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THE INFLUENCE OF PRIOR LAND USE ON THE SEDIMENTS OF A SMALL LAKE *

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ABSTRACT

An abrupt change from brown to black sediment is observed in the deepest part of meromictic Hännisenlampi Lake. The 1.2 m thick topmost black layer represents the meromictic phase. By varve counts the transition from holomixis is dated back to 1504 A.D. The change is a result of burn-beating cultivation and hemp soaking, which began 80 years before the lake became meromictic. During the early stages of settlement the annual influx of mineral matter rose 20 fold and in the 17th century up to 40 fold, in comparison to the pre-settlement rate. After a decline in land use from the beginning of the 18th century an improvement in the lake condition was indicated by paleoredox measurements, but the lake still is meromictic.

1. INTRODUCTION

Since 1974 a multidisciplinary project is in progress concerning human activities and their influence on the environment in eastern Finland. One paleoecological subject is meromictic Hännisenlampi Lake, nearby a neolithic settlement and early cultivations dating from the 15th century (Figs. 1, 2). In this initial report the influence of land use on the lake is described on the basis of the physical and chemical properties of the sediment.

2. STUDY SITE, MATERIAL AND METHODS

Hännisenlampi Lake (62° 05′ N, 30° 12′ E, 80 m a.s.l.) is situated in a kettle hole in the area covered by glaciofluvial deposits. The lake is small (1.5 ha) with a maximum depth of 16 meters. The volume of the lake is 78,300 m³ and the drainage area about 3.5 ha. At present Hännisenlampi has no visible outlet and the water is received by seepage.

The conductivity measurements of the water during the autumnal circulation indicate, that the lake has a permanent chemical stratification, the lake is meromictic. The mean conductivity (H_{25}) in the surface water is $68 \pm 9 \mu S$ and at 15 m $180 \pm 31 \mu S$. The chemocline is lying at 10—11 metres. The volume of

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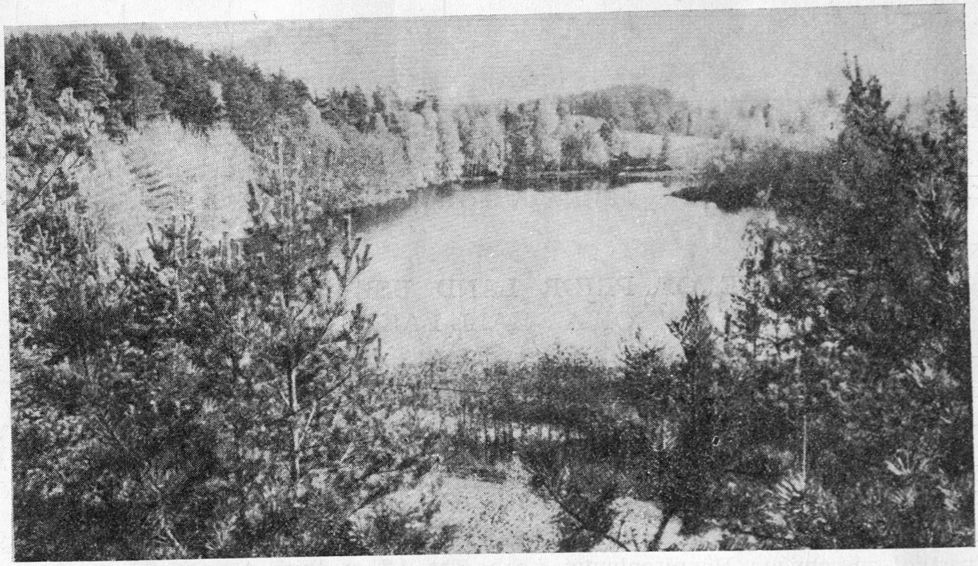

Fig. 1. Hännisenlampi Lake, view from NW (photo J. Vuorinen, September 1976)

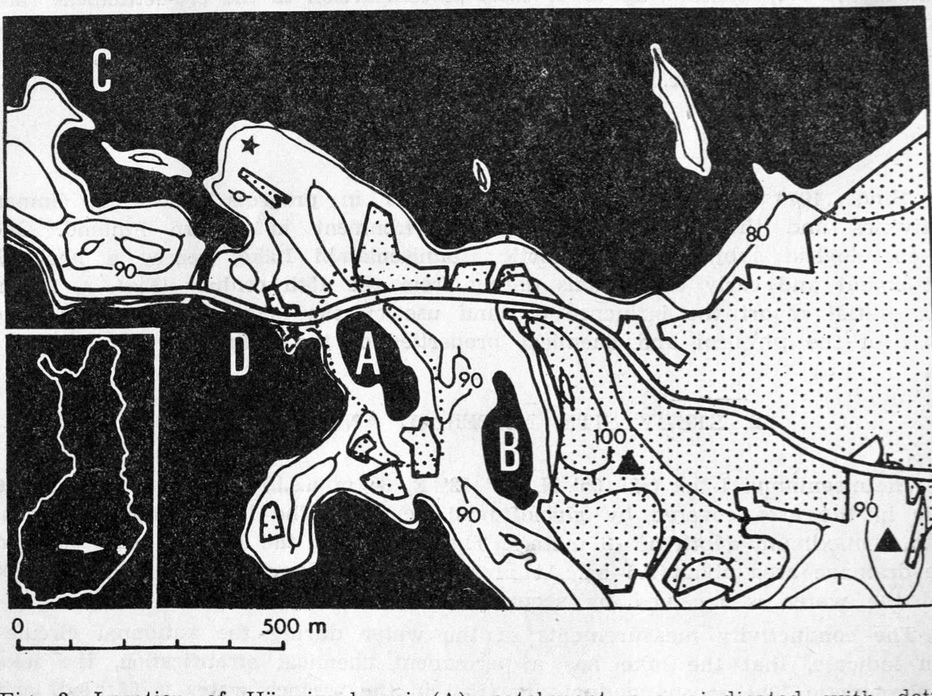

Fig. 2. Location of Hännisenlampi (A), catchment area indicated with dotted line. Surrounding lakes are Pekanlampi (B), Kiteenjärvi (C) and Hyypiönjärvi (D). Neolithic settlement shown with asterisks and settlement from 15th century with triangles, present cultivated area is dotted

the monimolimnion comparises about 6% of the total volume and monimolimnetic bottom about 15% of the bottom area of the lake. The summer thermal stratification is stable, due to the wind sheltered position, producing the thermocline between 4—5 m. The water layer containing dissolved oxygen has not been found to exceed the depth of 10 m and during the summer stratification the water layer, out of dissolved oxygen, can rise up to 6 m. The pH of the epilimnion range in summer from 7.4 to 7.9 and the transparency from 1.5 to 2.5 m.

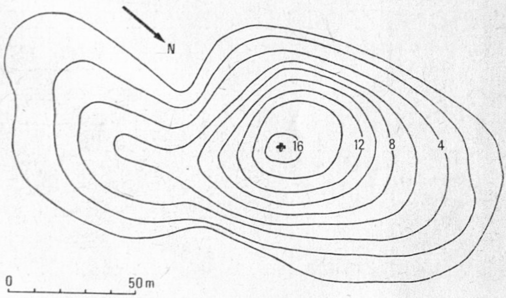

Fig. 3. Bathymetric map of Hännisenlampi Lake

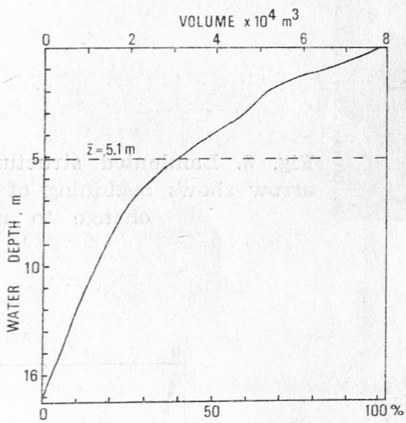

Fig. 4. Development of volume

The sediment samples were taken during winters 1975 and 1976 using three different methods. Because the uppermost sediment is very soft and contains hydrogen sulphide, two different freezing methods were used for preserving the sediment laminations undisturbed. The topmost 40 cm was obtained with a Hakala (1971) bottom sampler. Immediately after sampling some of these tubes were frozen with liquid nitrogen (Meriläinen, Huttunen 1978). The uppermost 150 cm was sampled by freezing the sediment in situ (Swain 1973, Saarnisto et al. 1976) using an aluminium tube (200 × 8 cm). The whole profile was taken with the Russian peat sampler (100 × 10 cm). The profiles were synchronized by means of sediment laminations.

After carrying the cores to the laboratory, Eh and pH of the sediment were measured at room temperature. In the tubes from the bottom-sampler

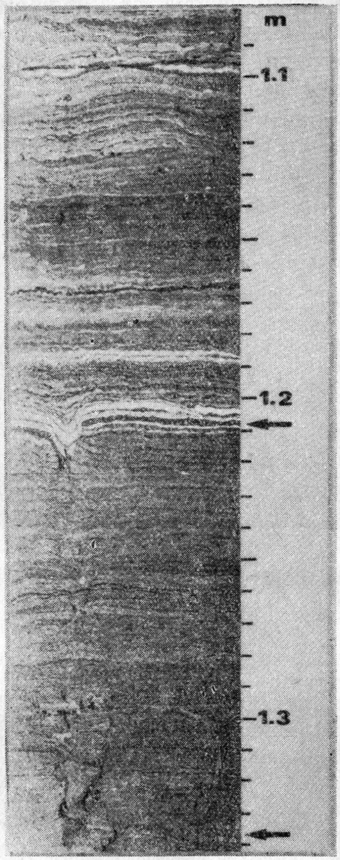

Fig. 5. Laminated structure of sediment. Lower arrow shows beginning of agriculture and upper-change to meromixis

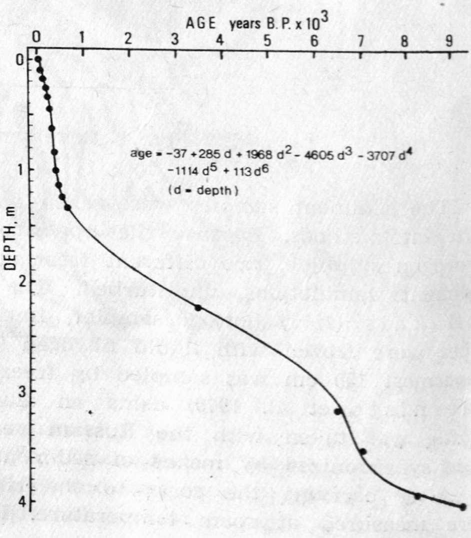

Fig. 6. Age (see text) versus depth in sediment and regression line fitted to these data

Eh and pH were measured by inserting the electrode vertically from the sediment surface. Eh was measured with a platinum-calomel electrode assembly and pH with a combined electrode (Radiometer GK 2303). A Methrom E 520 potentiometer was used. The Eh values were obtained as follows: $Eh = E_{Cal} + E' + 58 (pH-7)$, where E_{Cal} is the potential of the calomel electrode incl. junction potential and E′ is the electrode assembly potential.

To determine the density of the sediment volume samples were taken with a two ml cut syringe. Samples for the determination of water content were dried overnight at 105°C and then ignited at 550°C for ash weight. Cu and Zn analyses were made in the Geological Survey of Finland with the AAS technique from 1.5 to 5 cm sediment sections, which corresponds to the accumulation of 10 to 20 years.

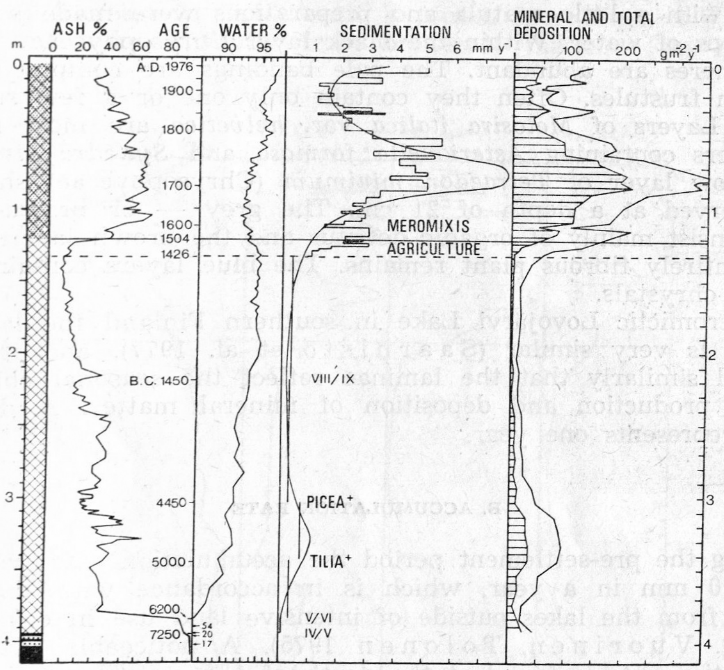

Fig. 7. Ash and water content, accumulation rates based on varve thickness (histogram) and regression analysis (curve), and annual influx of total and mineral matter

The annually laminated sediment made possible the age and accumulation rate determinations down to the depth of 134 cm, i.e. to the "agriculture limit". Varve counts were made from the frozen sediment cores in sequences representing fairly uniform accumulation, usually corresponding 5 to 20 years. Deviation between counts from three different cores was no more than 5% in the post-settlement sediment. The laminated texture exists also in the pre-settlement sediment and the counting of lamine is in progress. The varves are, however, more difficult ot distinguish, because light diatom bands are in general lacking and the laminae are very thin. For the pre-settlement sediment a preliminary accumulation rate was calculated on the basis of a pollen diagram using general radiocarbon ages to the pollen zones in Finland (Tolonen, Ruuhijärvi 1976). The ^{14}C ages were converted to real ages after Olsson (1972). A 6th degree polynomial, shown in Fig. 6, was obtained to the age-depth function. The inverted first derivative indicates the sedimentation rate (Fig. 7).

3. RESULTS

A. THE STRUCTURE OF LAMINATED SEDIMENT

The laminae consists, in general, of a thin black layer following a pale layer and a grey layer. Also blue and thick brown layers occur. To observe the quality of each layer type many laminae were subsampled with a little spatula and preparations were made by adding some drops of water. Within the black layer Chrysophyceae cysts and black spheres are abundant. The pale bandings are composed mainly of diatom frustules. Often they contain only one or a few species of diatoms. Layers of *Melosira italica* var. *helvetica* are most frequent. Also layers containing *Asterionella formosa* and *Synedra ulna* occur. One yellow layer of *Tetraedon minimum* (Chrysophyceae) shells was also observed at a depth of 21 cm. The grey — or brown-grey — layers consist mainly of organic detritus and the brown layers contain almost entirely fibrous plant remains. The blue layers contain chiefly vivianite chrystals.

In meromictic Lovojärvi Lake in southern Finland the lamination structure is very similar (Saarnisto et al. 1977), and it can be concluded similarly that the laminae reflect the seasonal changes of the lake production and deposition of mineral matter. A dark-light couplet represents one year.

B. ACCUMULATION RATE

During the pre-settlement period the accumulation rates vary from 0.3 to 1.0 mm in a year, which is in accordance with the results obtained from the lakes outside of intensive land use in eastern Finland (e.g. Vuorinen, Tolonen 1975). A noticeable rise in the accumulation rate is found at the depth of 134 cm. The frequency of NAP rises rapidly to 20% and rye pollen are found. Also the ash content of sediment increases from 10 to 70%. These are due to burn-beating cultivation in the watershed. The proportion of *Cannabis* pollen, up to 14%, indicates that the soaking of hemp was started at the same time in the lake. During the 16th and 17th centuries the accumulation rate is about 3 mm in a year, rising then to 5 mm in the 18th century. Thereafter a gradual decrease to 1.5 mm until 1937 is found. After that the accumulation rate is rising sharply to 3.5 mm and forms subrecent loose sediment at rate of 7 mm per year.

C. ASH CONTENT

In pre-settlement sediment the ash content remains nearly constant for over 3000 years; only a gradual decrease from 20 to 10 per cent can be found. Since the beginning of agriculture the ash content increases rapidly from 10 to 70 per cent. After the 1750's it decreases gradually to its present value of 35%. However, great short-term fluctuations in ash content are characteristic to the post-settlement sediment.

D. PALEOREDOX CONDITIONS: Eh AND Cu/Zn RATIO

To discover the ancient oxygen conditions of the bottom water, the sediment core was analysed for Eh, copper and zinc. According to Hallberg (1974) the Cu/Zn ratio is a valid paleredox indicator. The Eh of pre-settlement sediment is about 100 mV indicating poor oxygen conditions though the lake still was holomictic. Slightly before the start of agriculture the Eh begins to decrease and immediately after that a steep increase in Cu/Zn ratio is found. Soon after these changes the sediment turns abruptly from brown to black at the depth of

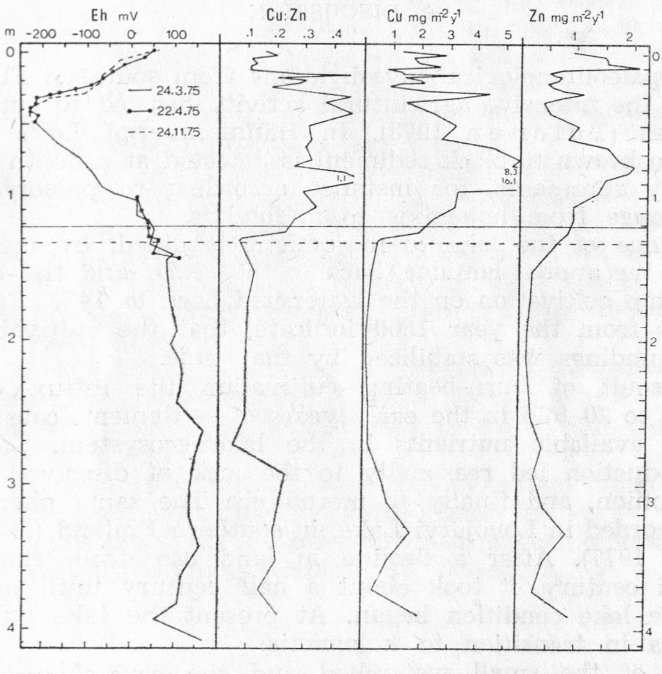

Fig. 8. Distribution of Eh and Cu/Zn ratio, annual influx of Cu and Zn

121 cm. The level is suggested to represent the change from holomixis to meromixis. Thereafter a deterioration in redox conditions up to the end of the 18th century is shown by both parameters. From the begining of the 19th century the oxygen conditions are restored. The redox changes are shown parallel in both indicators, even if the Eh measurements of the reduced sediments are associated with many problems. However, the correspondence between Eh measurements was quite good.

E. ACCUMULATION OF MINERAL AND ORGANIC MATTER

The mineral sedimentation shows low erosion in the pre-settlement period, rising to 20 fold in the early years of settlement. During the 17th century influx of inorganic sediment was up to 40 times the pre-settlement rate. After about 1740 erosion became more stable with a rate of 10 times that in the virgin stage. The accumulation of organic matter shows the same trend as the mineral sedimentation, but being before the 20th century slightly less than that of mineral matter. Some exceptions can still be seen. Immediately after the settlement limit the organic sedimentation is about two fold the inorganic sedimentation. This is apparently caused by a rapid washing of humic substances after the first deforestation. Later on, the great influx of organic matter about 1650's, 1720's and 1810's is probably connected with the intensive soaking of hemp, shown by many contemporaneous brown laminae of the sediment.

4. DISCUSSION

Several paleolimnological investigations from southern Finland have shown that the intensive agricultural activity has led to eutrophication of the lakes (Tolonen 1978). In Hännisenlampi Lake an abrupt change from brown to black sediment is detected at a depth of 121 cm, which likely represents, for instance according to paleoredox conditions, a change from holomixis to meromixis.

The change of the lake to meromictic is dated, by means of the counting of the annual laminae, back to 1504 A.D. and the begining of rye and hemp cultivation on the watershed back to 1426. Early historical records from the year 1500 indicate, that the cultivation of the lake's surroundings was stabilized by that time.

As a result of burn-beating cultivation the influx of mineral matter rose to 20 fold in the early years of settlement, causing a great increase of available nutrients in the lake ecosystem. The growing organic production led reasonally to the lack of dissolved oxygen of the hypolimnion, and finally to meromixis. The same phenomenon is recently recorded in Lovojärvi Lake, in southern Finland (Huttunen, Tolonen 1977). After a decline in land use, from the beginning of the 18th century, it took about a half century until an improvement of the lake condition began. At present the lake still is meromictic or is in transition to holomictic.

Because of the small watershed and the cone-shaped basin the accumulation is influenced greatly by the intensity of land use. The normal burn-beating process, with a short cultivation stage which followed the burning, alternated with a long period of forest growth. This must be the main reason for the accumulation changes during settlement time.

One more factor is climate. For example simultaneously with the crop failure years in 1660's, 1690's and 1860's a decrease in accumulation is observed. When comparing the declines in accumulation with the expansion of small alpine glaciers in Swedish Lapland (Karlen, Denton 1976), several similarities can be found. Especially low accumulation rates during 1680's, 1700's, 1850—1880 and 1920's are simultaneous with the expansion intervals. The increase in accumulation rates after 1937 is apparently connected with arable cultivation, but also a climatic effect of exceptionally warm summers during late 30's can be assumed.

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5. REFERENCES

Hakala, I. 1971. A new model of Kajak bottom sampler, and other improvements in the zoobenthos sampling technique. *Ann. zool. Fenn.* 8, 422—426.

Hallberg, R. O. 1974. Paleoredox conditions in the Eastern Gotland basin during the recent centuries. *Merentutk. lait. julk.*, 238, 3—16.

Huttunen, P., Tolonen, K. 1977. Human influence in the history of Lake Lovojärvi. S. Finland. *Finskt Museum.* 68—105.

Karlen, W., Denton, G. H. 1976. Holocene glacial variations in Sarek National Park, Northern Sweden. *Boreas*, 5, 25—26.

Meriläinen, J., Huttunen, P. 1978. The liquid nitrogen method in sampling of the uppermost lake sediment. *Pol. Arch. Hydrobiol.*, 25, 287—290.

Olsson, I. U. 1972. The pretreatment of samples and the interpretation of the results of C^{14} determinations. *Acta Univ. Ouluensis*, A3, 9—27.

Saarnisto, M., Huttunen, P., Tolonen, K. 1977. Annual lamination of sediments in Lake Lovojärvi, Southern Finland, during the past 600 years. *Ann. bot. Fenn.*, 14, 35—45.

Swain, A. M. 1973. A history of fire and vegetation in Northeastern Minnesota as recorded in lake sediments. *Quat. Res.*, N. York, 3, 383—396.

Tolonen, K. 1978. Effects of prehistoric man on the Finnish lakes. *Pol. Arch. Hydrobiol.*, 25, 419—421.

Tolonen, K., Ruuhijärvi, R. 1976. Standard pollen diagrams from the Salpausselkä region of Southern Finland. *Ann. bot. Fenn.*, 13, 155—196.

Vuorinen, J., Tolonen, K. 1975. Flandrian pollen deposition in Lake Pappilanlampi, Eastern Finland. *Publ. Univ. Joensuu*, B_{II} (3), 1—12.