ANALYTICAL SURVEY OF A SEDIMENTARY CORE FROM MUSKRAT LAKE, RENFREW COUNTY

S. R. Brown and John P. Smol

Queen's University

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ABSTRACT

A sediment core was taken from Muskrat Lake on October 27, 1982, with a view to determining the suitability of these lake sediments for reconstruction of the trophic history of this lake.

The evidence indicates that the stratigraphy of the core is not disturbed. Analysis of seven stratigraphic sections of the core shows good preservation of the algal microfossils, which occur in abundance and represent a wide diversity of species including those regarded as reliable trophic indicators. Judging by the pollen profile, sedimentation rates in the lake are relatively high. Clastic materials form the major component of the sediment matrix, a feature which tends to complicate interpretation of fossil pigmentary data, but does not preclude their use.

It is clear from these preliminary analyses that the lake has undergone episodes of trophic change in the past 100 years, and that the sediment materials contain an abundance of fossil evidence from which a satisfactory trophic history can be reconstructed.

Results of the analyses are reported together with as much historical interpretation as we feel is justified in view of the limited number of stratigraphic intervals sampled.

Recommendations, suggesting the most appropriate steps for development of a detailed trophic history of the lake, are provided.

INTRODUCTION

The designated goal of this study was to assess the usefulness of a sedimentary core from Muskrat Lake as a means of determining the trophic history of the lake over the past hundred or more years. In achieving the primary objective, considerable progress has been made towards realization of the ultimate purpose; thus the present data provide insights on the historical eutrophication of the lake as well as clear indications of what is required to develop a fine-grained reconstraction of its trophic history.

It seems appropriate, at the beginning of this report, to define the criteria used in the assessment of the capacity of a sedimentary core to reveal the trophic history of a lake, and to indicate why importance is attributed to specific characteristics. So much variability in lake sediments exists, that for any given lake, it is essential to conduct a preliminary survey of a core to ensure that a reliable record of trophic history is preserved, and over what period of time. In this laboratory, the paleolimnological record is based on three types of fossils: (a) pollen, as reflecting the terrestrial vegetational history of the watershed, (b) algal microfossils, mainly of diatoms and chrysophytes within the water column, and (c) fossil photosynthetic pigments of the algal assemblage, but focusing on those of algal species that do not leave morphological (microfossil) remains, yet are important members of the total algal assemblage (e.g. blue-green algae). Current knowledge of algal assemblages permits some assignment of trophic status to a lake, based upon composition of the dominant algal species. The fossil record extends that capability into the past, but reconstruction of trophic history is a matter of interpretation. Any single line of fossil evidence is weaker than multiple lines that fit together without major conflict. The combined evidence not only provides a more complete and valid record, but heightens the sensitivity with which trophic change can be detected.

The outstanding features of a sedimentary core from which trophic history is to be established, are essentially as follows:

1. Well-preserved stratigraphy The fossil rain arriving at the sediment surface is probably best preserved in meromictic lakes. Here. density gradients in the water column prevent resuspension and mixing of sediments at times of lake overturn, and anoxic conditions reduce the possibility of bioturbation. Sedimentray varves frequently confirm the integrity of the fossil record. In holomictic lakes, somewhat less ideal conditions exist, but it is apparent that deep basins can afford suitable cores for trophic analysis. Sediment focusing may cause minor problems, although these can be dealt with by the application of dating techniques. Assuming that physical conditions within a lake have not changed greatly through time, the minimal expectation is that trends in fossil evidence will be observed, if not sharply defined, in a given time frame. Aerobic conditions do increase the possibility of bioturbation, however.

2. Preservation of fossils Pollen grains are highly refractory to breakdown. Microfossils are more variable with respect to preservation, thus breakage and re-solution of siliceous materials are the two factors most frequently affecting them adversely. The causal agents have not been clearly identified, therefore in the absence of predictive characteristics, good preservation cannot be assumed, and visual inspection of core materials is necessary. This observation applies to the fossil pigments, as well. One of the major obstacles to their more universal use relates to problems of diagenesis. Light and oxygen promote their breakdown, as does gut-passage in grazing zooplankton. The use of pigments is most satisfactory and clear-cut in eutrophic environments, where light is attenuated, anaerobic conditions exist in much of the water column, and postdepositional change in the sediments is retarded by anoxic conditions. Diagenetic pathways are reasonably well established for the chlorophylls, thus extending their use, but the situation with reference to carotenoids remains more problematic, particularly in oligotrophic environments.

3. Compositional adequacy of fossil assemblages The analytical approach

used in this study relies not upon the presence of certain indicator species, in isolation, but upon their dominance within the total phytoplanktonic assemblage. For example, under increasingly eutrophic conditions the dominance of reliable eutrophic indicator species would be mirrored by decreasing presence of oligotrophic forms, trophic generalists would remain visible throughout the assemblage, and the relative frequencies of minor indicator species would be seen to change. Only under hypereutrophic or ultraoligotrophic conditions would competitive exclusion lead to the complete elimination of the antithetical species. Thus, the more diverse the fossil assemblage, the more valid the inferences that can be drawn. Both the number of taxa and the number of individuals are important considerations. (In this respect, the fossil pigments add a dimension beyond that offered by microfossil algae alone.) The planktonic forms within assemblages must include those recognized as valid indicator species.

4. Composition of the sedimentary matrix Some attention must be given to the enclosing sedimentary matrix in which fossils are found. The chief variables are organic content, carbonates, and clastic materials. Rapid sedimentation of inorganics dilutes the fossil content and may complicate procedures required in preparation of core sections for analysis. Although adequate techniques are available to deal with unfavourable situations, extreme dilution usually signals poor preservation of fossils and may reduce numbers to the point of precluding analysis. With moderate dilution, as with focusing, resolution may be facilitated because of the increased depth of sediment deposited per unit time. Unsatisfactory sedimentation occurs in high energy environments and is reflected by large particle size, as the warning signal.

The sedimentary core described in this report was taken from Muskrat Lake, near Cobden, on October 27, 1982, by Don Galloway of M.O.E., Kingston, assisted by John Smol and S. R. Brown, of Queen's University.

METHODS AND MATERIALS

The sediment core is 33 cm long. It was taken by the "frigid finger" method, beneath about 50 m of water. It was brought to the laboratory in the undisturbed frozen condition, where it was sawn into four longitudinal sections. Three of these sections were preserved at -20°C, and the fourth was cut in horizontal sections, each 1 cm in length. Those sections analysed were at depths 1, 5, 10, 15, 20, 25, 30, and 33 cm.

Preliminary analysis of the base of the core (33 cm) showed similar assemblage of microfossils as appeared at 30 cm, so was not subjected to complete analysis.

Preparation and analytical procedures were as described by Smol and Dickman (1981) for pollen and diatoms; Smol (1980) for chrysophytes; and Brown (1966), Daley, Brown and Gray (1973), Daley, Gray and Brown (1973) for chlorophyll pigments. The analytical procedures for carotenoids are ones that have been routinely used in our laboratory during the past two years, and are soon to be published.

RESULTS AND DISCUSSION

Sediments Fig 5 presents profiles of density, water, and organic content of the sediment at the stratigraphic levels sampled. The inorganic fraction contains a high proportion of clastic material. Carbonates are low, which seems slightly surprising in view of the fairly calcareous watershed in which the lake is situated. It is probable that considerable re-solution of carbonate takes place in deep, hypolimnetic waters. Organic content varies from 10 - 20%. This is not uncommon in large, relatively deep lakes, where considerable decomposition takes place in the water column. In smaller lakes, but similar in depth to Muskrat, the organic component often reaches as much as 40 - 50% or even more. The sedimentary composition of Muskrat lake indicates moderately rapid breakdown of organics coupled with relatively high rates of sedimentation of inorganics. (See below). Sedimentary microfossils are abundant, and concentrations of photosynthetic pigments (per g organic matter) are moderately high.

Pollen Pollen profiles (Fig 1) indicate that this core does not span a time-frame extending to pre-cultural conditions. The "ragweed rise" (Ambrosia) is not represented in this stratigraphy. For this part of Canada, the initial rise in non-arboreal pollen (e.g. Ambrosia, ragweed; and Graminae, grasses) is usually dated ca. 1850 AD. Hence, our 33 cm core represents a time period of less than 130 yrs. This is somewhat atypical, since most cores from this geographical region show the ragweed rise within the top 20 cm of sediment. The Muskrat Lake data suggest a relatively high sedimentation rate - a factor that may be considered desirable, since it increases the time-resolution possible within the core. Dating procedures (e.g. Lead-210) would be required in order to establish a more exact time-frame.

The pollen assemblage reflects the mixed deciduous/coniferous forests characteristic of the study area. High percentages of pine (Pinus) are found throughout the core. This is fairly typical, although not particularly useful, since the winged pollen of this genus may be air bourne for fairly long distances. Colonies of the Green alga Pediastrum and dinoflagellate cysts were noted in pollen preparations throughout several sections of the core. Their numbers increased somewhat at the 20 cm level, suggesting increased eutrophication at that time.

Diatoms and Chrysophytes In the past, trophic analyses based on algal micro fossils, have been largely restricted to diatoms. There is increasing evidence, now that chrysophyte remains can be identified reliably, that these organisms are valid indicators of ecological conditions, as well. Their response to changing environmental conditions is parallel in some respects to that of diatoms, but not wholly so, therefore the combined use of diatoms and chrysophytes heightens the sensitivity with which past limnological changes can be detected.

A total of 87 diatom taxa (from 22 genera) were identified. These diatoms are largely alkaliphilous and eutrophic species. A summary percentage diagram of the more abundant taxa is presented in Fig 2. The assemblage contains several reliable eutrophic indicators such as Stephanodiscus hantzschii, Melosira granulata var. angustissima, and M. ambigua. In contrast, Cyclotella stelligera is an oligo-mesotrophic taxon, and Cocconeis placentula, Fragilaria pinnata, Achnanthes spp., Navicula spp., and Nitzschia spp. are characteristic of littoral zone habitats.

Chrysophycean microfossils (synuracean scales and chrysophycean statospores) were very rare throughout the stratigraphy. These data reflect the eutrophic nature of Muskrat Lake over its recent history. Shifts in synuracean species composition (Fig 3) must be interpreted with caution, since the percentages are based on low scale counts. Of the taxa encountered, Mallomonas crassisquama is a generalist, whereas the other four Synuraceae are sometimes found in enriched waters. It is noteworthy that the large fluctuations in species composition observed in adjacent sediment sections indicate that bioturbation and other processes that might disturb the sediment profile are not a serious problem in Muskrat Lake stratigraphy.

Algal microfossils are also presented on an absolute concentration basis (Fig 4). These data must also be interpreted with caution at this time since they have not yet been corrected for changes in sedimentation rates.

Muskrat Lake appears to have shifted towards very eutrophic levels near the 20 cm stratum. Evidence includes a sharp decline in the relative frequency of *Cyclotella stelligera* accompanied by increases in eutrophic species such as *Stephanodiscus hantzschii*, *Melosira granulata* var. *angustissima*, and *M. ambigua*. The near disappearance of Synuarceae at this point is also indicative of eutrophication, as is the increase in dinoflagellate cysts. Shallow water diatoms begin to increase between the 10 and 5 cm levels, suggesting that littoral diatoms were relatively more successful at this time, and that eutrophication had probably stimulated macrophyte growth. A decline in the relative frequency of several eutrophic taxa, and a corresponding rise in *Cyclotella stelligera* at the very surface of the core indicates a shift to more oligotrophic conditions in the most recent history of Muskrat Lake.

Photosynthetic pigments The pigment composition of this core supports the data obtained from analysis of the microfossils, and adds significantly to it in providing information on algal species that do not leave morphological fossils. The pigments are present in relatively high concentrations, indicating primary productivity of meso- to eutrophic status. Throughout the core, concentrations of chlorophyll *b* (or its derivatives) are consistently high relative to those of chlorophyll *a*. Thus, green algae (Chlorophyta) have remained an important component of the algal assemblage. This evidence, too, suggests a mesotrophic environment. The 1 cm and 20 cm sections contain low concentrations of myxoxanthophyll, a carotenoid specific to blue-green algae (Cyanophyta). This observation is significant, but must be treated with some reservation. Although we have found this pigment at high concentrations in 8,500+ yr.-old sediments, these showed strong evidence of reducing conditions, thus diagenetic processes had been retarded (conversely, preservation was good). In Muskrat Lake there are two lines of evidence suggesting that oxidative processes, either in the water column or the sediments (or both) have been proceeding rather rapidly. The sedimentary chlorophylls include allomerized forms which are early products of oxidation, probably at oxygen tensions sufficient to degrade myxoxanthophyll to colourless compounds. The second observation is in line with this supposition. M.O.E. reports record metalimnetic oxygen minima, and restoration of higher oxygen values in deeper hypolimnetic waters. This evidence suggests high levels of bacterial activity in the metalimnion, resulting in the breakdown of organic materials at that level. It may be, therefore, that considerable destruction of myxoxanthophyll accompanies the bacterial processes. A more detailed examination of other carotenoids found (in high concentrations) in the sediment will provide clarification of this issue, and allow for more reliable estimates of the contribution of blue-green algae to the total phytoplanktonic populations. Better preservation of a labile compound is to be expected in the most recent sediments, thus its occurrence at 20 cm suggests that blue-greens may have been more abundant at that earlier time than they are to-day. If this were the case, the 20 cm level reflects more eutrophic conditions than have existed in Muskrat Lake at any more recent point in time.

RECOMMENDATIONS

Our preliminary study of the Muskrat Lake sediments indicate that there have been considerable oscillations in its trophic history.

Changes in the pollen profile are not sufficiently distinctive to permit us to pinpoint the time of these occurrences accurately.

1. It is strongly recommended that Pb^{210} dating of the sediments be undertaken, in order to provide a more definite time-frame relative to the sediment stratigraphy.
2. Additional analyses at closer stratigraphic intervals will be necessary to refine the emerging trophic history. It is clear that the fossil assemblages present have the potential to provide detailed information on trophic change, if this is desired.
3. It is desirable, although not essential, to obtain another sedimentary core that penetrates to greater depth thus that spans a longer time-frame. (to pre-cultural conditions).
4. Consideration should be given to the matter of how many stratigraphic samples should be analysed, and at what depths (after dating has established rates of sedimentation). The issue is whether a fine-grained record of trophic status over a short term is of greater practical value than a more extended historical survey that may reveal cyclic events in the lake's history. It is possible, of course, to analyse at close intervals where there is evidence of rapid change, and at wider ones when less change is evident. (This runs the hazard of completely missing a sudden trophic event and rapid subsequent recovery).

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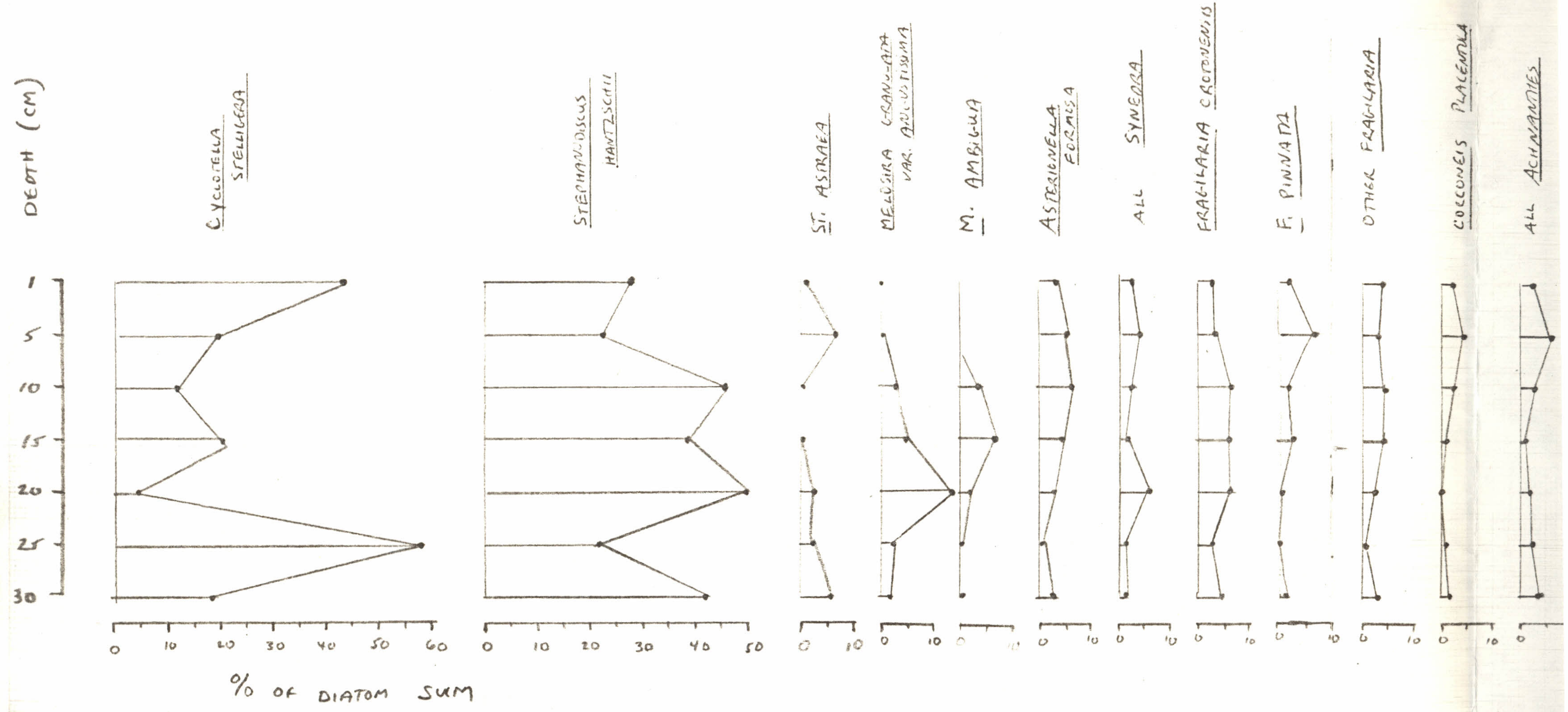
POLLEN PROFILE MUSKRAT LAKE

Fig. 1.



MUSKRAT LAKE DIATOMS

Fig. 2

MUSKRAT LAKE DIATOMS

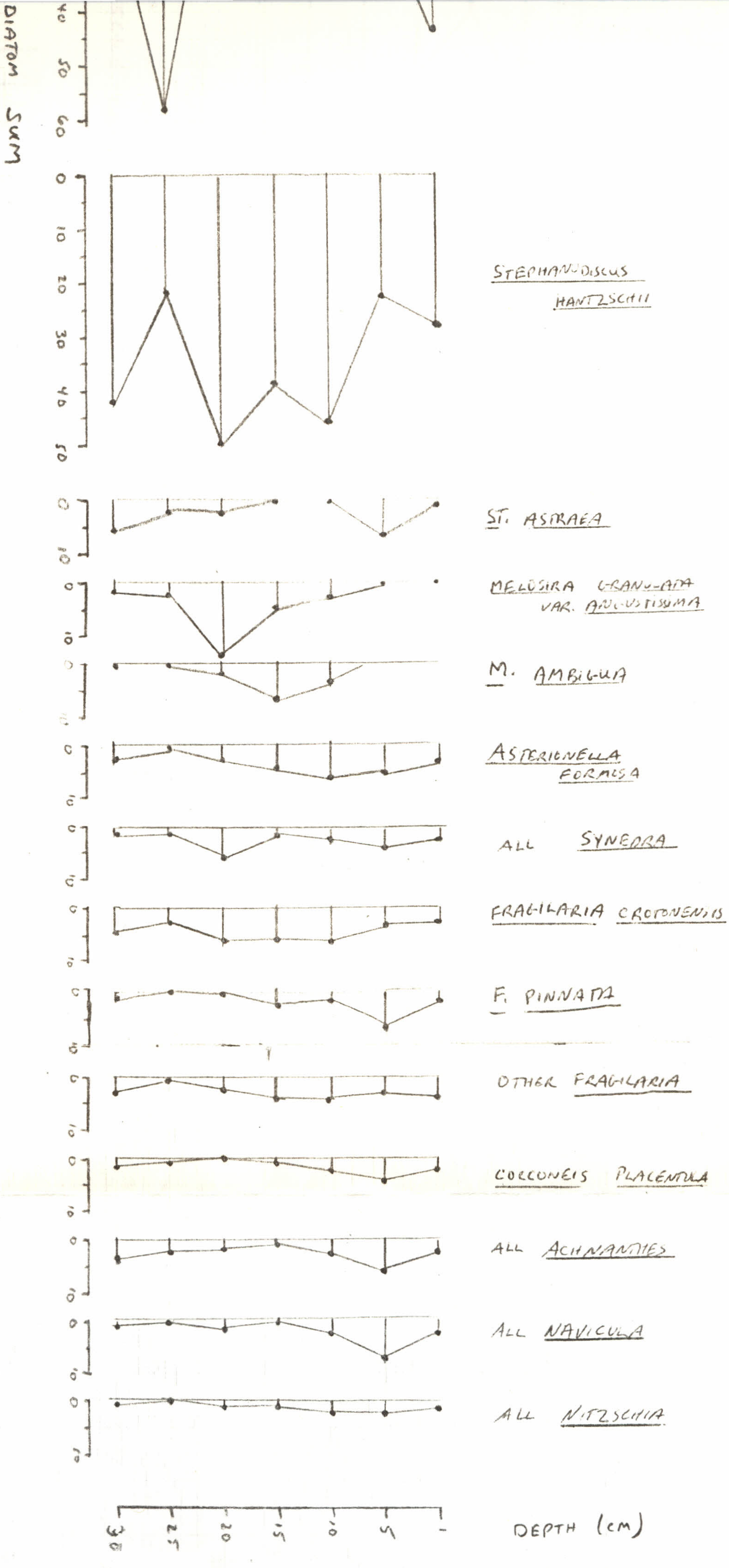
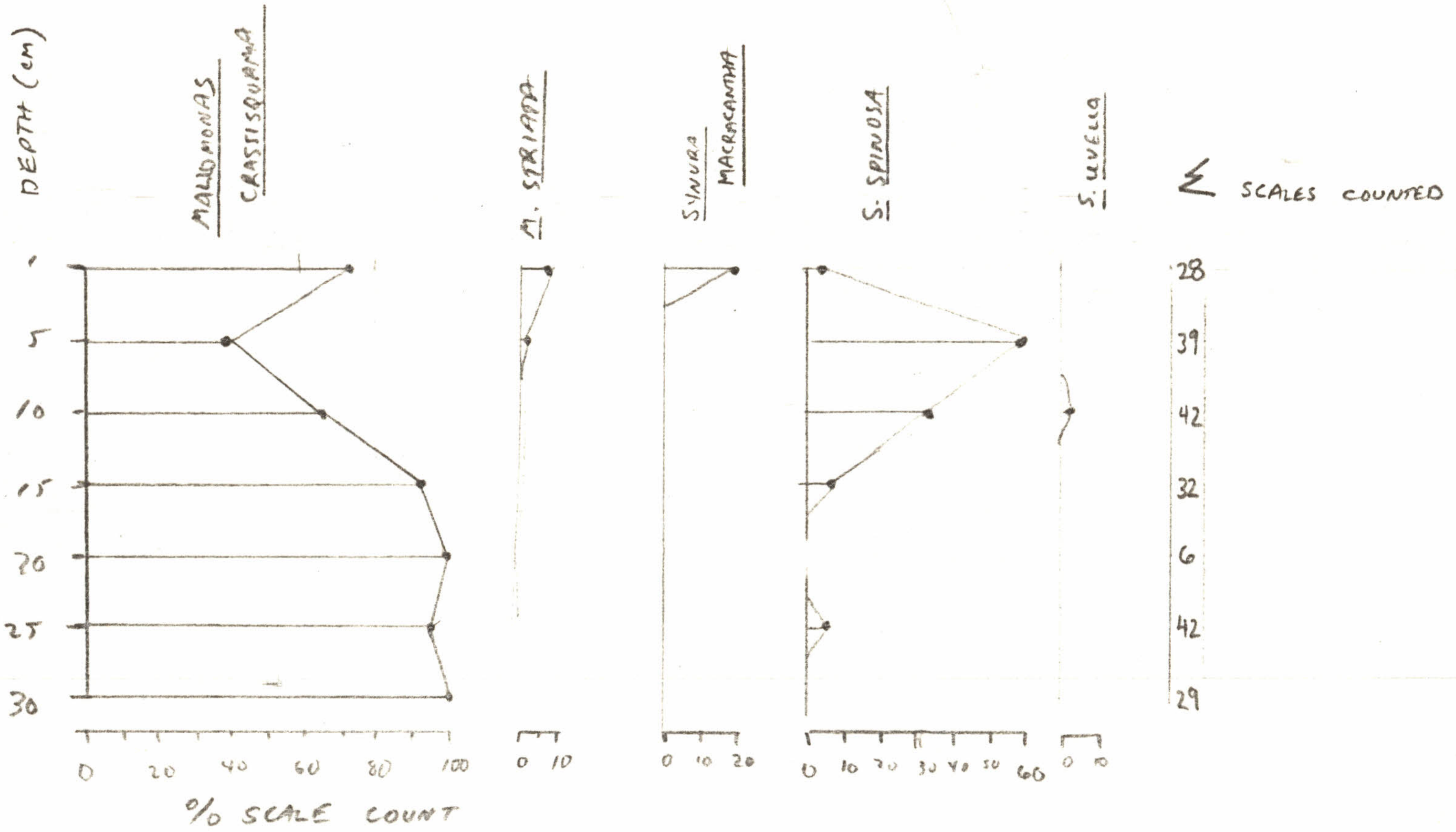


Fig. 2



MUSKRAT LAKE
SYNURACEAE

Fig. 3.

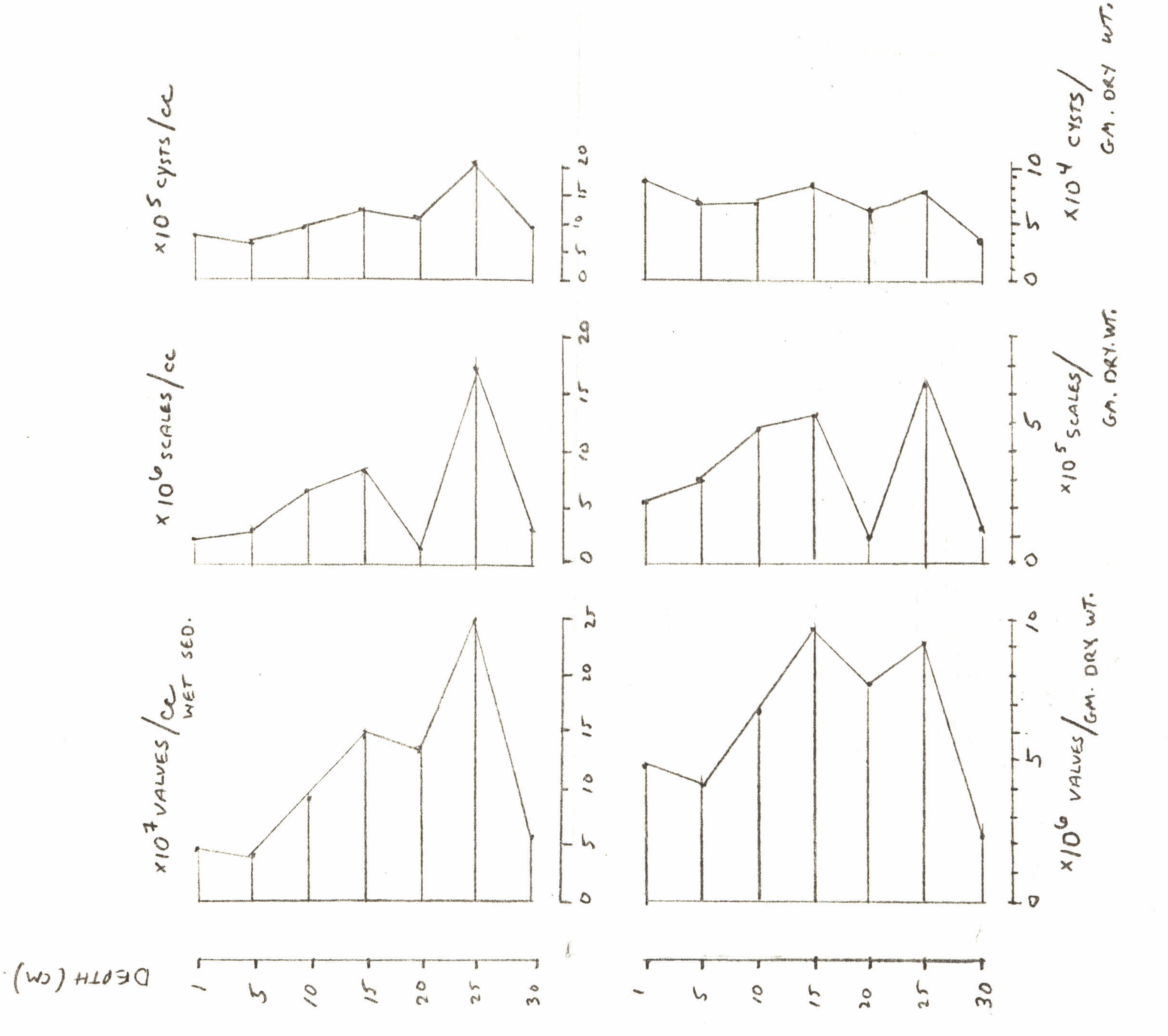


Fig 4. CONCENTRATION PROFILES OF DIATOM VALVES, SYNURACEAN SCALES, AND CHRYSOPHYCEAN CYSTS.

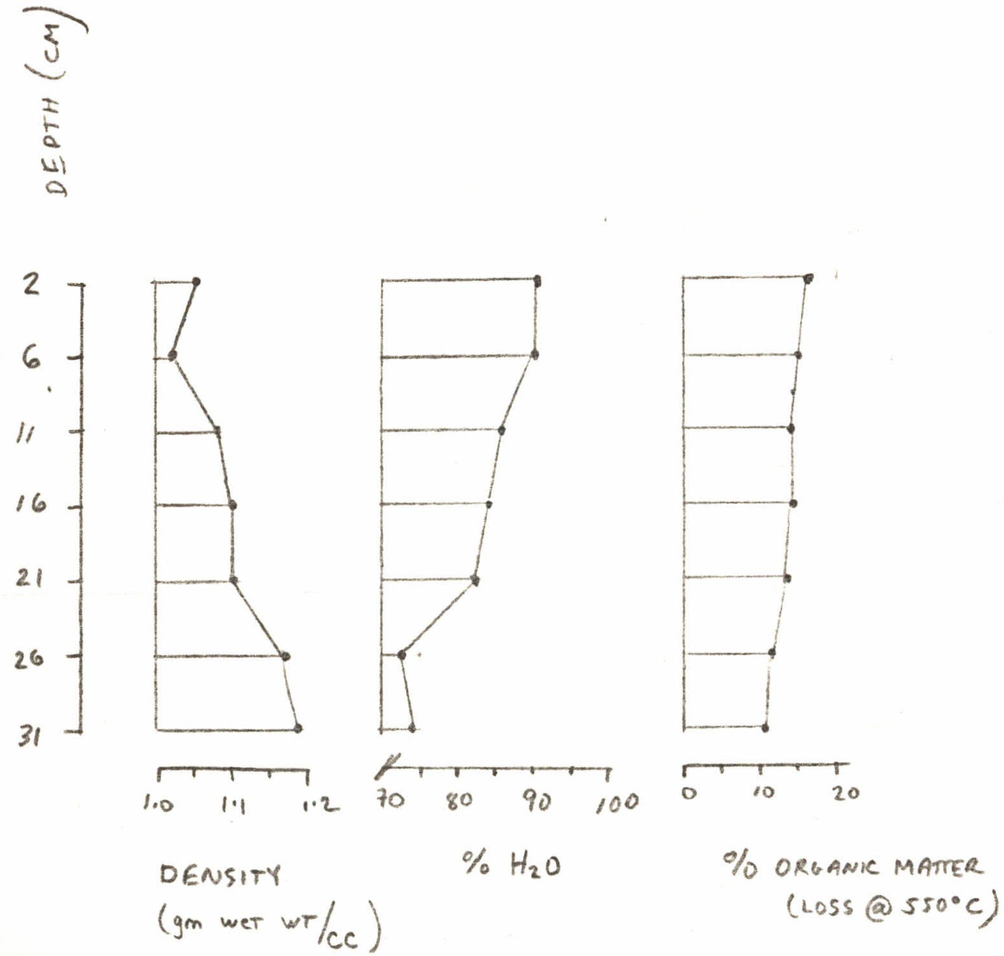


Fig 5. PHYSICAL AND CHEMICAL CHARACTERISTICS OF SEDIMENTS