bodanica Eulenstein.
comta (Ehr.) Kz.
glomerata Bachman.
kuetzingiana Thwaites
var. *suchamanni* Grun.
menighiniana Kz.
stelligera Cl. et Grun.
striata var. *bipunctata* Fricke
transylvanica Pant.

Cymatopleura W. Smith
elliptica (Bréb.) W. Sm
solea (Bréb.) W. Sm
var. *apiculata* (W. Sm.) Ralfs

Cymbella Agardh.
affinis Kz
amphicephala Naegeli et Kz.
var. *intermedia* A. Cl.
aspera (Ehr.) Hér.
austriaca var. *reducta* A. Cl.
brehmii Hust
caespitosa (Kz.) Brun
var. *ovata* f. *minor* A. Cl.
cesatii var. *capitata* Krieger
var. *genuina* A. Cl.
cistula var. *genuina* May.
cuspidata var. *angilica* (Lagst.) A. Cl.
elliptica (Prudent) May.
cymbiformis (Kz.) Bréb
var. *jimboi* (Pant.) A. Cl.
var. *longa* A. Cl.
var. *nonpunctata* Font.
var. *multipunctata* A. Cl.
delicatula Kz.
ehrenbergii var. *hungarica* Pant.
heteropleura var. *genuina* A. Cl.
hungarica (Grun.) Pant.
hustedtii Krasske.
laevis Naeg.
lanceolata var. *genuina* A. Cl
lata Grun.
leptoceros (Ehr.) Grun.
mexicana Ehr.
microcephala Grun.
parvula Krasske
prostrata var. *genuina* (Berk) Cl.
diluviana (Krasske) M.-B. Florin
tumida (Bréb.) Van. H.
tumidula (Grun.)
turgida (Greg.) Cl.
turgidula Grun.
ventricosa Agh
var. *excavata* A. Cl.

Denticula Kuetzing
tenuis Kz.

Diatoma De Candolle
elongatum var. *genuinum* May
hiemale (Roth) Heib.
vulgare Bory

Diploneis Ehrenberg.
elliptoca var. *genuina* f. *minor* Grun.
oblongella var. *genuina* A. Cl.
oculata (Bréb.) Cl.
puella (Schum.) Cl.

Epimtheia Bréb.
species (girdle view)
argus var. *genuina* (Grun.) May.
var. *intermedia* (Hilse) May.
var. *protracta* May.

TABLE 1 (*Continued*)

turgida var. *capitata* Fricke
var. *genuina* May.
var. *granulata* (Ehr.) Kz.
ocellata (Ehr.) Kz.
zebra var. *genuina* Grun.
var. *proboscidia* (Kz.) Grun.

Eunotia Ehrenberg.
species (girdle view)
arcus Ehr.
curvata (Kz.) Lagerst.
flexuosa (Bréb.) Kz.
maior (W. Sm.) Rabh.
monodon Ehr.
pectinalis (Dillow) Rabh.
var. *minor* (Kz.) Rabh.
f. *impressa* (Ehr.) Hust.
septentrionalis Ostr.

Fragilaria Lyngbye
brevistriata Grun.
capucina Desm.
var. *mesolepta* Rabh.
construens (Ehr.) Grun.
var. *binodis* (Ehr.) Grun.
f. *semibigibba* A. Cl.
var. *venter* (Ehr.) Hust.
crotonensis Kitton
var. *oregona* Sovereign.
intermedia Grun.
lapponica Grun.
leptostauron (Ehr.) Hust.
var. *dubia* (Grun.) May.
var. *rhamboides* (Grun.) May.
nitzschioides Grun.
pinnata Ehr.
var. *lancettula* (Schum.) Hust.
producta (Lagst.) Grun.
vaucheriae (Kz.) Bye pet
var. *continua* A. Cl.
var. *gracilior* A. Cl.
virescens Ralfs.

Frustulia Agardh
amphipleuroides var. *typica* (Grun.) A. Cl.
vulgaris var. *typica* A. Cl.

Gomphonema Agardh
acuminatum var. *coronatum* (Ehr.) Grun.
var. *genuinum* May.
var. *laticeps* Ehr.
var. *pentocseki* A. Cl.
f. *curta* A. Cl.
var. *pucillum* Grun.
angustatum (Kz.) Rabh.
var. *obtusatum* Kz.
var. *sarcophagus* (Greg.) Van. H.
augar var. *genuinum* May.
bipunctatum Krasske
constrictum var. *capitatum* f. *clavata* (Ehr.) Cl
f. *robusta* May.
f. *typica* May.
var. *genuinum* May.
var. *subcapitatum* f. *elongata* A. Cl.
gracile var. *auritum* A. Braun.
var. *genuinum* May.
var. *major* Grun.
intricatum var. *dichotomiforme* May.
var. *diminutum* A. Cl.
var. *fossile* Pant

var. *genuinum* May.
f. *intermedia* A. Cl.
var. *pulvinatum* (A. Braun) Grun
var. *pumilum* Grun
var. *pusillum* May
lanceolatum var. *genuinum* A. Cl.
montanum var. *acuminatum* May.
olivaceum var. *balticum* Cl.
parvulum var. *exilissimum* Grun.
var. *genuinum* May.
var. *micropus* (Kz.) Cl.
sphaerophorum Ehr.
subclavatum Grun.
subtile var. *rotundatum* A. Cl.
var. *sagittum* (Schum.) Cl.
var. *typicum* A. Cl.

Gyrosigma Hassall
acuminatum (Kz.) Rabh.
attenuatum (Kz.) Rabh.
exilis (Grun.) Reimer.

Hantzchia Grunow.
amphioxys (Ehr.) Grun.
var. *capitata* O. Müller.

Mastagloia Thwaites.
elliptica var. *danseii* (Thwaites) Cl.
grevillei W. Sm.
lacustris var. *amphicephala* (Grun.) A. Cl.
smithii Thwaites ex W. Sm.
var. *lacustris* Grun.
var. *lanceolata* Grun.

Melosira Aghardh
granulata (Ehr.) Ralfs
islandica f. *curvata* vel *spiralis* O. Müller
italica (Ehr.) Kz.
varians Ag.

Meridion Aghardh
circulare (Grev.) Ag.
var. *constricta* (Ralfs.) Van. H.

Navicula Bory
accomoda Hust.
americana var. *bacillaris* Hér & Per.
amphibola Cl.
angilica var. *subsalsa* Grun.
bacilliformis Grun in Cl. and Grun.
bacillum Ehr.
capitata Ehr.
var. *hungarica* (Grun.) Ross
cincta (Ehr.) Ralfs
constans Hust.
contenta var. *biceps* (Arn.) Cl.
cryptocephala Kz.
var. *venta* (Kz.) Rabh.
cuspidata (Kz.) Kz.
decussis østr.
dicephala var. *genuina* May.
var. *abiskoenensis* Hust.
diluviana Krasske
elginensis (Greg.) Ralfs.
var. *neglecta* (Krasske.) Patr.
gastrum (Ehr.) Kz.
graciloides May.
grimmei Krasske.
lanceolata (Ag.) Kz.
menisculus var. *upsalensis* (Grun.) Grun.
mutica var. *chonii* (Hilse.) Grun.

TABLE 1 (*Concluded*)

oblonga Kz.
odiosa Wallace
protracta Grun.
pupula Kz.
 var. *elliptica* Hust.
 var. *rectangularis* (Greg.) Grun.
radiosa Kz.
 var. *tenella* (Bréb. ex Kz.) Grun.
reinhardtii Grun.
rhyncocephala Kz.
salinarum Grun in Cl. & Grun.
schonfeldii Hust.
subhamulata Grun.
subtilissima Cl.
theinamanni Hust.
tripunctata (O. F. Müll.) Bory
tuscula (Ehr.) Kz.
tusculoides var. *mayeri* A. Cl.
validicostata A. Cl.
viridula Kz.
vulpina Kz.

Neidium Pfitzer.
affine var. *humeris* Reim.
 var. *tenuirostris* A. May.
amphirhynchus var. *majus* (Cl.) Meist.
 var. *medium* A. Cl.
binodis (Ehr.) Hust.
bisulcatum var. *genuinum* A. Cl.
distincte-punctatum Hust. var. *major* var. nov.
dubium var. *cuneatum* Fontell
 genuinum May.
iridis var. *amphigamphus* (Ehr.) May
 genuinum (May.) A. Cl.
 var. *vernalis* Reichelt
kozlowii var. *genuinum* Mereschk.
productum (W. Sm.) Cl.

Nitzschia Hassall.
acicularis var. *typica* A. Cl.
amphibia var. *acutiuscula* Grun.
angustata var. *acuta* Grun.
 var. *antiqua* (Schum.) Cl.
calida Grun.
denticula var. *curta* Grun.
dissipata var. *genuina* (Kz.) Grun.
filiformis var. *genuina* (W. Sm.) Hust
fonticula var. *genuina* A. Cl.
frustulum var. *perpusilla* (Rabh.) Grun.
linearis var. *genuina* W. Sm.
palea (Kz.) W. Sm
recta var. *typica* A. Cl.
sigma var. *genuina* Grun.
sigmoidea (Ehr.) W. Sm
sinuata var. *tabellaria* Grun.
sphaerophora A. Cl.
subtilis var. *paleacea* Grun.
thermalis var. *genuina* Grun.

Opephora Petit
myrtyi Hér.

Pinnularia Ehrenberg
abaujensis var. *abaujensis* (Pant.) Ross
 var. *rostrata* Patr.
biceps Greg.
borealis var. *genuina* f. *typica* (A.S.) Boye. Pet.
brebissonii var. *mormonorum* Boye. Pet.
cuneata var. *reducta* A. Cl.
hustedtii Moler
obscura Krasske.
sohrensis var. *septentrionalis* f. *interrupta* Hust.
stauroptera var. *longa* A. Cl.
streptoraphe var. *styliformis* (Grun.) Cl
viridis var. *genuina* Ehr.

Rhicosphenia Grun.
curvata (Kz.) Grun.

Rhopalodia O. Müller.
gibba O. Müller
 var. *ventricosa* (Ehr.) Grun.
gibberula (Kz.) O. Müller.
parallela var. *minor* A. Cl.

Stauroneis Ehrenberg
acuta W. Sm.
anceps Ehr.
 var. *americana* Reim.
 var. *gothica* A. Cl.
 var. *linearis* (Ehr.) Hust.
incerta A. Cl.
kriegeri var. *undulata* Hust.
phoenicenteron (Nitzsch.) Ehr.
 var. *gracilis* (Ehr.) Hust.
 var. *lanceolata* (Kz.) Brun.
smithii Grun.

Stephanodiscus Ehrenberg
astrea var. *minutula* (Kz.) Grun.
hantzschii Grun.

Surirella Turpin
angustata Kz.
biseriata Bréb
biseriata var. *genuina* f. *punctata* A. Cl.
didyma Kz.
guatimalensis Ehr.
linearis var. *costricta* (Ehr.) Grun.
ovata var. *minuta* Bréb.
tenera Greg.

Synedra Ehrenberg
capitata Ehr.
delicatissima var. *angustissima* Grun.
filiformis var. *exilis* A. Cl.
nana Meister
parasitica (W. Sm.) Hust.
rumpens var. *femiliaris* (Kz.) Hust.
tabulata var. *acuminata* (Grun.) Hust.
tenera W. Sm.
ulna (Nitzsch) Ehr.
 var. *amphirhynchus* (Ehr.) Grun.
 var. *danica* (Kz.) Van. H.
 var. *oxyrhynchus* (Kz.) Hust.
 subequalis (Grun.) Van. H.

Tabellaria Ehrenberg
fenestrata (Lyngb.) Kz.
flocullosa (Roth) Kz.

as being responsible. This may also be the case in Sunfish Lake, as many of the frustules have evidence of mechanical damage. Erosional activity during this period and the paucity of fossil planktonic diatoms suggest that conditions were largely unsuitable for plankton growth or preservation on the sediments. Sunfish Lake was probably colder than present and moderately alkaline with a diatom flora mainly restricted to the littoral zone.

The early littoral diatoms remain an important part of the fossil diatom assemblage throughout pollen zone B. *Mastogloia smithii* var. *lacustris* Grun. appears at 350 cm, and at 320 cm formed a major part of the sample. During pollen zone B, conditions in the lake apparently became suitable for development of a diatom plankton and (or) its preservation on the sediments. At 360 cm a few frustules of *Stephanodiscus astraea* var. *minutula* (Kutz.) Grun. were found in a small sample. This taxon is eurytopic in the Great Lakes and is generally more abundant in winter or early spring collections (Duthie and Sreenivasa 1971). It is never important numerically in the sediments of Sunfish Lake. At 350 cm, *Cyclotella bodanica* Eulenst. first appears, where it forms 50% of the sample. Since it is by far the most abundant diatom in the sediments of Sunfish Lake, its ecology should give a fair indication of the conditions under which it grew and was sedimented. According to Ruttner in Huber-Pestalozzi (1942), it is frequent in oligotrophic circumneutral lakes, particularly subalpine lakes, in northern and western Europe, and reaches its maximum in late summer and autumn at temperatures of 10–17°C. *Cyclotella bodanica* is common in oligotrophic areas of the Great Lakes though it appears tolerant of some enrichment. It was found in the postglacial sediments of Lake Huron (Stoermer and Yang 1968) and Lake Ontario (Duthie and Sreenivasa 1971). In general, the numbers of *C. bodanica* per sample increase throughout the core to a maximum between 130 and 90 cm though there is a very large isolated maximum at 240 cm.

The samples between 300 and 230 cm, making up pollen zone C_1, are characterized by an increasing number of individuals per sample and an increasingly rich diatom flora. *Cyclotella bodanica* is dominant throughout the period but *C. kuetzingiana* is codominant in one sample, at 250 cm. The stenothermal littoral diatoms of the A and B zones disappear or become rare but are replaced, particularly at 250 cm and above, by a large number of other littoral or epiphytic diatoms present as only one or two specimens per sample, e.g., species of *Achnanthes*, *Cymbella*, *Navicula*, *Gomphonema*, *Nitzschia*, and *Synedra*. The sample at 240 cm was richest with 3820 individuals in 63 taxa. It is possible that the increasing number and richness of the diatom flora in C_1 reflects amelioration of the climate and increasing lake productivity. Hutchinson and Wollack (1940) and Vallentyne and Swabey (1955) claimed that productivity of Linsley Pond reached a maximum in the later C_1. In Sunfish

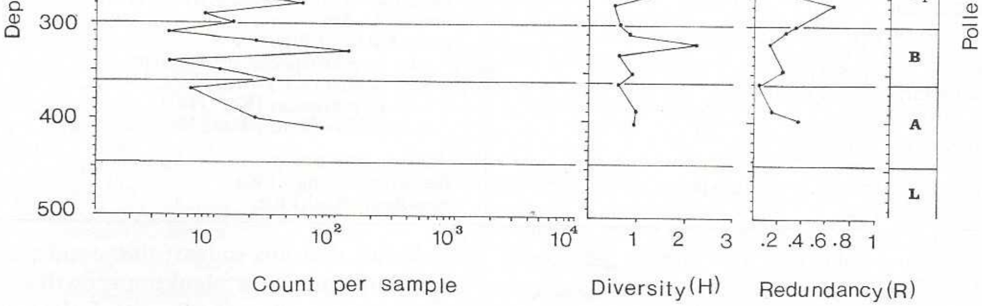

FIG. 4. Count per sample, diversity (H), and redundancy (R) of fossil diatoms in a sediment core from Sunfish Lake.

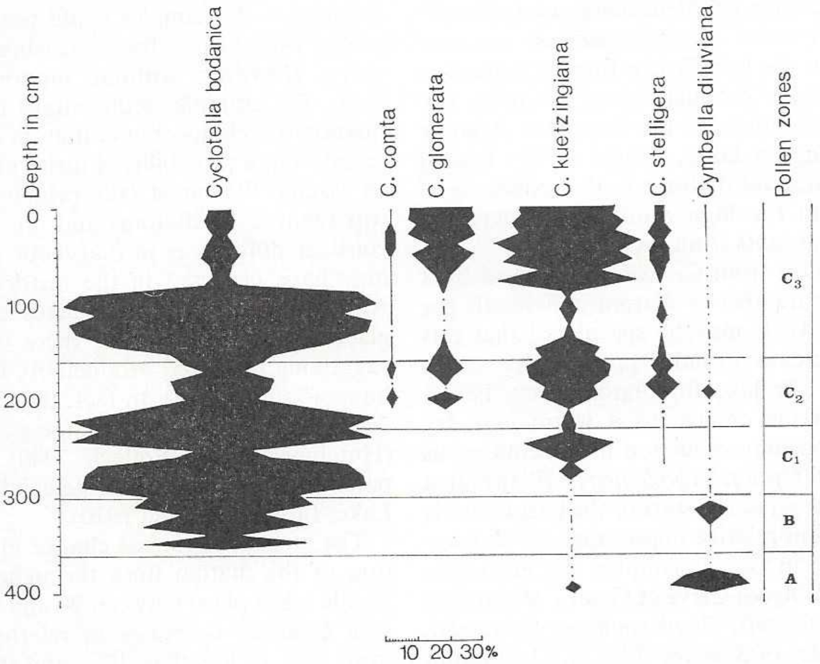

FIG. 5. Relative abundance of some diatom taxa in the sediment core.

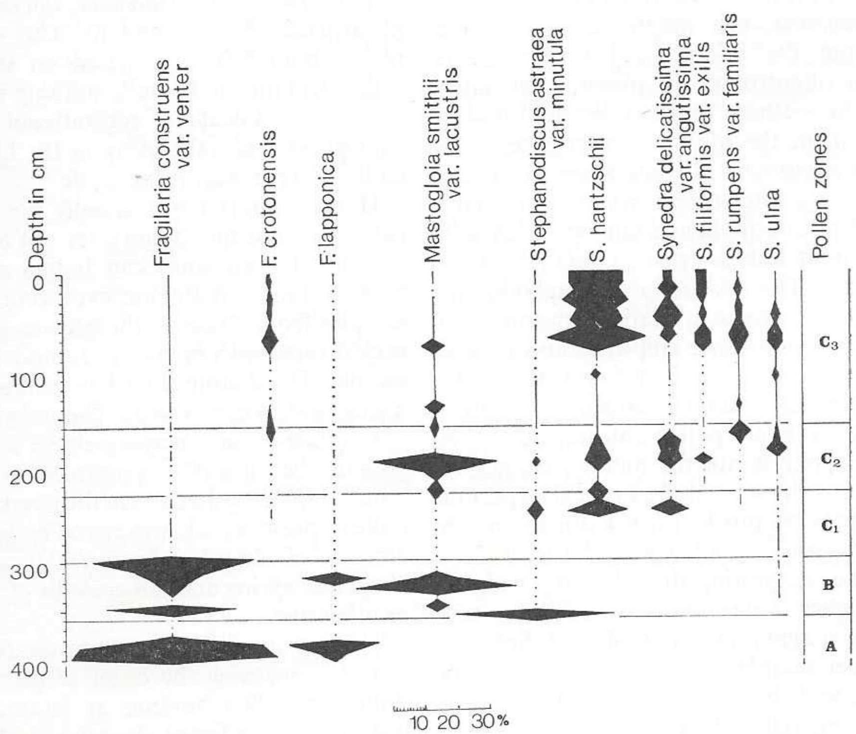

FIG. 6. Relative abundance of some diatom taxa in the sediment core.

Lake the presence of *Stephanodiscus hantzschii* Grun. and *Synedra delicatissima* var. *angustissima* Grun. in the late C_1 is a further indication of perhaps higher productivity at this time. The upper C_1 corresponds to the European Atlantic period. In English lakes, Round (1961) related the large number of diatoms in the sediments of that period to the high rainfall and increased leaching of nutrients from the watershed.

The transition from C_1 to C_2 is marked by a decline in the number of diatom individuals per sample (Fig. 4). It may be speculated that this apparent decrease in lake productivity or in suitability of the lake for diatoms may be associated with the change to a warm and dry climate and ensuing reduction in allochthonous nutrient input. *Cyclotella bodanica* is still the most important diatom at the start of the period but is later replaced in relative importance by *C. kuetzingiana* and in some samples *C. glomerata* Bachm., *C. stelligera* Cleve et Grun., *Mastogloia smithii* var. *lacustris*, *Stephanodiscus hantzschii*, and four species of *Synedra* (Fig. 4). The diatom flora in C_2 samples is fairly rich in species, particularly in the later C_2, but the total counts per sample are low to moderate (Fig. 2). *Cyclotella kuetzingiana*, the major diatom in the samples from the middle and upper C_2, is common in oligotrophic to mesotrophic lakes and ponds in southern Ontario. While found in the plankton, in the authors' experience, it is usually associated with shallow water or littoral communities. *Cyclotella glomerata* is found in the plankton of mesotrophic and eutrophic lakes in the lower Great Lakes region. *Cyclotella stelligera* is similar. The decline in the euplanktonic *C. bodanica* and increase in relative importance in *C. kuetzingiana* and other epiphytic and littoral taxa may be accounted for by lower water levels.

Zone C_3 marks a return to a cooler and moister climate (Fig. 2). From pollen data the change is gradual and there is not the marked change in diatoms seen at the start of C_2. In the first part of C_3, *C. bodanica* regains its former dominance in the fossil diatom assemblage and the littoral forms decline, suggesting that the lake had regained a higher water level. Conditions were probably once again very suitable for diatoms. The count per sample increases and the flora is very diverse with between 65 and 120 taxa per sample between 160 and 90 cm.

Again, as in zone C_1, increasing numbers of diatoms in the samples could possibly be interpreted as evidence for increasing lake productivity. However, without supporting evidence from, for example, sedimentary chlorophyll or quantitative cladoceran or diatom data, this must remain but a possibility. Furthermore, it is risky to assume that most lake primary productivity was realized by diatoms and one also needs to consider differences in diagenetic efficiency that may have occurred in the history of the lake. Another point is that, of lakes investigated in glaciated North America, there is no evidence suggesting increased productivity in C_3 (without human interference). In fact, there is generally a decline from a C_1 maximum, e.g., Linsley Pond (Hutchinson and Wollack 1940), or little apparent trend over the postglacial, e.g., Pretty Lake, Indiana (Wetzel 1970).

The most pronounced change in the composition of the diatom flora throughout the entire profile takes place between 90 and 80 cm. *Cyclotella bodanica* decreases in relative importance from 85% to less than 10% and there is a large increase in littoral species and species associated with a higher trophic level, e.g., *S. hantzschii*, *C. glomerata*, *C. kuetzingiana*, and several species of *Synedra* (Figs. 5 and 6). This change took place about 850 B.P., based on sedimentation rate calculations. There is nothing in the pollen record to indicate a vegetational or climatic change, so internal factors in the lake are most likely to have been responsible.

Human interference should not perhaps be ruled out, but the authors are not aware of any evidence for an American Indian settlement at Sunfish Lake. With one exception the diatom samples from 80 cm to the surface are large and very diverse with between 121 and 175 taxa per sample. The diatom flora has remained virtually unchanged to the present. The individual counts per sample do not increase above 80 cm. This is possibly because of cyanophytes or other algal groups replacing diatoms in the plankton. Sunfish Lake at present is characterized by large summer blooms of *Oscillatoria agardhii* var. *isothrix* Skuja and spring and fall growths of *S. hantzschii* or other diatoms.

There is no indication from the fossil diatom record concerning the onset of meromixis. The *Ambrosia* pollen horizon at 40 cm, about 140 B.P., indicating forest clearance and agriculture brought no significant change in the diatoms.

However, the black sulfide sapropel from 40 cm suggests meromixis was established around that time. Portions of *Chara* and molluscs and a large number of broken diatom frustules between 40 and 35 cm provide additional evidence for a disturbance at that level. Frey (1955) cites forest clearance and interference of man as one of the causes for the onset of meromixis in Langsee, Austria, around 2000 B.C. The main cause is the formation of a chemically dense hypolimnion as a result of rapid leaching and inflow of allochthonous material.

The apparent eutrophication between 90 and 80 cm in zone C_3 is a most interesting finding and at present cannot be explained. Lakes in similar latitudes in North America do not show any such comparable change in the C_3. For example, Stockner (1971) found no significant changes in the diatom floras of lakes in northwestern Ontario over the past 3000–4000 years.

In Sunfish Lake the overall trend is for the diatom count per sample to increase throughout the postglacial period (Fig. 4). Assuming a more or less steady sedimentation rate and no significant changes in diagenetic efficiency, it is possible to interpret this as evidence for increasing productivity. If this is so, then Sunfish Lake had not reached the state of trophic equilibrium with its environment early in the postglacial, which evidently is the condition of drainage lakes (Hutchinson 1969). In this regard Sunfish Lake could be exceptional and thus may be a rewarding site for further paleoecological investigation.

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