

CHAPTER 7

POSTGLACIAL HISTORY OF SUNFISH LAKE

Sunfish Lake ($43^{\circ} 28'N$, $80^{\circ} 35'W$) is a small, deep, kettle lake (Fig. 27) about 8 km west of Waterloo in southwestern Ontario. The watershed is underlain by a bedrock of shale, salt, and gypsum (P.F. Karrow, from Duthie and Carter 1970) surrounded by sandy kames. A detailed site description has been given by Sreenivasa (1973).

Physical and chemical characteristics of the lake were described by Duthie and Carter (1970), and are summarized below. The water is moderately alkaline (100 - 150 mg/l $CaCO_3$), and the pH in the epilimnion varies between 7.4 and 8.8, whereas the pH in the lower monimolimnion is usually near neutrality. Concentrations of total phosphate phosphorus vary from 0.01 mg/l near the surface to over 10 mg/l in the monimolimnion. The lake is presently eutrophic and is chemically stratified with a chemocline near the 13 m level; however, Duthie and Carter (1970) suggest that the lake's meromixis is tenuous.

Private ownership of the land around the lake began in 1848, after which it passed through a series of 12 owners, most of whom were farmers (Waterloo Registry Office). In 1953, waterfront properties were surveyed and divided into lots where cottages and, more recently, permanent residences were built (Fig. 27). In contrast to Little Round Lake, intensive cultural disturbances, such as agriculture, persist in the lake's watershed.

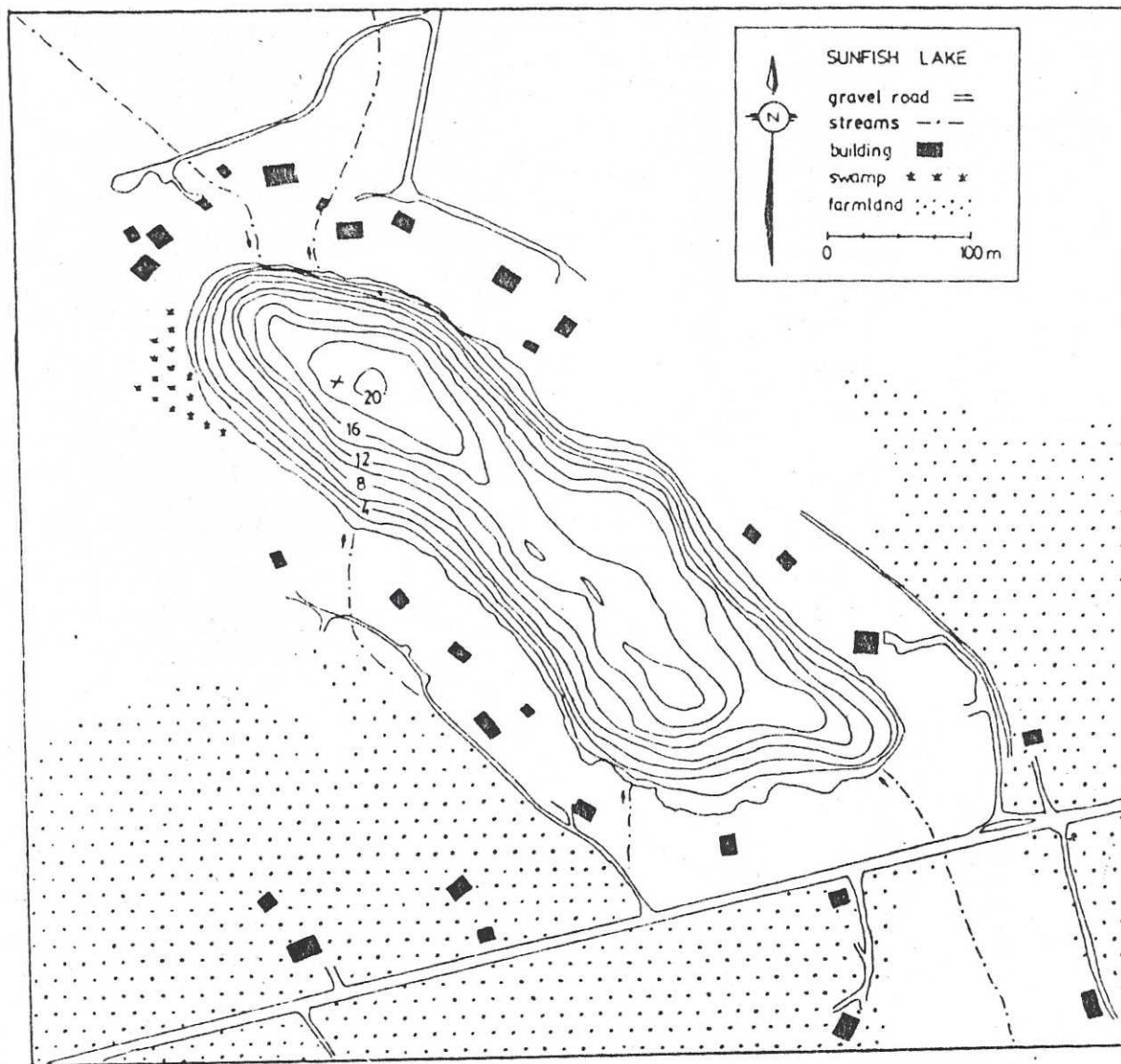


Fig. 27. Morphometric map of Sunfish Lake (surface area = 8.3 ha, maximum depth = 20 m, mean depth = 10.4 m, from Duthie and Carter 1970). 'X' marks coring site.

Several paleolimnological studies have already been completed on Sunfish Lake. M.R. Sreenivasa and Duthie (1973) published a percentage diagram of diatoms at 10-cm intervals throughout the lake's sedimentary record. Their analysis suggests that the lake was eutrophic prior to the arrival of European settlers, and that cultural disturbances had little effect on fossil diatoms. B.R. Sreenivasa (1973) described pollen and animal microfossils, whereas Adams and Duthie (1976) analyzed the sediment chemistry. In addition, H.J. McIntosh (Appendix III) is describing postglacial variations in fossil carotenoids.

In light of these studies, it was hoped that a closer-interval (5 cm) quantitative analysis of the lake's diatom stratigraphy, combined with a description of chrysophycean microfossils, would elucidate the postglacial history of Sunfish Lake. Furthermore, a comparison of my pollen and diatom data with profiles presented by previous workers would provide a test for core reproducibility.

Sediment Description

A 4.85-m core (Fig. 28) was obtained from the flat central basin of Sunfish Lake (Fig. 27). In contrast to Little Round Lake, there was no sharp boundary between clays and organic sediments. Instead the lower 2 m consist of layers of sand, silty clays, and laminated marly gyttja (Fig. 28). The large fluctuations in sediment density and

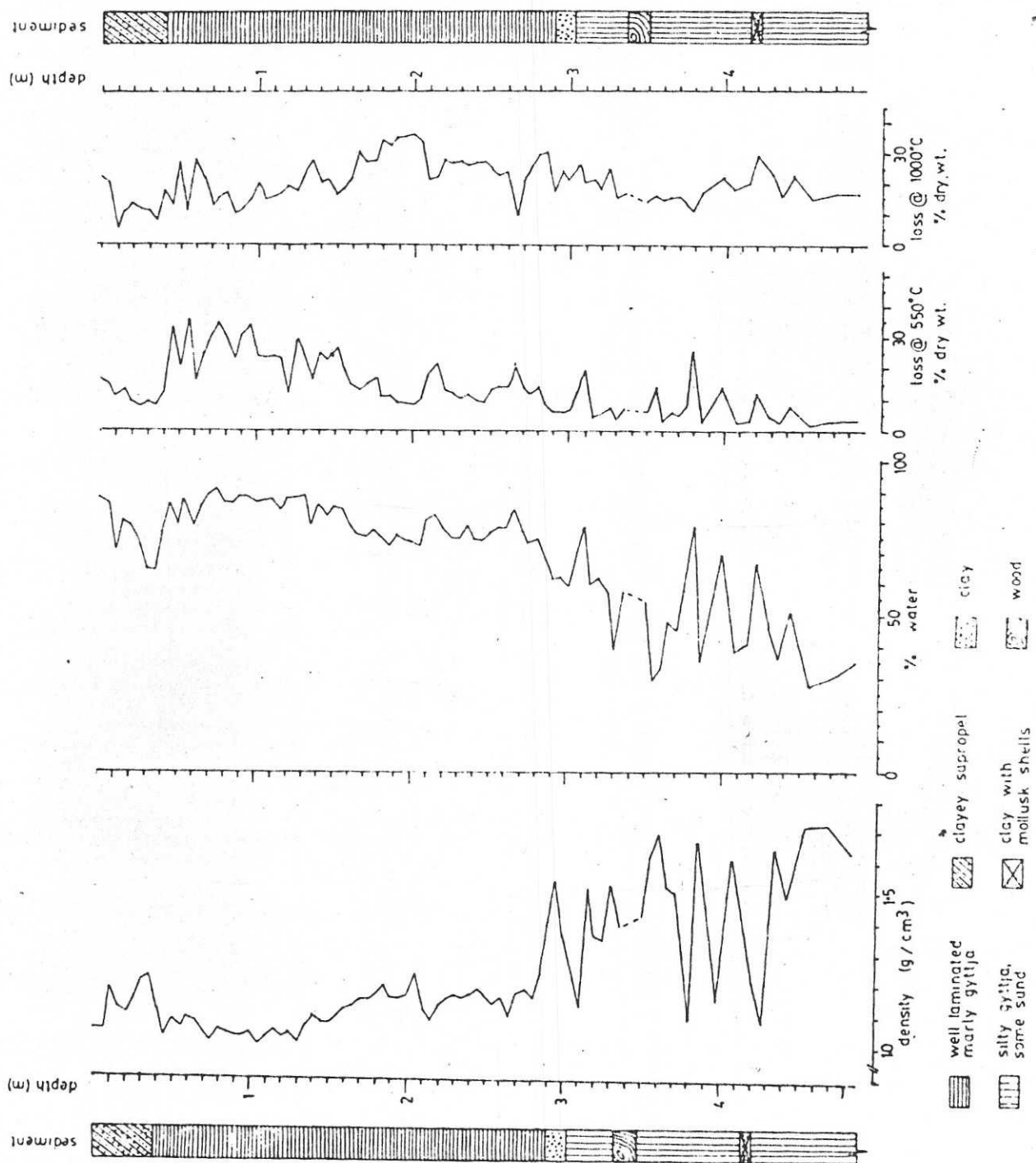


Fig. 28. Sedimentary characteristics of Sunfish Lake's postglacial sediments (estimates of CaCO_3 levels are presented in App. IV)

water content reflect these changes in sediment matrix. However, even in areas of predominantly sand deposition fine laminae can often be distinguished.

Above a depth of 2.85 m, the sediments resemble those in the Little Round Lake core, except that estimates of carbonate content (weight loss at 1000° C) are generally higher. Both water content and organic matter (weight loss at 550° C) tend to increase from older to younger sediment until the 40-cm level, where both variables drop (Fig. 28). This corresponds to an abrupt change from marly gyttja to a clayey sapropel.

Microfossil Analyses

A total of 179 diatom taxa was identified (Appendix II). Diatom preservation was a serious problem throughout large segments of the stratigraphy, and, therefore, at these levels species composition was not calculated. Similar problems were noted for synuracean scales, whereas chrysophycean statospores were well preserved. The concentration of algal microfossils (Fig. 32) was not calculated below a depth of 340 cm (i.e. the wood, Fig. 28), since these sediments had varying amounts of silts and sand, and consequently concentration data would reflect the sediment matrix more closely than microfossil populations.

Pollen preservation was good throughout the core, and data are presented in the same way as for Little Round Lake (Fig. 29, Table 3).

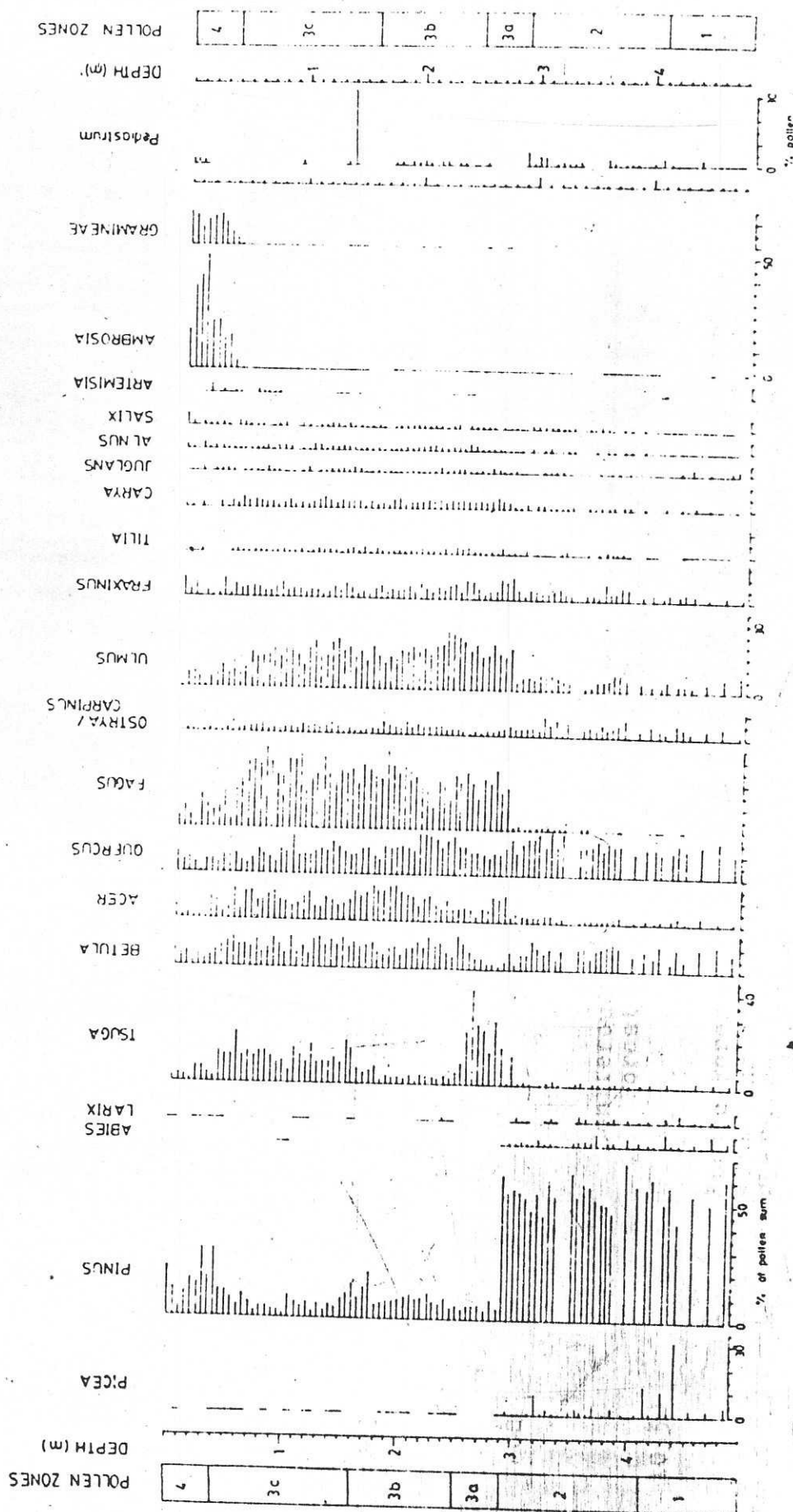


Fig. 29. Percentage diagram of pollen grains identified in Sunfish Lake's postglacial sediments

TABLE 3: Paleovegetation Zonation for Sunfish Lake, Ontario.

Dates* (approx.) E.P.	Zone	Paleovegetation	Characteristics	Interpretation
140	4	Disturbed Environment	large increase in non-arboreal pollen, such as ragweed	cultural activity in watershed, pre- sent climate
	3c		return of hemlock, oak decreases	wetter and perhaps cooler
4200	3b	Mixed Deciduous Coniferous Forest	sharp decline in hemlock; replaced by birch, maple, and beech	pathogen? warmer and drier
7600	3a		pine replaced by hemlock and hard- woods, especially beech and elm	warm and wet
	2	Coniferous Forest	pine dominates, some spruce and fir	warmer and drier
10550	1	Spruce Forest, with Pine and Fir Trees	high percentage of spruce, and other coniferous pollen	cool ↑

*Dating chronology follows Sreenivasa and Duthie (1973) and Terasmae (1981).

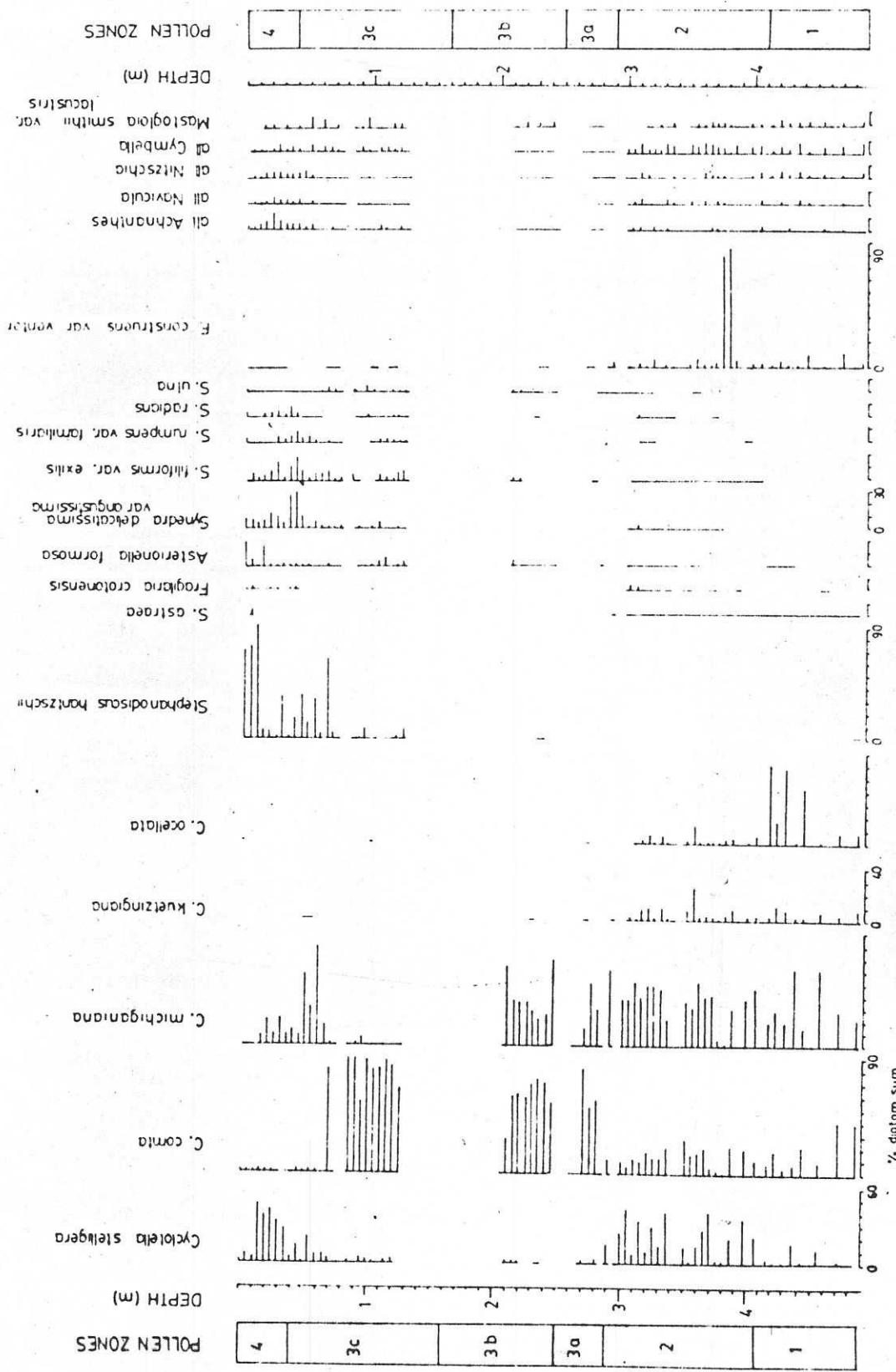
Zone 1 (4.85 - 4.10 metres)

High percentages of spruce pollen distinguish this zone (Fig. 29). The diatom flora is dominated by Cyclotella spp. such as C. compta, C. michiganiana, C. ocellata, and lesser amounts of C. stelligera and C. kuetszingiana (Fig. 30). Fragilaria construens var. venter is present in every sample, but it never exceeds 12% of the diatom sum. Synuracean scales are represented exclusively by Mallomonas pseudocoronata/crassisquama. Although concentrations were not calculated, microfossils were less abundant in the older sediments. Relative to diatoms, chrysophycean statospores represented about 25% of the assemblage (Fig. 33).

Zone 2 (4.10 - 2.95 metres)

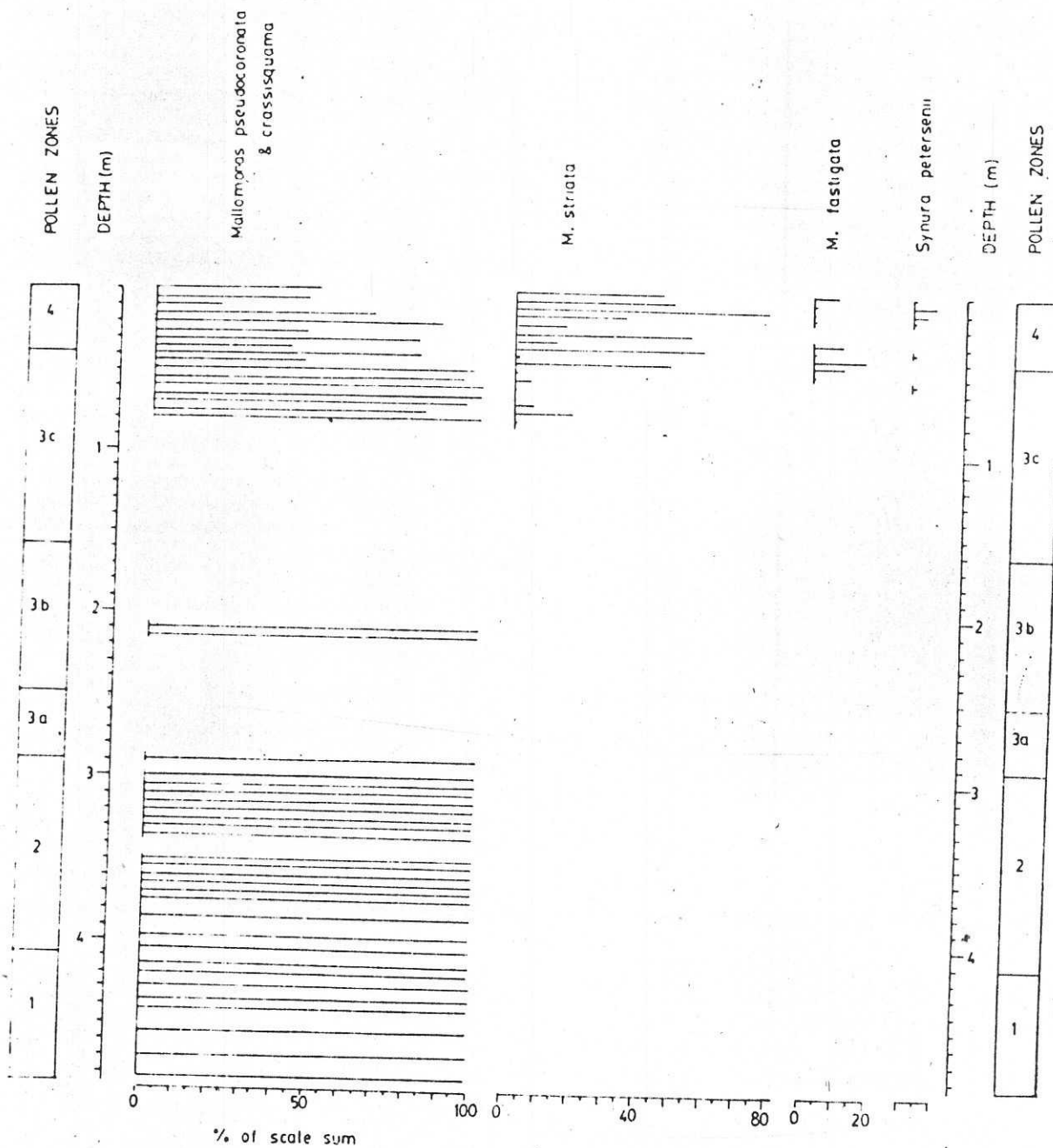
A decline in spruce and a dominance of pine characterizes this zone (Fig. 29). Hardwoods, such as elm (Ulmus) and ash (Fraxinus), also increase in relative frequency.

The fossil algae are similar to those recorded in zone 1. Cyclotella spp. are still common (Fig. 30), and Mallomonas pseudocoronata/crassisquama is the only synuracean taxon recorded (Fig. 31). A distinct community occurs between 375 - 380 cm, where Fragilaria construens var. venter represents over 90% of the assemblage (Fig. 30). At these 2 levels, synuracean scales and chrysophycean statospores are reduced to trace levels.



SUNFISH LAKE DIATOMS

Fig. 30. Percentage diagram of diatom taxa in Sunfish Lake's postglacial sediments.



SUNFISH LAKE SYNURACEAE

Fig. 31. Percentage diagram of synuracean species identified in Sunfish Lake's postglacial sediments.

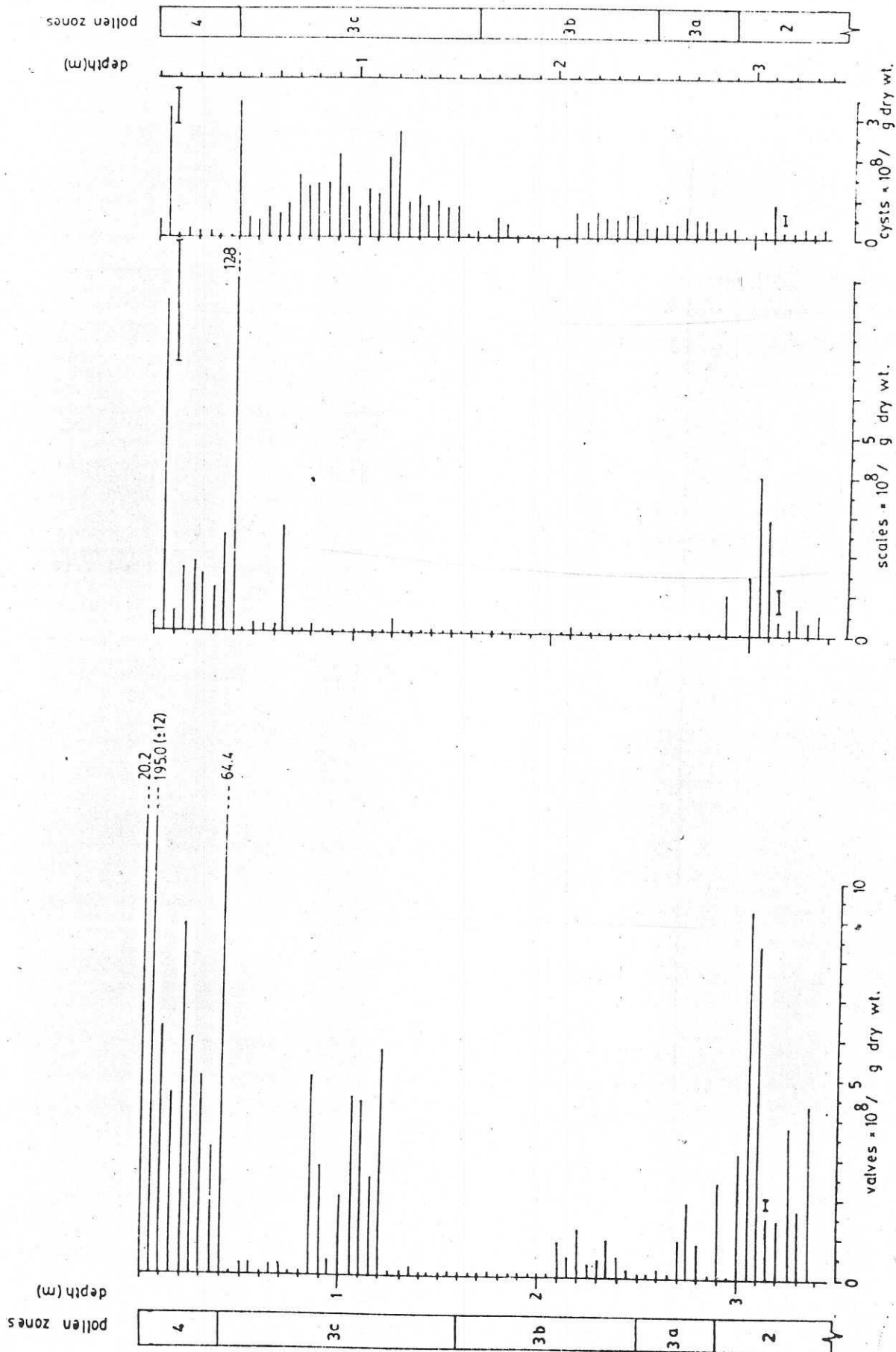


Fig. 32. Concentration profiles of diatom valves, synurian scales, and chrysophycean statosporas in buntish lake's postglacial

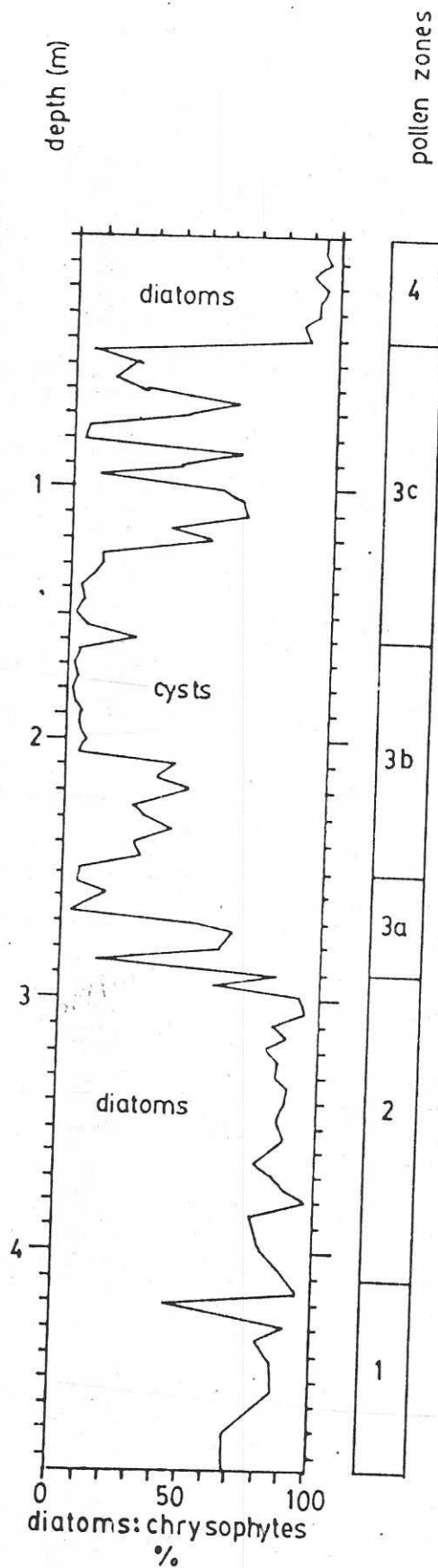


Fig. 33. Relative proportions of diatoms to chrysophytes in Sunfish Lake's post-glacial sediments.

Diatom valves are abundant (Fig. 32) and well preserved until the upper boundary of this zone. Synuracean scales generally increase in abundance from the older to younger sediments, but then also drop off sharply at the 3 m level (Fig. 32). The concentration of statospores is low (Fig. 32) and, relative to diatoms, chrysophytes were less successful than in zone 1 (Fig. 33).

The piece of wood (identified as belonging to Poplar (Populus) by Mr. R. Mott, of the Geological Survey of Canada) present in the core between 338 and 349 cm did not coincide with any stratigraphic changes in pollen or algal microfossils. Similarly, sediment scraped from this wood did not contain a distinct assemblage, but was dominated by the Cyclotella species common in this zone.

Zone 3a (2.95 - 2.50 metres)

A dramatic decline in pine and its replacement by hemlock (Tsuga), maple (Acer), beech (Fagus), elm (Ulmus) and other hardwoods delineate this zone (Fig. 29).

Poor preservation of diatom valves and synuracean scales began to be a serious problem in this zone. Large Cyclotella spp., several benthic diatoms, and Mallomonas pseudocoronata/crassisquama scales are present; but they are all badly eroded. Meanwhile, chrysophycean statospores are relatively well preserved and, although concentrations are low, their abundance relative to diatoms is very high (Fig. 33). This probably reflects the preferential dissolution of diatoms relative to the more thickly silicified statospores.

Zone 3b (2.50 - 1.60 metres)

The near disappearance of hemlock and its replacement by deciduous trees characterize this zone (Fig. 29). Preservation of algal microfossils is very poor.

Zone 3c (1.60 - 0.40 metres)

The return of hemlock delineates zone 3c (Fig. 29). At the 140-cm level, Pediastrum colonies are present in large numbers (Fig. 29).

Diatom preservation is still a serious problem in the lower portion of this zone; however, near the 1.2 m level intact valves represented mainly by Cyclotella comta are more common (Fig. 30). At 60 cm, the assemblage shifts abruptly to one dominated by Cyclotella michiganiana and Stephanodiscus hantzschii.

Synuracean scales are also better preserved in the upper portion of this zone, but concentrations are low (Fig. 32). Mallomonas pseudocoronata/crassisquama dominates the assemblage. M. striata Asmund is recorded for the first time at the 80-cm level. The concentration of statospores is high throughout this zone (Fig. 32).

Zone 4 (0.40 - 0.00 metres)

This zone is distinguished by a large increase in non-arboreal pollen, especially ragweed (Ambrosia) and

grasses (Gramineae). Pine also shows a modest increase, whilst most of the other taxa decline (Fig. 29).

Several Synedra spp. (including S. delicatissima var. angustissima, S. filiformis var. exilis, and S. radians) increase in relative frequency at the lower boundary of this zone, but then gradually decrease towards the surface (Fig. 30). Cyclotella stelligera follows a similar stratigraphic pattern. The surface 15 cm is dominated by Stephanodiscus hantzschii valves.

Asterionella formosa is also more common. Diatom concentration (Fig. 32) is very high during this zone, with especially high peaks at the 1, 5, and 40-cm levels.

Synuraceae are represented by approximately equal proportions of Mallomonas pseudocoronata/crassisquama and M. striata (Fig. 31). M. fastigata is common near the lower boundary of this zone and then again in the surface sediments. Synura petersenii also shows a modest increase in the top 15 cm. Scale concentration (Fig. 32) is relatively high with peaks at 40 and 5 cm. These two levels also contain high concentrations of statospores (Fig. 32); although cysts are usually very sparse during this zone, an observation that is reflected by the striking drop in the relative abundance of chrysophytes to diatoms (Fig. 33).

Discussion

The paleolimnological data indicate that the 4.85-m long core used in this study did not penetrate the entire postglacial stratigraphy of Sunfish Lake. Although my core is approximately the same length as the one Sreenivasa (1973) used for his pollen analyses, he recorded an herb pollen assemblage in the lowermost sediment, whereas my basal sediment is still dominated by coniferous pollen. This suggests a cool, rather than cold, climate during zone 1; an interpretation that is corroborated by the abundance of Cyclotella spp. and Mallomonas pseudocoronata/crassisquama scales. These are all planktonic algae and therefore the pelagic region was already free of ice (cf. reasoning in Chapter 4 on arctic lakes).

The early postglacial sediments, which consisted of a silty, sandy gyttja interrupted by clay lenses, were probably derived from solifluction processes in the young watershed. Nutrients contained in these eroded sediments were presumably in an unavailable form, as the assemblage indicates oligotrophy throughout this zone. Interestingly, changes in sediment matrix (e.g. clay versus silty gyttja) had little effect on microfossil species composition, suggesting that this sediment more closely reflects regional processes occurring in and around the watershed (e.g. sand blown in from the surrounding kames) rather than limnological changes.

The decline in spruce about 10,500 years ago indicates a somewhat warmer climate. The predominantly clastic nature of the sediments suggests that the watershed was still unconsolidated. Throughout most of this period, oligotrophic Cyclotella spp. and Mallomonas pseudocoronata/crassisquama scales, similar to those described in Little Round Lake, still dominate the assemblage. Export of available nutrients from the watershed was low for the same reasons discussed in the previous chapter.

A very distinct community developed between the 375- and 380-cm levels, where Fragilaria construens var. venter represented about 90% of the diatom sum (also recorded by Sreenivasa and Duthie 1973). In addition, both synuracean scales and chrysophycean statospores were reduced to trace levels. This assemblage is very similar to the one recorded for Pim Island (Chapter 4). Since there are no accompanying changes in the pollen stratigraphy, it is unlikely that either a change in climate or redeposition of older (i.e. late glacial) sediment had occurred at this time. The organic nature of the sediment also argues against an allochthonous origin for this assemblage. Consequently, the ecological significance of these data is unknown at this time.

Another unusual feature of zone 2 was the presence of a piece of poplar between the 336 - 350 cm levels. Since there were no synchronous changes in pollen or algal microfossils at these levels, the wood probably has little limnological

significance, but simply represents a piece of organic debris that was washed in from the unconsolidated watershed. It does, however, suggest that poplar was present in the lake's watershed, even though Populus pollen grains were only recorded at trace levels during this zone. Mott (1978) believed that poplar was important in early postglacial forests, but that it has been overlooked since its pollen grains are poorly preserved (Sangster and Dale 1961). The presence of the wood sample in the middle of zone 2 supports Mott's hypothesis.

The replacement of pine by a mixed deciduous - coniferous forest, indicating warmer and wetter conditions, occurred very abruptly at the 285 - cm level (ca. 7500 B.P., Terasmae 1981). It is unlikely that the steepness of the decline in pine pollen was an artifact of my core, since Sreenivasa (1973) noted a similarly abrupt change in his pollen diagram. The presence of clay in the sediment stratigraphy probably reflects increased erosion in the drainage basin resulting from this rapid shift in the vegetation.

It is difficult to interpret the limnological repercussions of this watershed event, since microfossil dissolution becomes a serious problem at this time. Dissolution processes are still poorly understood, and consequently the ecological significance of these findings is speculative; but it is possible that meromixis was involved.

Merilainen (1971) found that diatom dissolution in the four lakes he studied was much greater in monimolimnetic sediments. Although dissolution cannot be considered a rule for meromictic lakes (cf. Chapters 5 and 6), there is evidence to suggest that meromictic stability was enhanced with the establishment of a mixed deciduous - coniferous forest (i.e. zone 3a). This evidence includes: 1) the appearance of fine varves in the sediment; 2) a large increase in the Fe:Mn ratio (Adams and Duthie 1976), indicating reducing conditions in the hypolimnion (Mackereth 1966); and 3) an increase in the concentration of some bacterial carotenoids (McIntosh Appendix III). Further, the clay present at the transition between these two pollen zones is similar to Frey's (1955) description of sediments in Langsee. Frey postulated that following the agricultural period the increased runoff of morainal clays increased the density of hypolimnetic water and triggered biogenic meromixis. Increased erosion may have enhanced meromixis in Sunfish Lake at the transition to zone 3a.

Diatom preservation improves somewhat in the middle of zone 3c when mostly Cyclotella comta valves were recorded. This assemblage indicates oligotrophy (Stockner 1971) and, combined with the continued presence of varves in the stratigraphy, suggests that the lake was still meromictic. Preservation may have been improved simply because these microfossils are younger.

The microfossil data indicate eutrophication near the 70-cm level. For example, the eutrophic diatom Stephanodiscus hantzschii is much more common, and Mallomonas striata, a taxon which has been reported in enriched water (Cronberg and Kristiansen 1980), increases in relative frequency. This portion of the stratigraphy has puzzled previous investigators (e.g. Sreenivasa and Duthie 1973) since this eutrophication occurs centuries before cultural activity began in the watershed. It is possible that meromixis was beginning to break down at this time; the progressive disappearance of varves and changes in bacterial carotenoids (H. McIntosh Appendix III) supports this reasoning.

Documents in the Waterloo Registry Office indicate that private ownership of the land around Sunfish Lake began in 1848, with most of the 12 owners being farmers. A large increase in ragweed and grass pollen signifies the intensification of cultural disturbances in the watershed. A synchronous shift to more clayey sediment indicates increased erosion following deforestation (cf. Frey 1955).

Changes in algal microfossils are similar to those recorded in Little Round Lake. During the early portion of this zone, the increase in relative frequency of thinly silicified Synedra spp. probably reflects decreased light penetration resulting from turbidity and/or higher productivity, as discussed in Chapter 5. The increase in Mallomonas fastigata scales also suggests enrichment (Smol 1980);

however, the continued presence of Cyclotella spp. indicate that the lake was probably mesotrophic rather than eutrophic.

Eutrophication clearly accelerated in the surface 10 cm, where Cyclotella spp. were replaced by the eutrophic Stephanodiscus hantzschii. In addition, Mallomonas striata, a taxon that also increased in Crawford Lake following cultural activity (Smol, unpublished), dominated the synuracean community. Assuming a mean sedimentation rate from the surface of the core (1979) and the rise in non-arboreal pollen at 40 cm (ca. 1848), the 10 cm level corresponds to the early 1950's. Waterfront property was surveyed and sold at this time (Waterloo Registry Office), and the eutrophication probably reflects the intensification of cultural activity around the lake's perimeter. S. hantzschii, along with Asterionella formosa which also increased in the surface sediments, still form blooms in Sunfish Lake (Duthie and Carter 1970).

In contrast to Little Round Lake, eutrophic conditions persist in Sunfish Lake to the present time, even though the lake is still meromictic. This probably reflects the continuation of intense cultural disturbances, such as agriculture, in its watershed. If these activities would stop and meromictic stability could be maintained, the lake would probably revert to oligotrophy.

A comparison of my microfossil data with those gathered by previous workers (Sreenivasa 1973, Sreenivasa

and Duthie 1973) suggests that core reproducibility in the central basin of Sunfish Lake is generally good. With the exception of my basal sediments (as discussed earlier), my pollen diagram is almost identical to Sreenivasa's (1973). The main discrepancies are probably related to differences in sedimentation rate during the pine pollen zone, since my zone is 1.15 m long whereas Sreenivasa's zone is only 0.60 m long. Consequently, although our cores are approximately the same length, my stratigraphy did not extend into the herb pollen assemblage recorded by Sreenivasa, but ended in the spruce period.

The major discrepancies between my diatom data and the percentage diagram published by Sreenivasa and Duthie (1973) are also found in the early postglacial sediments; likewise, these variations probably reflect differences in sedimentation. For example, Sreenivasa and Duthie recorded a basal assemblage of benthic and alkaliphilous diatoms, similar to my Pim Island assemblages (Chapter 4). My core did not penetrate to this depth, and Cyclotella spp. dominate the early sediments.

The diatom stratigraphies are very similar above the pine pollen zone, and discrepancies that exist are related to taxonomic opinions, rather than differences in the sedimentary sequence of microfossils. For example, in my opinion, Cyclotella bodanica and C. comta, as well as C. glomerata and C. stelligera, cannot be distinguished in this core,

and are therefore recorded as C. compta and C. stelligera, respectively, on my diagram. Another taxonomic discrepancy appeared to be between C. kuetzingiana in the Sreenivasa and Duthie profile and C. michiganiana in my analyses. These two taxa look very similar using the light microscope and their differentiation was difficult until Lowe (1975), two years after the Sreenivasa and Duthie paper, described C. michiganiana in detail with the electron microscope. My SEM work suggests that the C. kuetzingiana in the Sreenivasa and Duthie paper was probably C. michiganiana.

I did not present the relative frequencies of diatom species during periods of poor preservation in zones 3a, 3b, and the early part of 3c. Sreenivasa and Duthie (1973), however, show a complete profile. Although Sreenivasa and Duthie did not calculate microfossil concentrations, they did record the total number of diatom valves they counted at each stratigraphic level. For most of the points where I noted poor preservation, Sreenivasa and Duthie had based their percentage data on counts of less than 100 valves and, for many points, less than 10 valves. In my opinion, an interpretation of species composition based on so few microfossils is not justified. However, had I presented my diatom species composition during these periods, the profile would look very similar to the one described by Sreenivasa and Duthie.

Sreenivasa and Duthie (1973) claimed that cultural disturbances in the watershed "brought no significant change in the diatoms". However, my finer sampling interval (i.e. 5 cm) as well as the calculation of microfossil concentrations, reveal that both quantitative and qualitative changes occurred in the diatom community at this time. The larger sampling intervals used by Sreenivasa and Duthie obscured the details of these events. Moreover, the chrysophycean microfossils clearly delineate cultural activity, with striking changes in scale and cyst concentrations, shifts in synuracean species composition, and the abrupt decline in the relative abundance of chrysophytes to diatoms.

APPENDIX III

Acknowledgement

The data presented in this appendix are from a contemporary study by Hamish McIntosh. His thesis has not yet been presented for examination or publication. I am grateful to him for permission to refer to this powerful evidence of change in the microflora of Sunfish Lake, observed in the same sediment core and in the same time-frame as my study.

CAROTENOIDS FROM SUNFISH LAKE SEDIMENTS

Okenone is a carotenoid specific to photosynthetic bacteria of the purple sulfur taxon Chromatiaceae. Isorenieratene and β -isorenieratene are specific to brown-coloured species of photosynthetic green sulfur bacteria of the family Chlorobiaceae. Myxoxanthophyll is the characteristic carotenoid of blue-green algae (Cyanophyta), and is unique to that taxon. Within it, some species of the Oscillatoriaceae contain the distinctive carotenoid oscillaxanthin. In this study these five fossil carotenoids have been used to map the stratigraphic occurrence of the organisms that produce them, throughout the history of the lake. Although other carotenoids are known to have degrees of taxonomic specificity, they were not isolated in this study, but together are reported as "other carotenoids" indicating general levels of productivity by organisms mainly other than those specified.

The Chlorobiaceae and Chromatiaceae are obligately anaerobic and phototrophic, and are sulfide dependent. They are thus restricted to anoxic regions of the hypolimnion where reducing conditions preserve the sulfides generated by heterotrophic breakdown of organic matter. Within this vertical zone, the organisms are spatially distributed along overlapping gradients of light (diminishing from above) and sulfide (diminishing from below). Populations of the two groups thus tend to stratify in two layers, an upper one dominated by purple sulfur bacteria and characterized by higher light intensity and low sulfide concentrations, beneath which is the layer of green sulfurs that tolerate lower light intensities and richer concentrations of sulfide.

With few exceptions, the mode of photosynthesis in blue-green algae is oxygenic. They are known to form deep-water layers in some lakes, but, in general, their populations flourish in nutrient-rich epilimnetic environments where water temperatures are high and light is abundant. Oxygen production from their photosynthesis is unfavourable to photosynthetic purple and green bacteria, consequently the blue-greens and other algae occupy positions in the water column above the layers of photosynthetic bacteria. It is reasonable to assume that, in times of high algal productivity, these populations exert such a strong shading effect that little light is available to the bacteria beneath them. What light does penetrate to the deeper strata must be shared by the surviving bacteria,

and of these the purples by virtue of their position will be less adversely affected. It is conceivable that the greens might be eliminated when virtually all light is absorbed by organisms positioned higher in the water column. In times of lowered algal productivity, greater light penetration would permit bacteria of both groups to flourish, provided that sufficient organic matter is sedimented from above to maintain anoxia and a suitable sulfide gradient, or alternatively that soluble sulfides from another source enter the deep waters of the lake basin.

Fig. 1 presents the results of the carotenoid analysis. It offers the first evidence ever produced in relation to oscillations in populations of two naturally-occurring photosynthetic bacterial groups, throughout the history of a lake. It also provides a history of eutrophication in the lake, as evidenced by the occurrence of blue-green algae, and much less conclusively, points to periods of varying productivity by other unidentified algal taxa. By deductive reasoning, a hypothetical light-nutrient climate can be constructed which permits intelligent speculation about lacustrine microfloral assemblages of the past. The emerging picture is not uniformly satisfactory at all points in this time nor is it explicit in fine detail, but certain episodes can be recognized in a fashion analogous to the pollen zones familiar to palynologists. These pigment zones are tentatively defined as follows:

Pigment zone VII: 340 - 280 cm

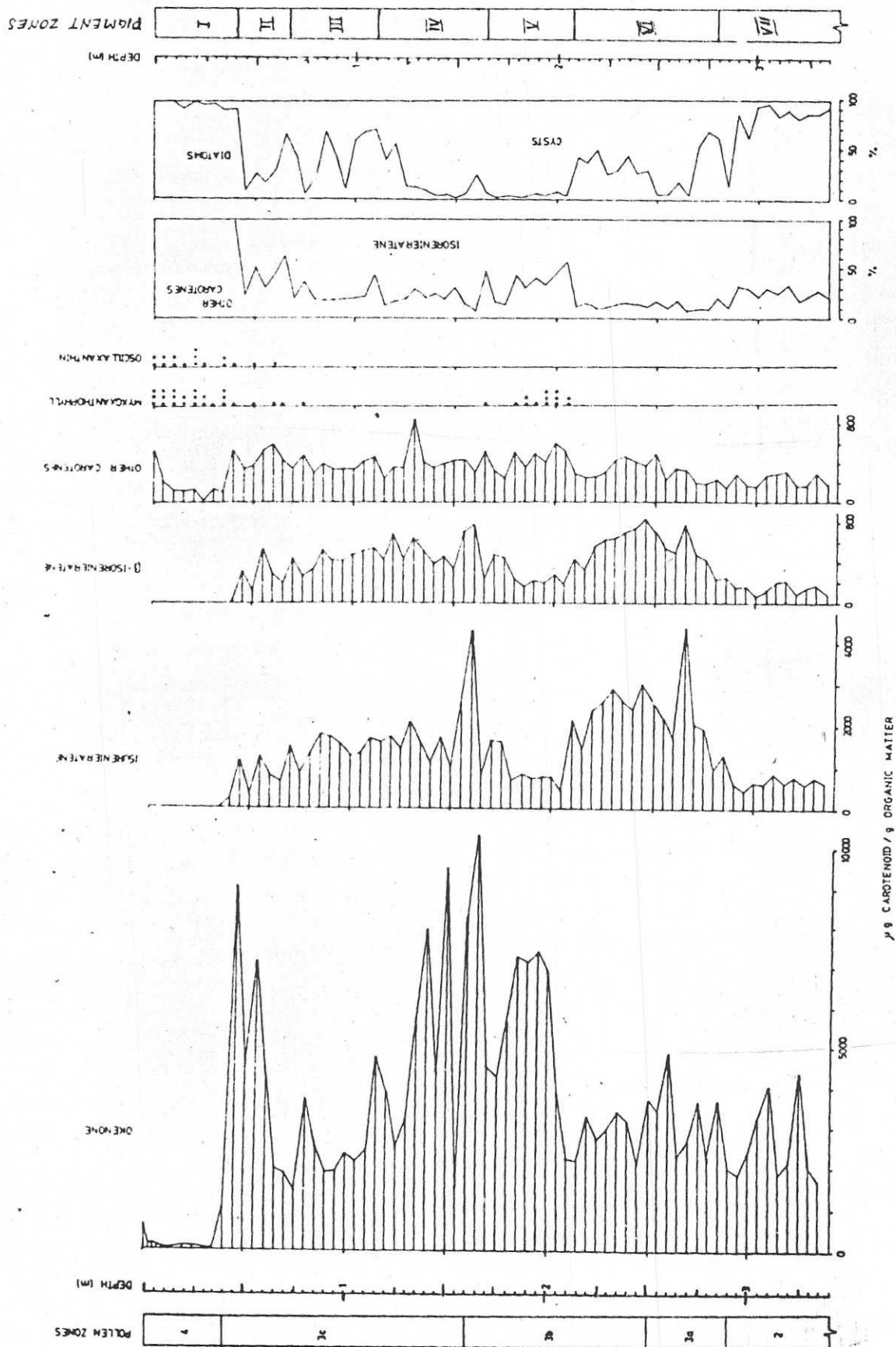
Modest productivity. Light penetration adequate to supply the requirements of photosynthetic bacteria; possibly high enough to be inhibitory to greens; possibly seasonal in nature, relating to pulses in algal productivity. Sufficient sulfide present to maintain purple sulfurs, but not high enough to sustain high populations of greens. Meromictic stability low, lake possibly holomictic, retaining minimal populations of the bacteria near a reduced sediment-water interface. Preservation of the fossil carotenoids probably reduced through diagenetic oxidation.

Pigment zone VI: 280 - 210 cm

Markedly higher productivity in this zone, reaching a maximum during the mid portion of this phase of the lake's history. A very adequate light-nutrient climate for the photosynthetic bacteria. Much more favourable than zone VII for the green sulfurs, possibly through greater input of sulfides and maintenance of anoxia. May reflect increasing meromictic stability.

Pigment zone V: 210 - 165 cm

Period of marked nutrient enrichment. Populations of blue-green algae develop strongly. Strong evidence of light shading by algae which still permits the purple photosynthetic bacteria to flourish, but the combined shading by these and the algae reduces populations of the greens. If meromictic stability increases in this zone, nutrient recycling losses are offset by nutrient-rich run-off from the watershed. This maintains high levels of algal populations.



SUNFISH LAKE CAROTENOIDS

Fig. 1: Selected fossil carotenoids from Sunfish Lake's postglacial sediments.

Pigment zone IV: 165 - 110 cm

Period of outstanding bacterial productivity, possibly indicating clearing of the epilimnetic waters and increased light penetration. This interpretation is not supported by contribution of "other carotenoids". Very probably high meromictic stability, potentially of biogenic origin, and a major input of nutrients into the monimolimnion through mineralization of organic sediments on the lake floor. Marked oscillations in productivity of the two bacterial groups, possibly, though unlikely to have been caused by light inhibition of the purple bacteria at the point of their crash. It might be argued that extreme gradients in sulfide concentration were inhibitory to the purples, but this too is unlikely since their motility would allow them to migrate to a region of more favourable concentration. This is a very difficult zone to interpret on the basis of fossil carotenoids alone. The pigments may be especially well preserved during this time-frame, and unusual seasonal pulses of productivity may obscure interpretation of the record.

Pigment zone III: 110 - 65 cm

A period of diminished productivity of the purple sulfurs; continuing high productivity of the greens and algae other than blue-greens. The zone itself is clear-cut, but ecological interpretation is very difficult. Data from other fossils and probably other lakes will be required to shed light on this episode.

Pigment zone II: 65 - 40 cm

This is a period of increasing eutrophication. Myxoxanthophyll begins to appear, "other carotenoids" remain high, and the purple sulfur bacteria increase dramatically. There is a roughly corresponding decline in the green sulfurs, indicating evidence of light shading.

Pigment zone I: 40 cm - surface

This is the period of cultural influence on eutrophication; man has appeared on the scene. The blue-green algae become immensely productive, nutrient "pollution" is indicated by the appearance of Oscillatoria species producing oscillaxanthin. The photosynthetic bacteria virtually disappear, clearly not from lack of sulfide which is abundant in hypolimnetic waters at the present time. Light penetration falls short of the depths at which bacterial blooms can develop. Meromictic stability is low, to the point that if holomixis does not actually take place there is certainly considerable entrainment of monimolimnetic waters at the time of autumnal circulation.

APPENDIX IV

ESTIMATES OF CALCIUM CARBONATE

In this study, the sediment organic matter was estimated by 'weight loss at 550°C' and the amount of CO₂ evolved from carbonate minerals by 'additional weight loss at 1000°C' (Dean 1974). The calcium carbonate content of the sediment can be estimated by dividing the weight loss between 550 - 1000°C by 0.44 (the fraction of CO₂ in CaCO₃, Dean 1974). In addition, expressing the CaCO₃ content as a percentage of the ash (i.e. the residue left after ashing at 550°C) estimates the relative amount of CaCO₃ in the inorganic fraction of the sediment (Fig. 1,2). Changes in these profiles for both Little Round Lake (Fig. 1) and Sunfish Lake (Fig. 2) are very similar to my original figures based on the weight loss between 550 - 1000°C expressed as a percentage of the sediment dry weight (Text Fig. 11, 28).

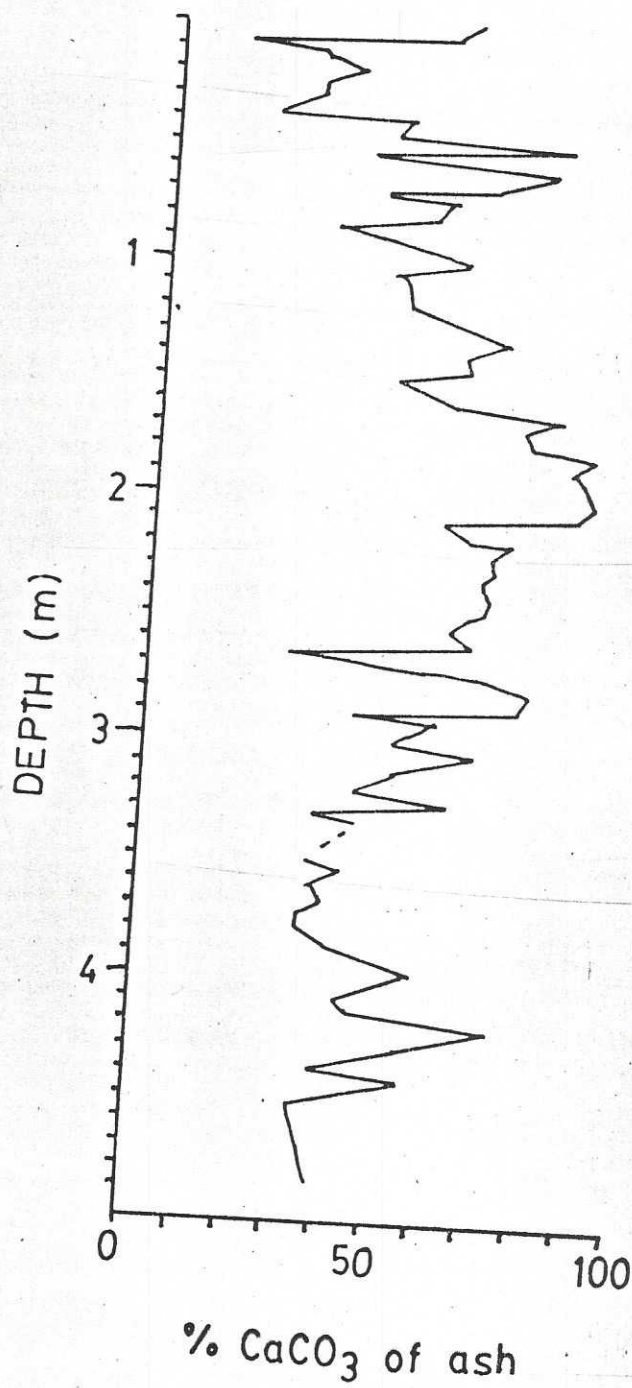


Fig. 2. Estimates of CaCO_3 content in surficial lake's postglacial sediments