Microscopic Charcoal Resulting from Human Activity : a Palaeoecological Factor

Abstract

Microscopic charcoal, present in the soil and in gyttja and peat deposits, is an indicator of former fires, whether these be of natural origin or caused by human activity. The charcoal particles in soil horizons, although not reacting chemically themselves, together with the microfossils, indicate changed pedological and physical conditions. The vegetational changes which follow a fire and which result from the increased light conditions, increased ash content and a changed microclimate, can be reconstructed by means of microfossil analysis. Both palynological and botanical evidence shows that the effect of these factors may last for centuries.

Introduction

Charcoal originates from the burning of organic material, usually wood under anoxic conditions at temperatures above 200° C (Cope and Chaloner, 1981), while ash represents the remains of totally burnt organic material. Thus both these fossil groups are indicative of fire. The ash or charcoal can either occur *in situ*, or have been transported by wind (Patterson III *et al.*, 1987) or water and deposited in the soil or sediment at some distance from source. Whether the fire has been of natural origin or the result of human activity, and what has been the purpose of such a man induced forest fire are very complex questions for which other fossil materials are needed in order to arrive at a correct interpretation.

In this analysis of microscopic charcoal as a palaeoecological factor the fact will be emphasized that palaeoecology is nothing more than ecology seen in a time perspective. The main ecological factors : the object (plants, animals, soil), the dynamics (competition, food chains, succession), and the energy (food substances) are to be reconstructed for the time span represented by the stratigraphy of the profile, on the basis of the microfossils and microscopic charcoal contained in that profile and set in an established chronology.

Of the ecological factors, the soil structure, soil chemistry, light, temperature, and water balance all have to be taken into consideration. If any of these change, the whole situation will change in order to reestablish a new ecological balance. In practice, this often means new species which compensate for those previously growing on the site. This succession can be traced by means of pollen analysis.

THE INDICATION VALUE OF MICROSCOPIC CHARCOAL

When analysing peat or gyttja layers or cultural layers, the palaeoecological interpretation should be made from several points of view. Microscopic charcoal in soil deposits not only provides evidence of fire, of burnt wood, somewhere more or less in the vicinity of the sampling site but it also tells of considerable changes in the past ecological balance : changes in soil chemistry, as well as a changed microclimate. Appreciating this also helps us to interpret the reactions of the local flora and fauna (microflora and microfauna) to the new environmental conditions, which include for instance :

- an increased light factor in connection with deforestation by forest fires ;
- increased temperature during the fire in the first place but also as part of the microclimate caused by the exposed, dark soil surface ;
- increased erosion ;
- changes in the groundwater level ;
- and an increase in the pH-values of the top soil caused by the high ash content resulting from the fire. The conditions mentioned here represent only the main factors affecting the local plants and animals in connection with, and as a result of, the fire which resulted in the deposition of the charcoal. The vegetation changes are then recorded for the present-day palaeoecologists by changes in the pollen spectra. The interpretation of these changes is ultimately based on plant ecological facta.

Chemical and physical changes also take place. The humus layer, for instance, may decrease considerably thus causing a hiatus in the stratigraphy. If this humus layer was originally very thin, erosion of the charred organic substances and leaching of nutrients usually take place in connection with the erosion of the mineral soil. This development, in turn, may cause delayed reforestation and unstable ecological conditions for a long period

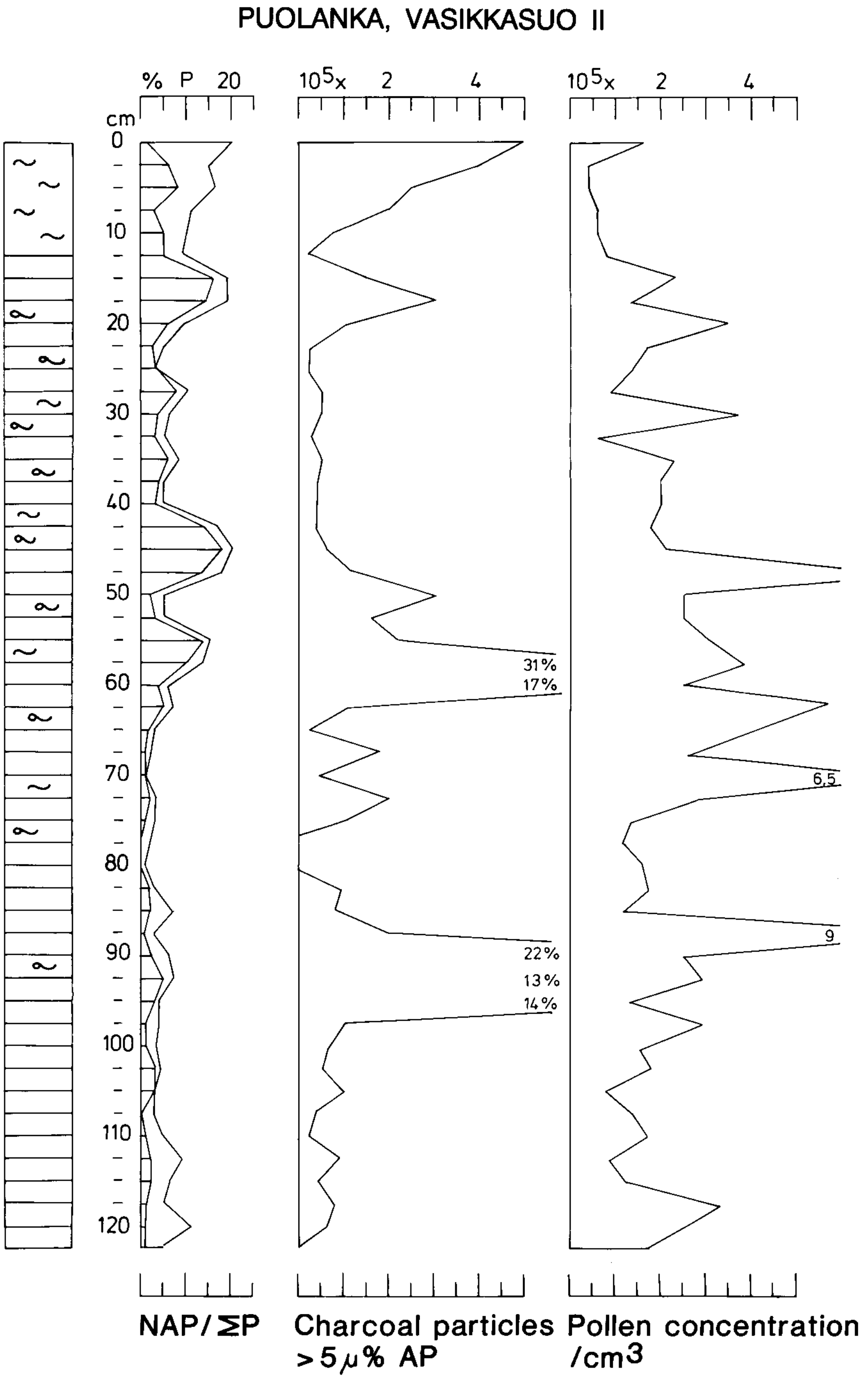

Fig. 1. An example of early fire phases caused by man and their reflectation in pollen concentration values and herb pollen frequencies. The time covered by the diagram is 0 - 4500 BP.

of time. The present-day palaeoecologist may confirm this development through certain changes in the pollen data, or through the increased mineral material in the organic sediments reflected by increased ash residue values (Vuorela, 1983).

Microscopic charcoal is easily transported by wind and water from the site of the fire and can thus be traced in the deposits of adjacent peat bogs and lakes (Fig. 1). These light, bouyant particles may sometimes be found in considerable concentrations at the border between marine and lacustrine sediments (Vuorela, 1990) where they represent an indeterminate region. When it occurs in peat and gyttja deposits together with pollen indicating past vegetation, microscopic charcoal may, however, help us to determine the distance from the fire. This calculation, however, is not an easy one. Several investigations have been carried out using the shape, size, and frequency of charcoal particles to show the distance from the source of the fire (cf. Clark, 1982). It has been demonstrated that several factors, *e.g.*. the direction and strength of the wind, the means of transportation, and the matrix of the final location, for instance, all affect the resulting concentration values and even the particle size of the charcoal.

Microscopic charcoal as an indicator of ancient land use

Charcoal layers in deposits dating from the mesolithic period have recently been interpreted as the most reliable – and in many cases the only – evidence for the presence of mesolithic man. That man was present often remains the sole interpretation to which the pollen data very rarely adds anything.

With regards to later periods it is not only the existence of settlement but the human activities related to them which we try to solve. Changes in the pollen frequencies and/or the occurence of certain pollen indicators, *e.g.*. Cerealia pollen, usually provide an explanation for the fire, such as deforestation for grazing or for cultivation.

The early traditional form of cultivation, slash-and-burn-cultivation and its palaeoecology, is a good example of human activity resulting in the deposition of microscopic charcoal. This cultivation technique started with the burning of the forest and made use of the increased nutrients thus available in the ashy soil. Simultaneously, certain tree species, *e.g. Betula*, were very much favoured by the resulting pedological changes, as well as by the increased light conditions, and regenerated rapidly, both by means of seeds and sprouts. In connection with the regenerating vegetation, the relatively high pH-value of the ashy soil strongly affects the plant succession and the species present, some of them being favoured by high ash values,

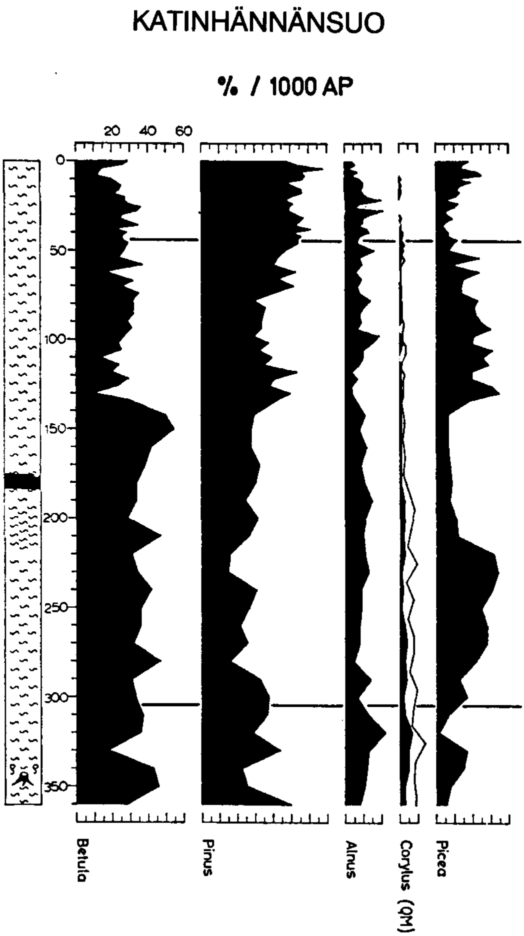

Fig. 2. An example of the indications of early land-use in the form of a delay in reforestation, mainly reflected by low Picea *pollen frequencies. The time covered by the diagram is 0 - 4000 BP (Vuorela 1972).*

others (*e.g. Picea* ; Vuorela, 1972, 1986) being negatively affected by the same factor.

What kind of ecological – or palaeoecological - changes occur in connection with fire and how are – or were the plants influenced by these conditions ? The most important question remains, however : how is this shown in the palaeoecological data ?

In temperate latitudes early forest clearances are usually reflected by increasing pollen frequencies of the heliophilous tree species. Such trees must have been growing around the clearing and have been affected to a minor degree by the changed chemical situation.

The post-fire regeneration of the forest is also strongly influenced by pedological factors, including the soil chemistry. The increased pH-value of the soil, caused by the high ash content, is one of the main factors causing changes in the vegetation composition. The delay in the regeneration of *Picea*, for example which is partly caused by the high pH-values is one of the main features in the pollen diagrams (Fig. 2). The prolonged period with decreased spruce pollen frequencies also tells us that the original feature has been a long-lasting slash-and-burn/grazing activity rather than a natural forest fire.

The herb vegetation growing in the clearing, immediately after the fire, has special ecological characteristics including a high tolerance for the physical and chemical effects of the ash in the soil. One of the pioneer species is *Epilobium angustifolium* which is a circumpolar plant growing in temperate and cool northern latitudes. It is the most common species on recently burnt soils. Under normal conditions the germination of *E. angustifolium* is hampered by the forest litter but after this has been burnt the seeds germinate immediately. The seed production of this species may reach 300.000 m^{-2} during the few optimal years following a fire. Despite the abundance of the plant itself, the pollen evidence of this zoogamous species remains extremely low, « fire-weed » being represented in the pollen spectra only by sporadic occurrences even in deposits rich in charcoal. On the other hand, one single pollen grain of this plant is enough to bear evidence of burnt soil in the vicinity.

Another indicator of the same kind of activity is *Pteridium aquilinum* which produces spores only in burnt forest clearances (Oinonen, 1967). A forest fire seldom destroys the roots of *Pteridium* which normally grow horizontally, deep below the soil surface and thus enable vegetative reproduction. From there new sprouts arise immediately after the fire and produce spores which are thus important palaeoecological indicators. The reforestation process may become delayed for several decades by dense litter layers of *Pteridium*. This succession is to be seen in the pollen diagrams not only in the occurrence of spores of *Pteridium* but also by several other indicators of prolonged forest clearance. Among such features high herb pollen frequencies or pollen frequencies of heliophilous trees or trees with a low maturity age should be mentioned.

The palaeoecology of cultural soils

Of the other herbs, the weeds demand specific pH-ranges and this partly restricts their occurrence. This dependence is also seen in the relationship between the pH value of the ploughed soil and the associated weed vegetation. This weed vegetation produces the most important part of the pollen flora for a palaeoecologist investigating pre-historic human activity. Every species has a certain pH range which limits its occurrence in places where other ecological factors would permit it to exist. According to Kurki (1982) the average acidity of the ploughed layer of different soils in S-Finland varies between 5.0 and 5.93. The reaction of the soil where most weeds occur for the same area of the country ranges between 4.4 and 6.7 (Aarnio, 1931). The most common weeds and their pH amplitudes are given in Table 1.

TABLE 1. — SELECTED LIST OF MOST COMMON WEEDS AND THEIR PH-AMPLITUDES

Cirsium arvense	4.6-6.3
Centaure cyanus	4.8-6.1
Lapsana communis	5.0-6.3
Stellaria media	5.0-6.5
Chenopodium album	4.4-6.7
Equisetum arvense	4.4-6.5

These figures partly explain the scarcity of weeds in slash-and-burn clearings with a high ash-content and high pH-values.

The pH range of different natural subsoils in southern Finland has also been determined by Kurki (1982). The pH-values of the mineral soils are higher than those of the organic deposits all, however, varying between 4.7 and 6.3. In areas with high ash concentrations, in the soil of medieval towns, for example, the pH-values mainly vary between 6.5 and 8.4. This feature has been investigated by Dr Annikki Saarisalo-Taubert (1963) for three towns located on the southern coast of Finland. She has also shown that the relatively high pH-values, originating in medieval times, affect the recent herb vegetation up to the present day. It was not only the final destruction by fire of the former towns which, in Fennoscandia, were built mostly of wood, but also the frequently occurring fires inside the towns which caused the high charcoal and ash values (Vuorela and Hiekkanen, 1991) and the high pH-values of the soil. The ash and charcoal content of the cultural layers of an ancient town, which is usually already recognizable during the excavations, adversely affects the preservation of pollen grains by increasing the pH-value of the soil. The charcoal particles also hamper the investigation of the material under the microscope (Vuorela, in press).

CONCLUSIONS

The present examples aim to demonstrate that microscopic charcoal resulting from human activity is an important palaeoecological factor. It is also quite obvious that the interpretation of this relatively new type of palaeoecological indicator will improve. From what has been demonstrated here, we can see that, when dealing with microscopic charcoal we encounter several kinds of difficulties, questions and sources of error. These difficulties may decrease as more investigations are made. So far, the main question remains : what kind of changes did the fires, indicated by the microscopic charcoal, cause in the past vegetation and the ecology of the past milieu ?

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