PALEOLIMNOLOGY OF ANCIENT LAKE MÄTÄJÄRVI

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Introduction

Lake Mätäjärvi is situated in south-western Finland, in an area characterized by washed rocky hills. The lowest lying parts of the area consist of clay material, which forms even beds. There have been unfavourable conditions for the formation of lakes, and lakes are thus few. The present rate of land uplifting is approximately 5 mm/y and it can be estimated that Lake Mätäjärvi was formed by isolation of a small bay near the mouth of the river Aurajoki (Fig. 1) in the 6th century A.D. (Glückert, 1976). At the time of isolation the size of the lake was only about 200 m by 300 m, and it was further reduced rapidly through peat forming processes.

The lake now lies under the city of Turku. From the time of isolation human activity has been the most significant factor in its development. The purpose of this study is to examine the impact of this activity by using different paleolimnological analyses.

The limnic sediments of this ancient lake are now under 2—4 m thick cultural layers. The presence of lake sediments was verified by drillings. The samples analyzed in this study were taken from the wall of an archeological excavation pit.

Litho- and chemostratigraphy

From figure 2 it can be seen that at the sampling point, under the cultural layers and filling earth, there is a one meter thick layer of gyttja. The upper surface of this layer is at 8.5 m a.s.l.

Lowest in the sediment column there is a gradual transition from Litorina-clay to fine-grained detritus gyttja. This gyttja was only about 10 cm thick, and in some excavation pits it was totally absent. At 90 cm in the sediment column the gyttja becomes more coarse and contains increasing amounts of coarse allochthonous material such as plant remains, pieces of brick, sand etc. (at this point an artificial outlet or »krooppi» was dug to replace the old, natural outlet). At 80—70 cm there is an abundance of wood-trash and further up at 65—50 cm clay material. From 50 cm upward the amount of coarse mineral material increases substantially and the amount of human waste such as bones, leather and ceramics is considerable. The upper surface of this sediment is marked by a layer of wood-trash and filling earth, which represent timewise the 18th century (Pihlman et al. this volume). These layers were omitted from the paleolimnological analyses.

Due to contraction caused by filling earth, the density and dry weight of the gyttja were above normal values. Loss ignition was 10—15 % in fine-grained detritus gyttja

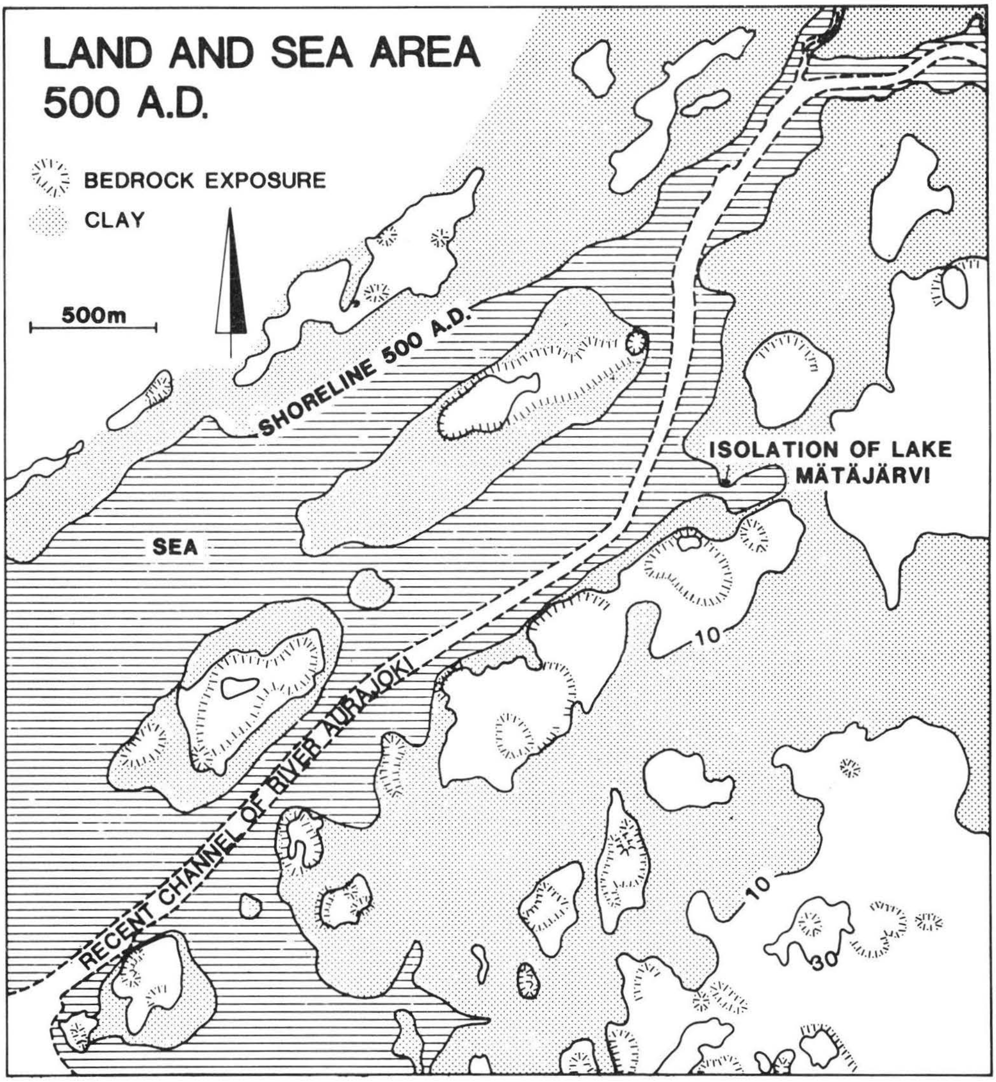

Fig. 1. Situation and isolation of the lake.

and 20—30 % in coarsegrained detritus gyttja. The elements phosphorus and calcium were present in exceptionally high concentrations, especially above 50 cm (Fig. 7). This high concentrations of phosphorus could also be detected with the naked eye. Crystallized vivianite was present, particularly above 50 cm. At 65—50 cm the coarse mineral fraction was found to contain iron carbonate, siderite, ($FeCO_3$) formed by precipitation. Above 50 cm the »natural components» of lake sediments, iron, magnesium and potassium, are present in decreasing amounts. Above 70 cm the concentration of copper is notably high (100—150 p.p.m.)

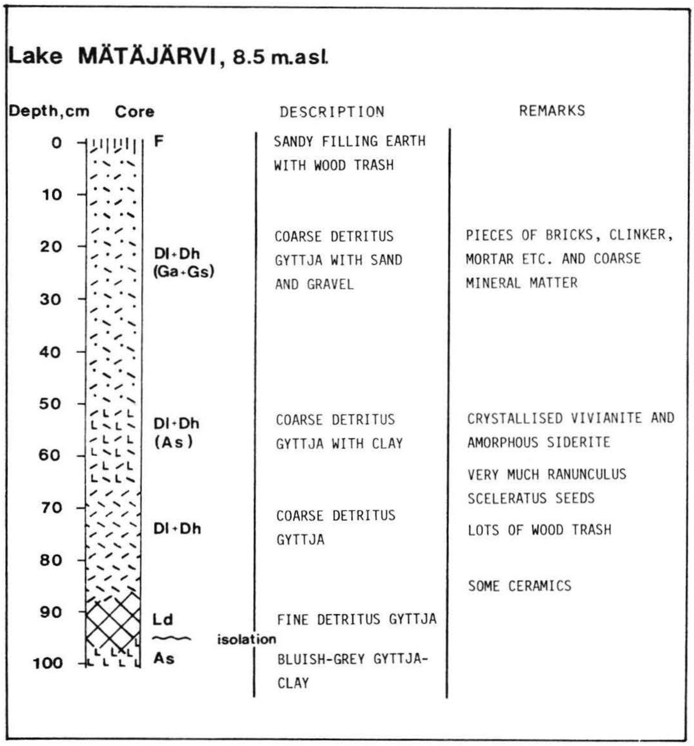

Fig. 2. Description of sediment core.

Dating

For dating the different levels of the sediment, a total of 13 radiocarbon samples (Table 1) were taken from two correlated cores (Sp 1 and Sp 2). The radiocarbon dates (1390 ± 100 and 1470 ± 90) obtained for the lowest limnic sediments represent, when calibrated (Klein et al. 1982) the 6th and 7th century A.D. These dates correspond well with the time of isolation estimated by shoreline displacement (Fig. 4). The radiocarbon dates leave a hiatus in the sediment column: gyttja sediments from 600 to 1260 A.D. are missing. The analyzed samples therefore do not give any information about the land use in Prehistoric Turku area. The hiatus is at the level of 90 cm corresponding to the boundary of fine and coarse detritus gyttja.

From the hiatus upward until a depth of 50 cm the radiocarbon dates form a chronological series with an average rate of sedimentation of 1.48 mm/y. The radicarbon dating is supported by archeological findings and coin found between the archeological layers 130 and 132; the coin is from 1540 A.D. at the latest (Pihlman et al. this volume). The radiocarbon dates for the top 50 cm of the sediment column are too old, because the sampling point was very close to where the shoreline had been at that time, and older material from the shore has been mixed in the sediment.

Table 1. Radiocarbon dates

Sample	Depth/cm	Age (B.P.)
Core Sp 2		
Hel-1918	16—21	510 ± 80
Hel-1919	26—30	380 ± 80
Hel-1719	39—41	770 ± 90
Hel-1720	49—51	770 ± 80
Hel-1730	69—71	640 ± 90
Hel-1731	89—91	1470 ± 90
Hel-1732	94—96	2280 ± 120
Core Sp 1		
Hel-1839	52.5—55	350 ± 80
Hel-1840	65—67	450 ± 90
Hel-1841	76—79	600 ± 90
Hel-1842	84—86	450 ± 90
Hel-1843	88—90	700 ± 90
Hel-1844	92—95	1390 ± 110
Wooden outlet-channel, the »krooppi»		
Hel-1733		830 ± 80
Hel-1734		820 ± 90

The sedimentation rate in the basin has varied, being 5—10 times more above the level of 90 cm than below this level, and growing slower toward the top of the column.

Evaluation of the material

Although the sediment has been reliably dated by using radiocarbon samples and archeological findings, and the average rate of sedimentation has been reliably estimated, the sediment cores studied do not allow for the examination of annual deposition of chemical and biological variables. The lake has always been shallow and the unhomogenous gyttja-layers have been subject to strong mixing. The afore-mentioned hiatus has also been gradaded by later mixing. The limitations that mixing poses for the analysis of results are well exemplified by the study of annual soot particle accumulation (Fig. 4).

At the lowest levels of the sediment (100—90 cm), which correspond to the years 500—600 A.D. the soot particle deposition is 0.1—0.3 $\mu m^2/cm^2/y$. This value is in line with the natural backround values. For the later 7th century the values are in line with those connected with slash-and-burn cultivation (cf. Tolonen, 1983). Pollen analysis at this level of the sediment shows that at this period forests have disappeared from the proximity of Lake Mätäjärvi (Vuorela, this volume).

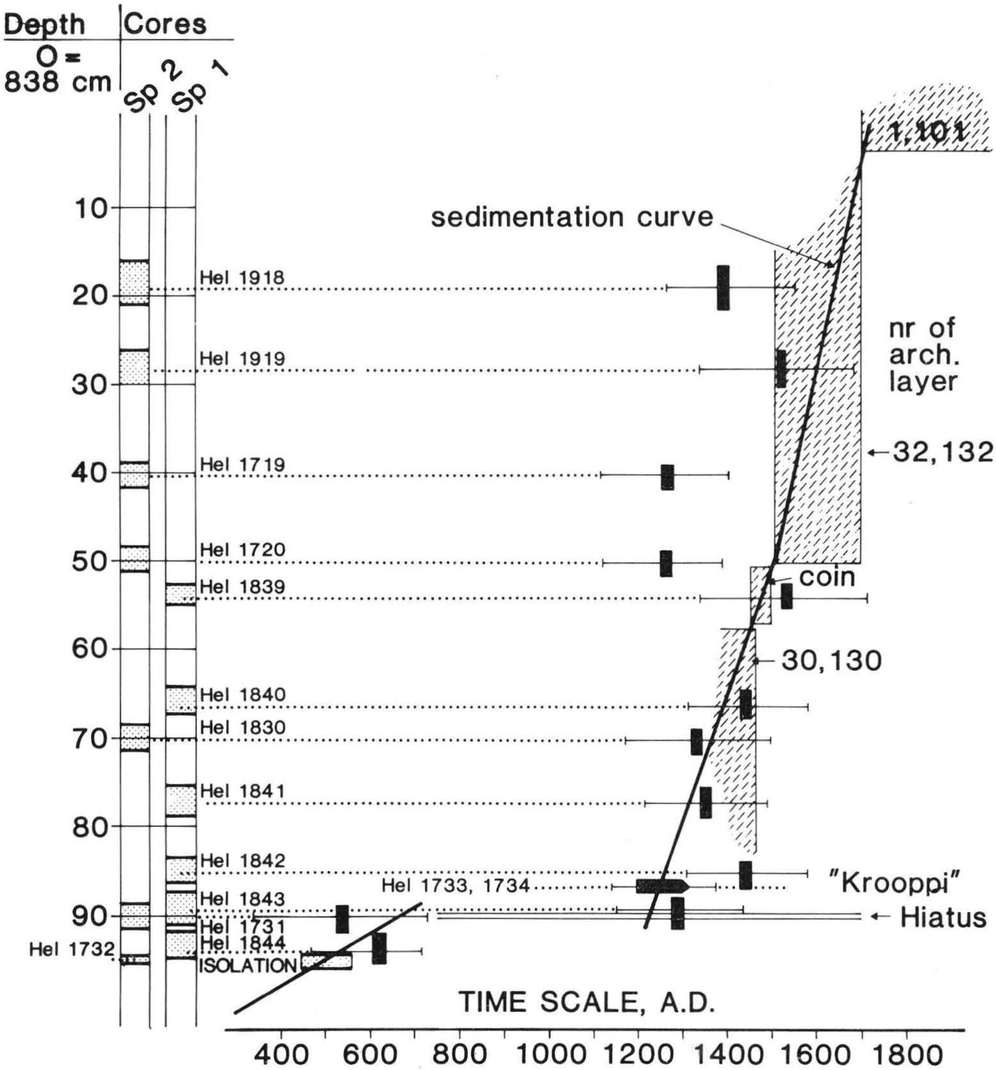

Fig. 3. Dating of sediment cores.

From the 13th century onward the soot particle deposition can be even a hundred times greater than previously. When the peaks in soot particle deposition are compared with information about the fires in Turku (Dahlström, 1930), the single peaks are seen only seldom to coincide with the dates of the fires. This shows that sedimentation has

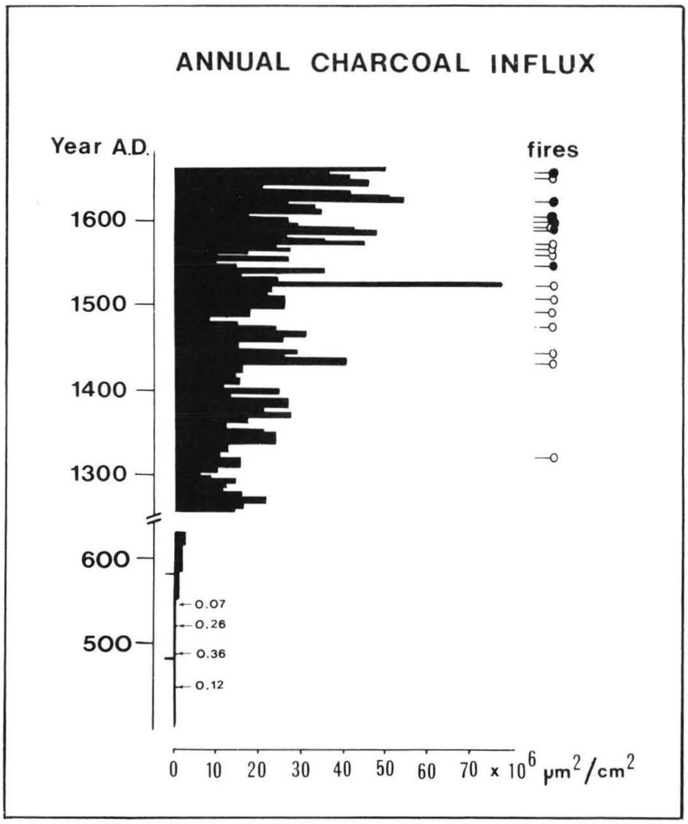

Fig. 4. Charcoal analysis.

been continuously disturbed by coarse allochthonous material which is why a more detailed analysis of dates is not justified.

However, when the soot particle deposition is studied more extensively it can be seen that the amount of soot is generally greater when fires have been more common. This is true particularly of the great fires of early 17th century, when housing in the proximity of Lake Mätäjärvi was burned several times.

The sediment has been subject to strong mixing, but the development interpretations are justified since the sediments are in chronological order, lower sediments being older than the upper sediments.

Results

On the basis of lithostratigraphy the sediment column can be divided into three members, of which the central Mätäjärvi-member can again be separated into three beds

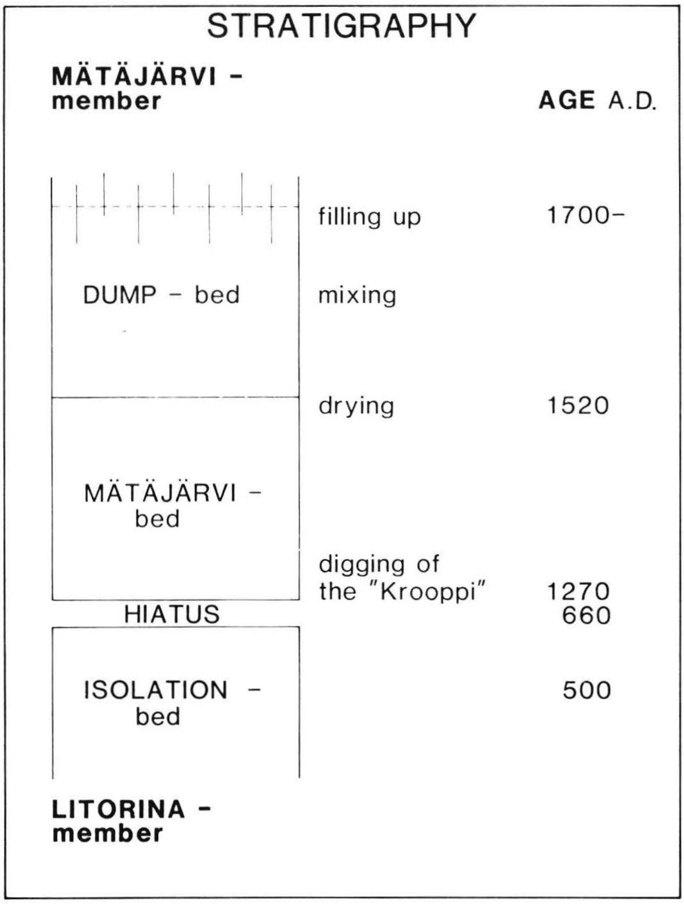

Fig. 5. Lithostratigraphy.

(Fig. 5). The chronostratigraphical and biostratigraphical results also divide the gyttja into three distinct units. The boundaries of the chronozones coincide with those of lithostratigraphy.

The classification illustrated in figure 5 will be used when, on the basis of results obtained, the development of Lake Mätäjärvi from a natural bay of the Baltic Sea to a filling-earth foundation for building is described. In the first phase (500—660 A.D.), the lake was isolated from the Baltic Sea. The sediment deposited during this phase consisted first of clay gyttja and later of fine-grained detritus gyttja. Mineral material consisted mainly of clay material (Fig. 6). The Fe:Mn-ratio is typical of an acid, reduced lake bottom (Digerfelt, 1977). Calcium content is low. The number of sediment pigments could not be measured because of the abundance of clay material.

The diatom flora of this first phase contains a small number of meso- and polyhalophilous species that belong to the Baltic diatom community (Fig. 7) (cf. Ignatius and

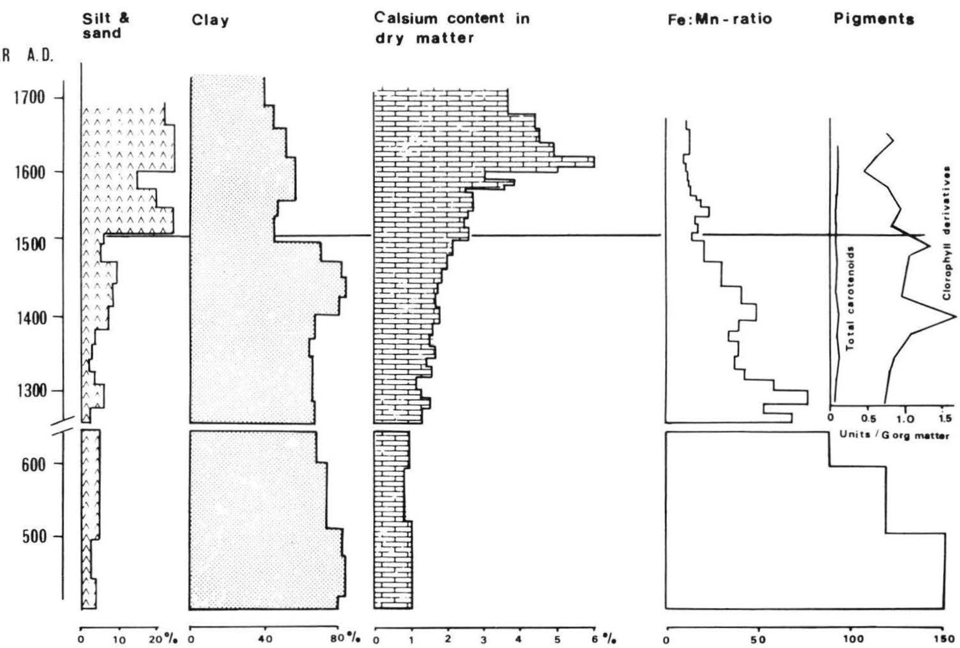

Fig. 6. Physical and chemical properties of the sediment.

Tynni, 1978). The majority of the species consists, however, of acidophilous, indifferent and alkaliphilous fresh water species. The species illustrate the diatom succession connected with the isolation of a typical small lake. Diptera-analysis showed an abundance of remains of midge head capsules. The dominant groups were Chironomus plumosus and Procladius, which indicate an eutropic basin. Remains of Cladocera fauna were not found in this or in any other phase of Lake Mätäjärvi.

The following phase, dated 1260—1500 A.D., is the time of Lake Mätäjärvi's actual existence as a lake in the studied area. During this phase the amounts of clay material and mineral material remained constant. The Fe:Mn-ratio decreases throughout the phase indicating the increasing oxydation of the sediment as the basin becomes shallower. The pigment ratio in the sediment is exceptional, for chlorophyll derivatives are present in a greater number than carotenoids. This further proves that the basin has been shallow and the pigments have been efficiently decomposed. An abundance of siderite ($FeCO_3$) was found at 65—50 cm in the minerological analysis. From the presence of siderite as well as that of crystallized vivianite it can be concluded that the iron present in the water of the lake has formed carbonate and phosphate compounds. Organic decomposition has been strong, yet iron sulfides have not been formed. The environment has at this point been characterized by a low redox-potential and alkalic state (cf. Price 1976).

At the end of this phase the lake has been an exceptionally difficult environment for most of the species, which require an acid-neutral habitat rich in oxygen. At this point the lake was covered by a strong growth of Ranunculus Sceleratus, which is generally known to flourish in such conditions (Lempiäinen, this volume). Acidophilous diatom

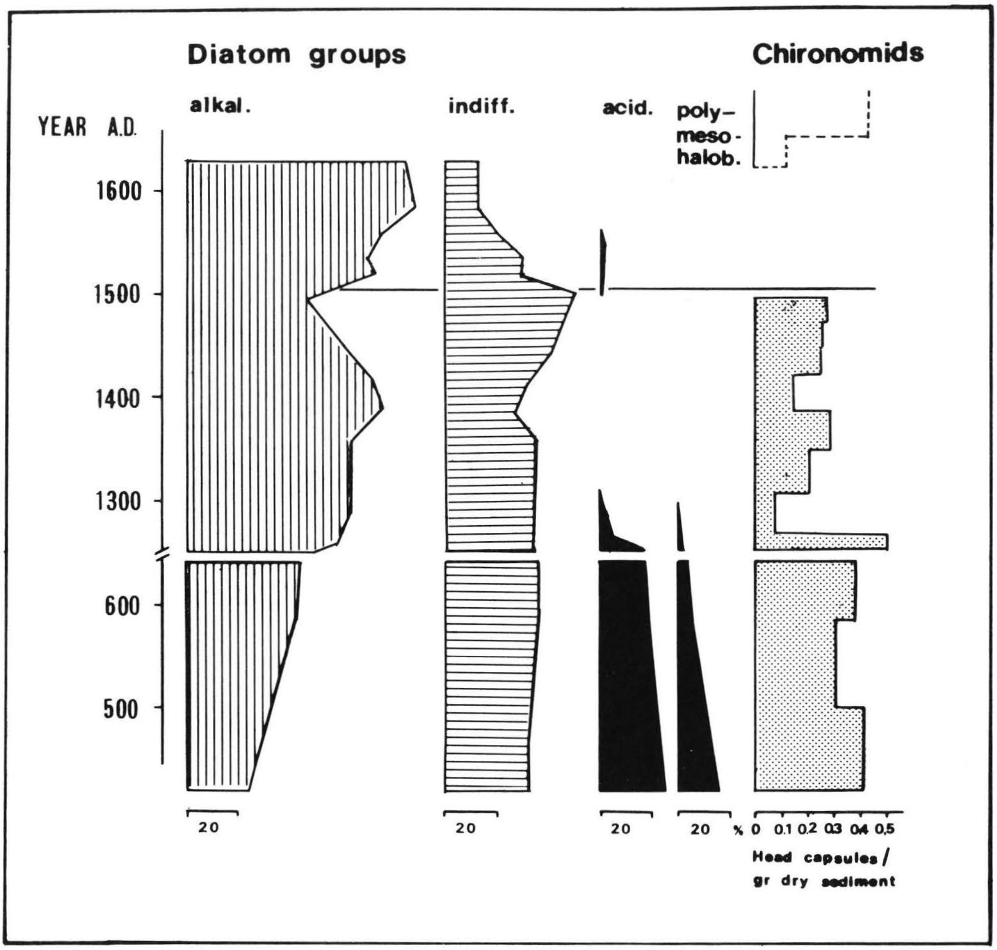

Fig. 7. Some bioindicators in Mätäjärvi sediment.

species had by this time disappeared completely and alkaliphilous species formed the majority of the species. Chironomidae also disappear from the fauna during this phase, Chironomus plumosus being the last species present and indicating polluted water (Saether, 1979).

During the most recent phase, the so-called waste land phase, from 1520 to 1700 A.D:, the mineral material consisted mainly of coarse fraction (quartz) (Fig. 6). This shows that the shore has been in the near proximity of the sampling point. A decrease in the number of chlorophyll derivatives and Fe:Mn-ratio suggest a dryer environment. Concentrations of phosphorus and potassium are abnormally high and the chemistry resembles that of a dumping area.

The alkalic state of the environment is indicated by changes in the diatom flora where alkaliphilous species become more dominant and the number of indifferent species decreases sharply. At this level there were no more midges found. On the other hand, strongly sclerotized mites, also found on dry land, were prevalent (Niemi, this volume). The presence of diatom flora and the clearly gyttja-like characteristics of the sediment show that the sampling point had, at least periodically been rather wet.

The uppermost 15 cm of the core have apparently been mixed in the final filling of the lake. At this level there are resedimented remains of fauna from the lower sediments. These have not been taken into account in the interpretations.

Conclusions

The exceptional physio-chemical and biological nature of Lake Mätäjärvi was determined using paleolimnological analyses. The forming of this whole paleolimnological picture has been supported by pollen, macrofossile, mite analyses and osteological and archeological analyses, which also appear separately in this volume. Thus many results that at first seemed uncertain have been verified by other results and no contradictory evidence was left unexamined. This was the case with the dating of the sediments: because extensive human activity had caused the sediments to be mixed, radiocarbon dates alone would have led to false conclusions.

The development of Lake Mätäjärvi is unique in Finland. A natural lake ecosystem was changed by agricultural and urban activities into a damp patch of no value, overloaded with nutrients and heavy metals. Under the pressure of the growing population of Turku this useless waste land was finally filled in for building ground. During its history of one thousand years the lake has undergone an eutrophication process that has become more common in Finland only in this century.

The development of the lake can be summarized as follows: The lake was isolated in the 6th century A.D., yet its use in prehistoric times cannot be studied since the sediments from 660 A.D. are missing. These sediments have presumably been used for soil improvement on the fields before the year 1260 A.D. which is when sedimentation began again. At that time the lake was very close to the center of the town. It was already polluted and attempts were made to dry it.

From the 16th century onwards, the area was useless land, water-logged only parts of the year and used as a dumping area by the surrounding population. From the 18th century onwards the lake area has been permanently inhabited and from this time on there are no more lake sediments found in the excavation area.

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