Indications of Anthropogenic Erosion in a Palaeo-Environmental Context

Abstract

Natural erosion of mineral soil is a predominating feature in bare areas lacking vegetational cover. Such circumstances occurred on the one hand during the late-glacial periods and on the other hand in coastal environments. These natural erosional processes have been considered as background for the interpretation of the corresponding anthropogenic processes in the palaeo-environmental investigations.

In the neolithic period and in the historical time the main factor for erosion has been the deforestation for agricultural purposes. Especially lately, industrial activities, such as forestry and mining of mineral ores, have also been of great importance.

The determination of anthropogenic erosion — both mechanical and chemical — has been elucidated by selected, principally previously published sedimentological, and geochemical investigations.

INTRODUCTION

Soil erosion takes place, and has always taken place, everywhere. Under normal conditions the vegetation effectively prevents this process but as soon as the mineral soil becomes uncovered for some reason or other, erosion sets in. This is clearly seen, not only in natural environments such as the sea shores, high mountain areas or in periglacial regions, but as a result of the ever increasing pressure of human activity. Evidence of anthropogenic erosion in connection with palynological investigations of settlement history can be found by several analytical methods.

The earliest prehistoric deforestation in Finland, for instance, took place in order to improve the grazing conditions for game in the forests (Siiriäinen, 1980). Since the land was not tilled and the clearings were scarcely very large, this activity is difficult to determine by palaeoecological, palaeo-environmetal studies of lake sediments. Small changes and erosional processes certainly occurred but mostly they were sufficiently modest not to show up in the sedimentological data.

An increasing erosional processes did not take place until agricultural activities and use of fire after felling the trees began to be practiced. This « cultural revolution » later led to the more or less total deforestation of wide areas — not least in the Mediterranean soil. The simultaneously increasing erosion which accompanied this process is to be seen not only in the rate of quantitative sedimentation but also by means of several palaeoenvironmental analyses, both chemical and biostratigraphical.

During the last few centuries more modern forms of livelihood, like forestry and industry, have also left strong traces in the sediments, as we are going to see.

Erosion, transportation and deposition

Erosion hardly ever occurs alone. Usually it is part of a three-fold process consisting of 1) erosion itself, 2) transportation of the eroded material and 3) deposition or redeposition of the eroded, transported material somewhere in the surroundings (Fig. 1). The distance of the transportation depends on the topography, on the quality of the material and on the means of transportation.

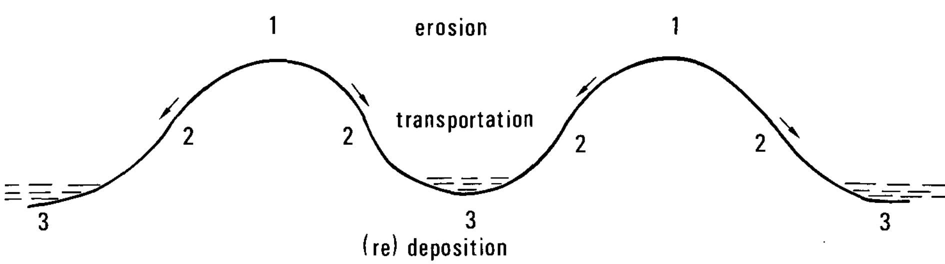

Fig. 1. Schematic diagram of erosion and closely related phenomena.

When we look for the possibilities for measuring the degree of past erosion, we hardly can do it at phase 1. In only a few cases does anything exist to show the degree of removal — and it is extremely difficult to read the past from the absence of something. The second phase — transportation — is somewhat easier to estimate or determine but, in practice, again usually somewhat unreliable for reconstructing the past. In these cases, the estimation must be based, more or less, on the present-day transportation in the same area or in corresponding circumstances.

What remains for any investigation of prehistoric erosional events is to concentrate on the deposition and, in doing this, to take into consideration the estimated past transportation in each case.

Two main forms of erosion exist : a) mechanical and b) chemical. Under natural circumstances these usually occur together and they can only be separated artificially under experimental conditions. Principally, transportation of mechanically eroded material takes place by both wind and water, while chemical erosion includes leaching of soil compounds and elements in water.

As an example of cases which lead to each of these two forms of erosion let us think of two separate forested areas of different types. In one of the areas the water table is at a reasonable depth while in the other it is considerably higher. In both cases the roots of the growing trees are in balance with the water table and the nutrient supplies of the soil. Then the trees are felled — in this connection it should be pointed out that deforestation was the basic and predominant anthropogenic activity to affect the virgin forest vegetation.

Let us first study the example with a low water table (Fig. 2a). The roots which are essential for the water economy of the xerophytic (plants growing in

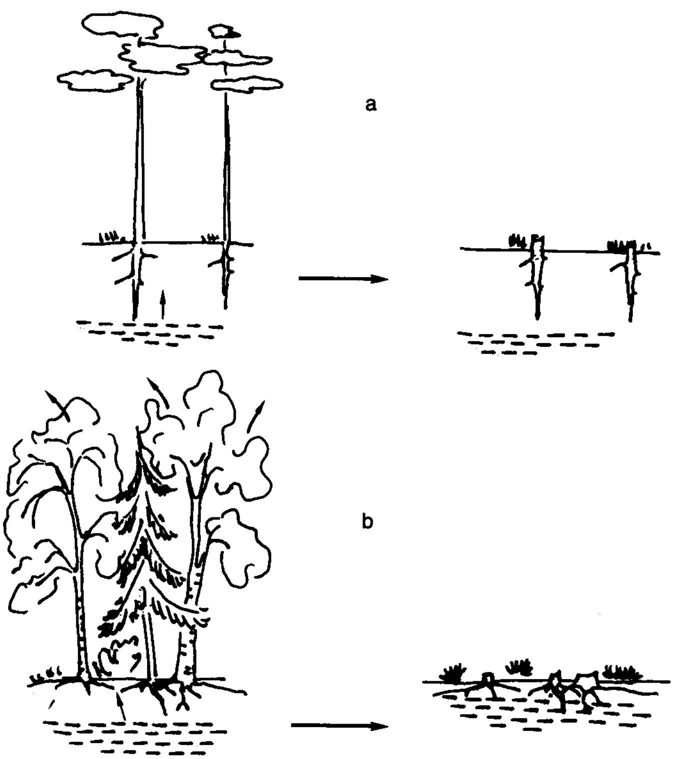

Fig. 2. The influence of deforestation on the water table in (a) dry soil with xerophytic vegetation and (b) wet soil with hygrophytic vegetation.

dry soil) trees penetrate deep into the soil in order to reach the water. If in such a case the trees are felled, this connection is cut off. The possibilities for reforestation remain very small because the soil surface from now on remains too dry and there is no vegetational cover to prevent the sun's rays from reaching the field layer. Usually the herb vegetation changes as a result of the new microclimate or, in the worst case even disappears because of the increasing dryness. At this phase erosion grips the soil — mainly mechanical erosion by wind or occasional heavy rains. It attacks the surface soil which is now less bound by the vegetation and considerable amounts of mineral material are transported. This is the type of erosion typical of the Mediterranean region, for instance.

The grain size of the wind born sand — aeolian sand — depends of course on the velocity of the wind but usually it varies between 0.6 and 0.06 microns (Núnèz and Alhonen, 1974).

In our second example (Fig. 2b) deforestation takes place on a wetter soil with a high water table. Here the result is the opposite of that on dry soil. In this case the balancing factor for the water table in predeforestation periods has been the deciduous tree canopy from which enormous amounts of water evaporate. After the trees are felled this function ceases, the ground water starts to rise and in doing so causes both chemical and mechanical erosion in form of leaching and outwash. Even here the circumstances change, they can lead to permanent deforestation *e.g.* in places where paludification takes place. In areas with humid climate, such as the Scandinavian countries, this phenomenon is possible.

Determination of anthropogenic erosion

Mechanical erosion

There are several ways in which mechanical erosion can be determined. All the methods, however, focus on phase 3 (Fig. 1) — the determination of deposited or redeposited allochthonous material. Any investigation of this process is usually made in parallel with microfossil analyses — pollen or diatom analyses. The material for these investigations consists either of limnic sediments or a certain type of peat, ombrothrophic Sphagnum-peat (Faegri and Iversen, 1975). Such peat has no contact with the mineral soil beneath it and so any mineral material present in this kind of peat must be wind born and must originate from outside the bog (Vuorela, 1983).

The determination of anthropogenic erosion around lake basins is not always easy, especially with respect to the early cultural periods. Later, on the contrary, the bare mineral soil of cultivated fields located close to the lakes or rivers is especially sensitive to erosion and usually clearly documented in the limnic sediments.

The way to determine this secondary mineral material is to ignite samples of the sediment in a temperature of 550°C, measure the ash-residue and then look at the fluctuations in the relative values between adjacent samples (Alhonen, 1967).

The investigations carried out on the sediments of Lake Vanajavesi (Fig. 3) in Central South Finland provide several examples of the determination of anthropogenic erosion. The lake is surrounded by wide clayfields which are known to have been cultivated for several centuries, and obviously for a considerably longer period (Vuorela, 1982). Clay material is especially easily washed out, transported by water and redeposited in the lake basin. The diagram in figure 4 shows a clear correlation between the loss-on-ignition curve and the Cerealia curve. The lower the former curve is, the more

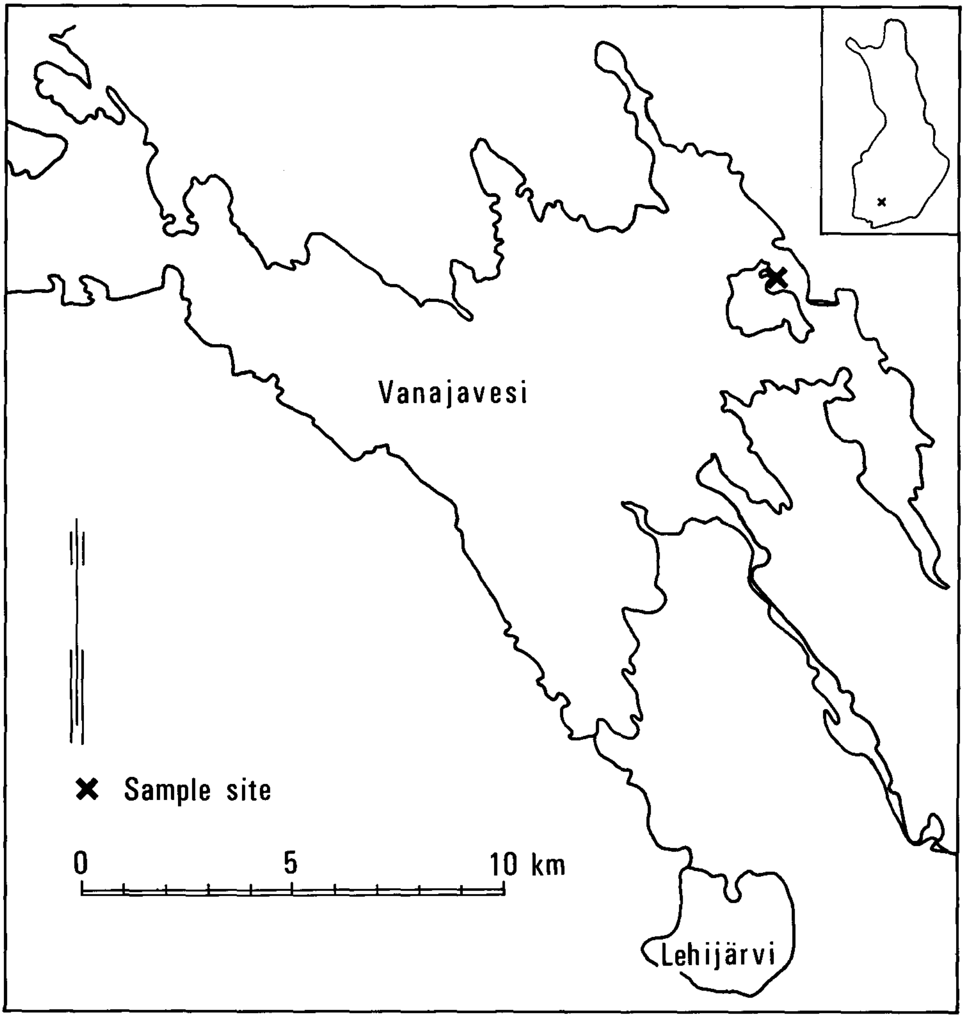

Fig. 3. Lake Vanajavesi and the location of the sampling site (after Vuorela, 1980b).

mineral material reflecting erosional processes is present. In other words, the curve shows the relative degree of field erosion by water around the lake basin.

The corresponding phenomenon, — field erosion by wind — has been demonstrated by means of the same method from several ombrothrophic bogs (Vuorela, 1983) using ash content values (*i.e.* ash residue after ignating the sample). An example of these (Fig. 5) again shows how well the ash-content correlates with the Cerealia curve especially during the early cultivation periods (Vuorela, 1986) and thus reflects the fluctuations in agricultural activity. Fluctuations in the ash residue values of peat samples are usually extremely small and the analysis must be done very carefully in order to pick out these tiny changes.

Corresponding results have also been obtained by counting the number of dust particles in the same kind of peat under the microscope. This work was carried out by Kramm (1978). In making correlations with agricultural activities he used the *Rumex*-pollen curve instead of the Cerealia one, *Rumex* being one of the commonest weeds in cultivated fields. These both serve as excellent pollen indicators of local cultivation.

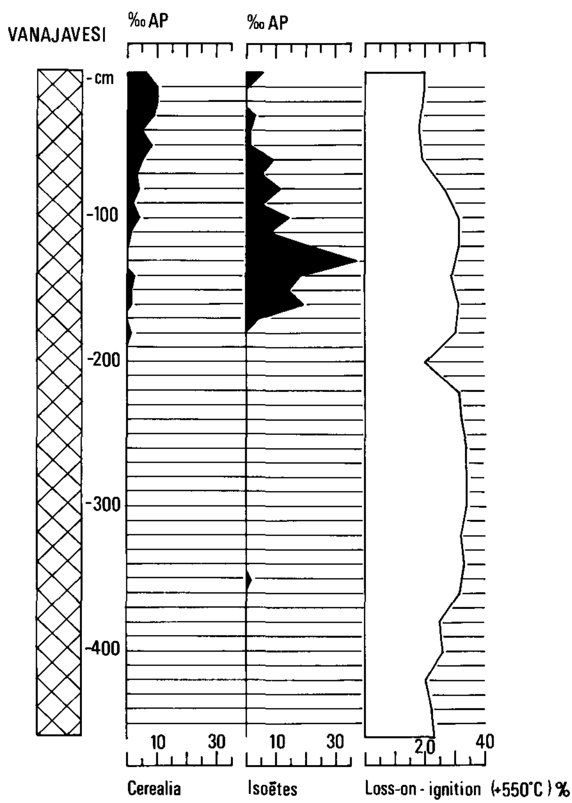

Fig. 4. Diagram showing the correlation between the curves for Cerealia, Isoëtes and loss-on-ignition (after Vuorela, 1980a).

Another way of demonstrating mechanical pre-historical erosion is to study the rate of sedimentation in lake basins. This can be done using 14C-dates or/and pollen concentration values. In the Vanajavesi material (Fig. 6) the dates, which should normally decrease towards the surface of the sediment core are all at about 3000 B.P. from the beginning of cultivation — indicated by the presence of Cerealia pollen — up to the present time. This is a result of the strong erosion in the surroundings of the lake basin, of retransportation and resedimentation of older material along with the contemporary material, as was also confirmed by the pollen data (Vuorela, 1980). The bottom-most date, 3129 ± 140 may indicate the real start of cultivation in the area while the following dates stratigraphically above this show an increasing rate of erosion accompanying the agricultural activities.

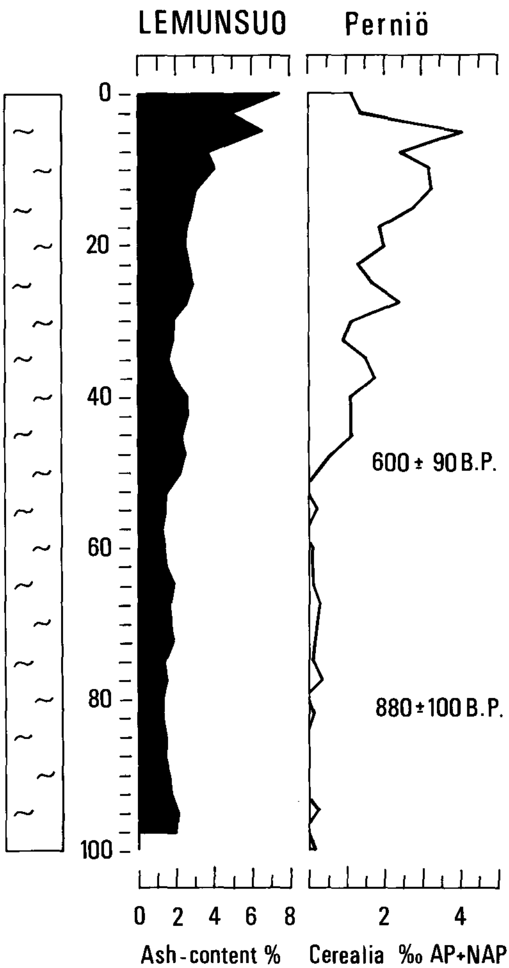

Fig. 5. Ash-content values for the ombrotrophic peat of Lemunsuo, Perniö, SW Finland compared with the Cerealia curve (after Vuorela, 1983).

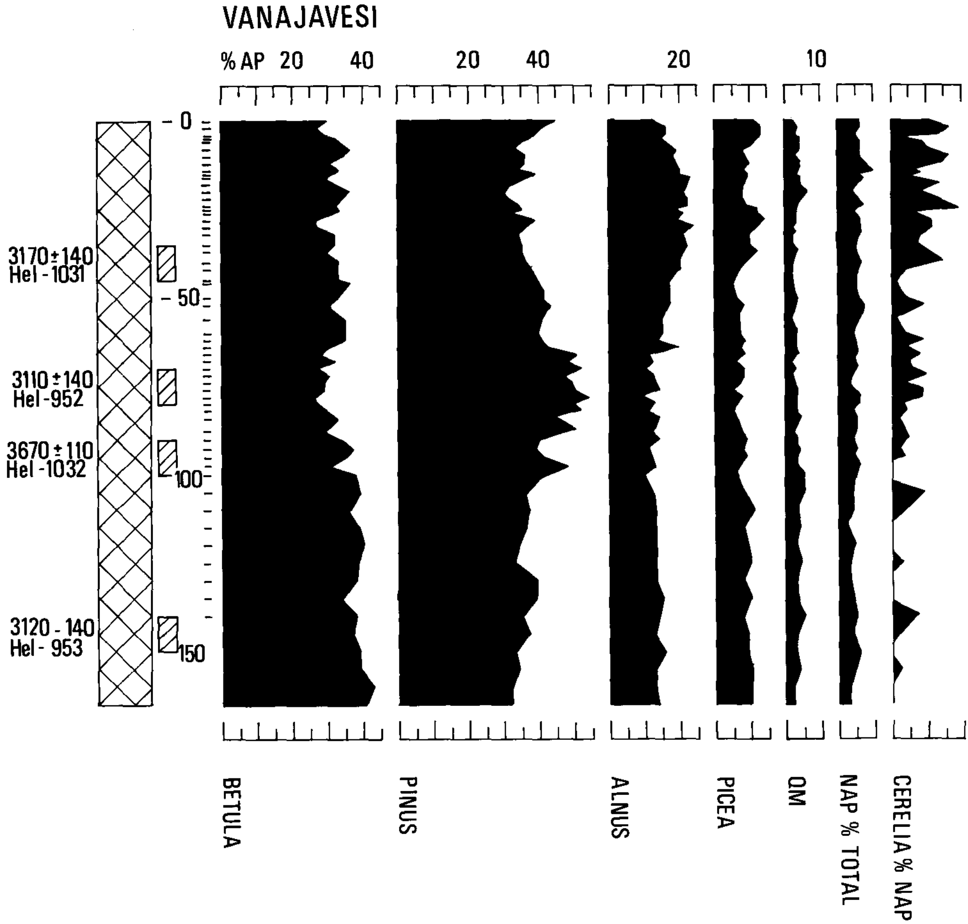

Fig. 6. ^{14}C dating of the Vanajavesi profile affected by the redeposition of eroded material as a result of field erosion by water (after Vuorela, 1980b).

In the same material pollen concentration values also indicate (Fig. 7) strong erosion in the surroundings of the lake basin. If the sedimentation rate remains unchanged then pollen concentration values of lake sediments normally stay fairly constant with only slight fluctuations. However, at Vanajavesi these values decrease abruptly from pre-agrarian values of 400.000 grains/cm^3 to 200.000 in connection with early agricultural practices and, towards the present time, even to half of that, thus reflecting an increased rate of sedimentation due to increasing field erosion. As a logical result of increasing sedimentation the ecological conditions for the submerged aquatic phanerogams change. Usually the pollen production of aquatic plants is too low for a detailed interpretation of these particular pollen data, but an exception to this is provided by the microspores of *Isoëtes lacustris* which can be used for this purpose. This plant has a poor competitive ability among other aquatics and is therefore favoured by the eroded mineral material transported into the lake which occasions worse circumstances for the most of the other aquatics.

The phenomenon can be found in diagrams from several countries (e.g. Pennington, 1964), Vanajavesi (Fig. 4 ; Vuorela, 1980) being one instance. The relative occurrence of *Isoëtes* rises rapidly at the start of agricultural activities as indicated also by the Cerealia pollen and the loss on-ignition values. Later, when the nutrient economy of the lake improves, *Isoëtes* has to give way to stronger competetors. Thus it mainly indicates the commencement of field erosion within the drainage area of that lake.

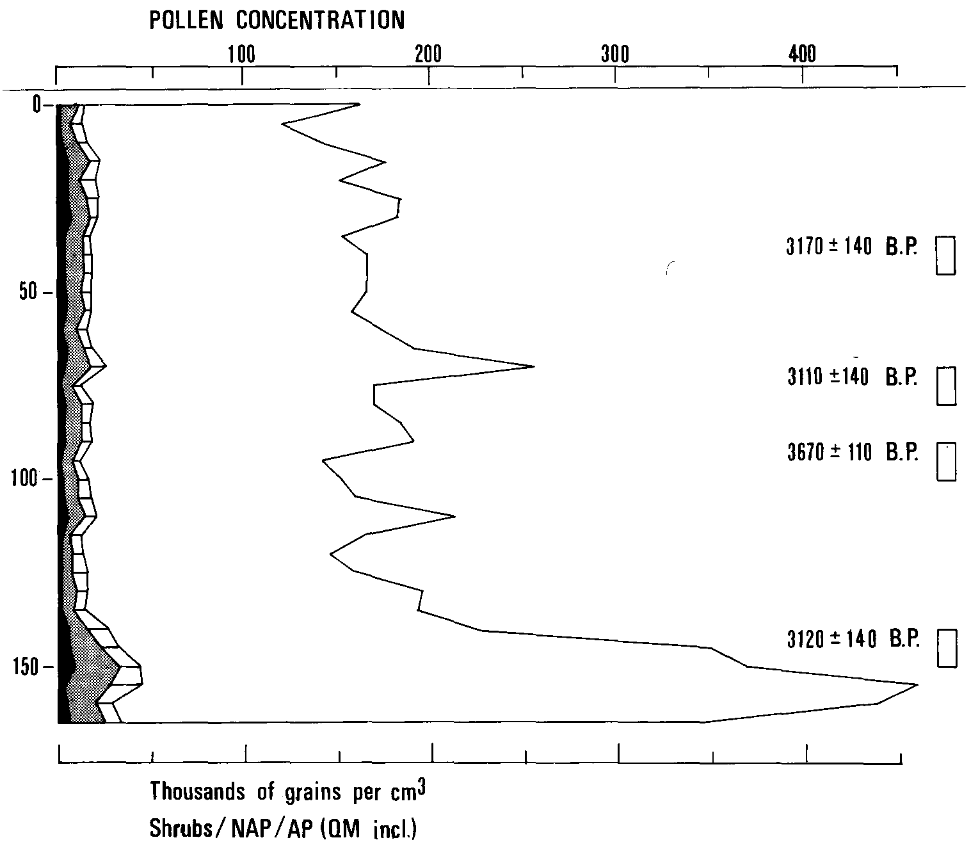

Fig. 7. Pollen concentration values for the Vanajavesi profile indicating increasing sedimentation as a result of agricultural activities around the lake basin (after Vuorela, 1980b).

Chemical erosion

In order to demonstrate the great sensitivity of chemical soil substances and elements to erosion, let us look at an example from the present day. Bormann and Likens (1970) showed the degree of leaching of calcium among

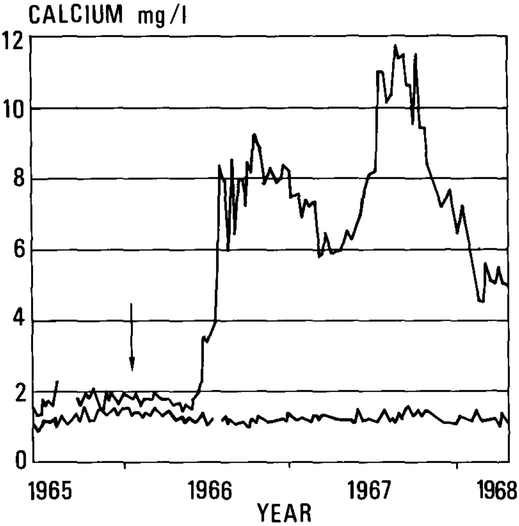

Fig. 8. Input of calcium to a river flowing through an area deforested early in 1966 (arrow ; upper curve) compared with an undisturbed catchment in the same area (after Borrmann and Likens, 1970).

other elements into the water of two small rivers flowing through a forested area (Fig. 8). In the diagram the values in both rivers fluctuate smoothly and regularly along with the seasonal succession until the forest around one of the rivers was felled. Even though deforestation took place for forestry purposes rather than agricultural, the leaching of calcium increased considerably while its values in the other catchment area remained unchanged. A corresponding phenomenon happened frequently in the past in connection with forest clearance starting from the very modest ones in Early Mesolithic times. It is easy to understand how enormously these values later increased at the turn from the Mesolithic to the Neolitic and even more especially during the last few centuries in connection with the improved methods of agriculture and forestry.

Prehistoric anthropogenous changes are encountered in the geochemical composition of lake sediments. The interpretation of these, however, is usually based on the pollen flora indicative of agricultural practice — mainly the Cerealia. This is the case in the diagram published by Kukkonen (1973), for instance (Fig. 9) where the fluctuations in the relative values for the main chemical components are a result of both local allochthonous input and of transported autochthonous matter. The decrease in the nitrogen, carbon, iron and phosphorus concentrations is here associated with the increase in the bacterial decomposition of humus at the commencement of agriculture. The importance of palynological evidence in the interpretation easily leads one to ignore earlier fluctuations probably caused by smaller Mesolithic clearings. In Kukkonen's diagram such a phase can possibly be found at the 200 cm level.

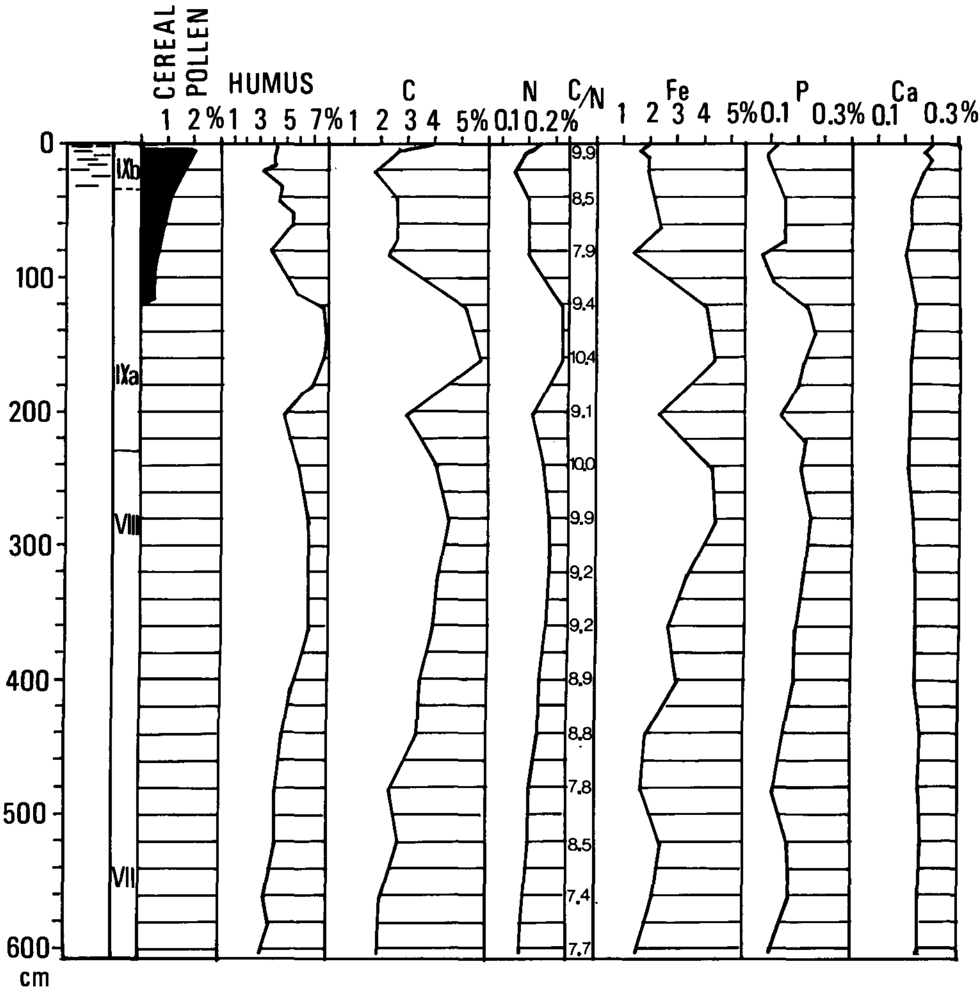

Fig. 9. Reduced diagram from Lake Lohjanjärvi showing the geochemical fluctuations in the sediment correlated with the Cerealia pollen data (after Lappalainen, 1973).

This phase may also be the earliest evidence of local slash-and-burn cultivation which because of sample statistics was never determined by Cerealia pollen (cf. Fig. 4).

During the last few centuries chemical erosion has heavily increased, not only due to agricultural activities but also in connection with industry, especially mining. An example of this is seen in material from two lakes in the village of Nyberget, Central Sweden (Fig. 10). Human activity — both settlement and mining, started there in the 15th century ; the smeltery ceased in the 18th century. The activities were concentrated on a 500 m broad isthmus situated between the two lakes Dammsjön and Lissjön. By investigating the sediments of these basins it has been possible to prove that the rivers

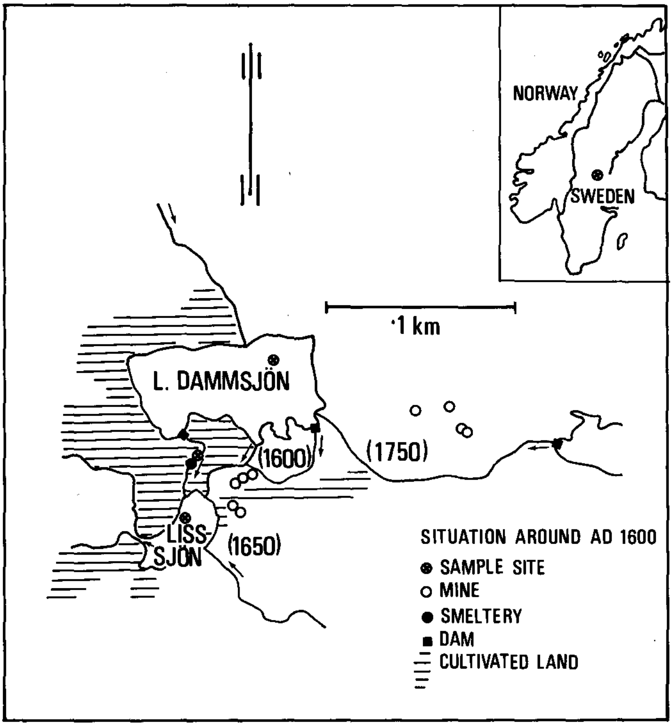

Fig. 10. The location of the lakes Lissjön and Dammsjön in the village of Nyberget, Central Sweden.

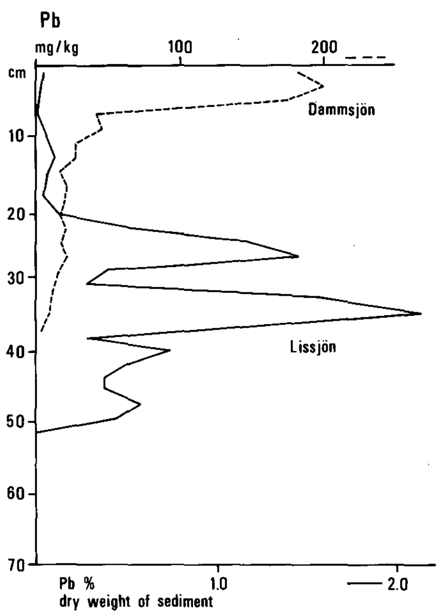

Fig. 11. The values for Pb in the sediments of Lissjön and secondarily polluted Dammsjön (mg/kg) (after Vuorinen et al., *1988).*

flowing from Dammsjön into Lissjön and passing the smeltery and mines have transported large amounts of chemical elements, here represented only by Pb (Fig. 11 ; Vuorinen *et al.*, 1986 ; 1988). The sediments in the up-stream lake remained relatively clean at first but were later secondarily polluted in connection with the 3-m rise of the water level by dam constructions (Vuorela *et al.*, 1986 ; 1988). Even though it has not been possible to date the profiles absolutely, the results from Lissjön clearly indicate the main period of agricultural and industrial activities, which can be dated on the basis of historical archives mainly to the 15th-19th centuries. The cultural landscape resulting from anthropogenous erosion is, however, reflected not only in the geochemical but also in the palaeobiological data (Fig. 12). When comparing the curves it seems evident that even the palynological indicators and charcoal dust may to some extent have been transported by the rivers.

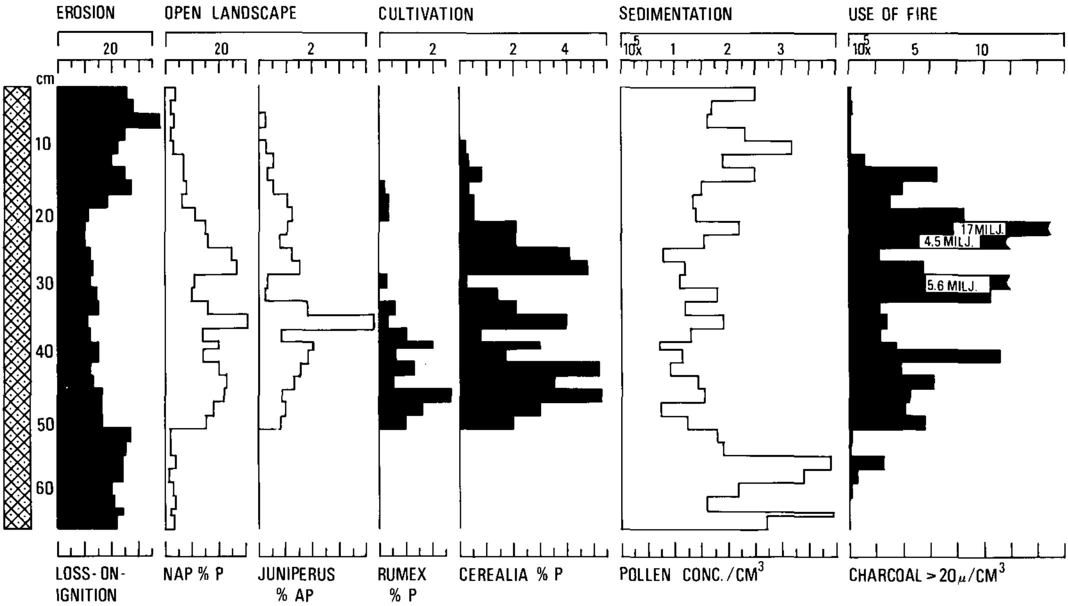

Fig. 12. Reduced summary diagram of Lissjön showing the main components of the cultural landscape and their representation in a palaeoenvironmental investigation of the lake sediments (Vuorinen et al., *1988).*

Conclusions

The material represented in this paper illustrates several means of determining anthropogenous erosion in palaeoenvironmental contexts.

Mechanical erosion is demonstrated by :

i Loss-on-ignition analyses carried out on either gyttja or *Sphagnum* peat and reflecting water or wind erosion.

ii Pollen concentration values and 14C-datings both of which reflect the rate of sedimentation, which in turn is strongly affected by erosion.
iii Pollen stratigraphy which may, in certain cases, reflect palaeoenvironmental changes inside the lake basin as a result of increasing input of eroded mineral material transported from the surrounding areas.

Chemical erosion is traced by geochemical studies of the sediment. In the selective summary diagram of Lissjön (Fig. 12) the loss-on-ignition and the pollen concentration values clearly reflect anthropogenous erosion. Simultaneously, an open landscape is indicated by increased herb pollen (NAP) values and by a distinct curve for *Juniperus* ; agricultural activities are correspondingly indicated by high Cerealia and *Rumex* values.

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