

FIELD EROSION BY WIND AS INDICATED BY FLUCTUATIONS IN THE ASH CONTENT OF SPHAGNUM PEAT

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The ash content curves for three *Sphagnum* peat profiles were correlated with those for Cerealia and the natural indicators of bare mineral soil. The fluctuations in the ash values seem to indicate erosion of fields by wind as a result of tilling and other activities in cultivated fields.

The increase in these values in the uppermost samples is an even better indicator of improvements in agriculture than are the curves for Cerealia and weeds, which decrease together with the small pollen production of the recently dominant crop species and advances made in agricultural technology.

The local pre-agrarian cultural phases revealed by the C¹⁴ datings and the tree pollen data cannot be documented by the ash content values of the *Carex* peat profiles.

Key words: Field erosion, ash content, Sphagnum peat, aeolian, pollen, ignition residues.

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Introduction

The first application of loss-on-ignition values of limnic sediments in Finland (Alhonen 1967) was connected with the research of natural lake sedimentation. The method became later (Tolonen *et al.* 1975, 1976) an established part of the investigation aimed at searching for indications of prehistoric agriculture. Until recently, however, the term

»field erosion« referred only to lake sediments affected by larger amounts of mineral matter being washed into the basin.

Kramm (1978) has made a detailed microscopical analysis correlating the frequencies of airborne inorganic dust particles and *Rumex* pollen in two peat profiles from NW Germany. The results show that these components correlate particularly in the upper part of the profile, indicating human activity.

Field erosion by wind has also been documented in two *Sphagnum* peat profiles from southern Finland (Vuorela 1975, Nunez & Vuorela 1979), where the ash content values of the moss samples increase along with the pollen indicators of human activity. The interpretation from Loimansuo was confirmed by submitting the ignition residues to electron microscopy and by analysing them at certain levels (see Vuorela 1975, fig. 17). Not less than 72 % of the detrital inorganic grains were quartz.

Information on the ash distributions in raised bogs has been reported from several countries (e.g. Driessen *et al.* 1979), but the sampling intervals of the profiles are usually as great as 0.5–1 m. Even so, this component tends to increase towards the surface layers.

The ash content values of Finnish bog mosses have been published in connection with the inventory of peat resources for industrial use (Raikamo 1982). The results are, however, based on very rough measurements of layers 40–100 cm thick of ombrogenous *Sphagnum* (S) or *Eriophorum*–*Sphagnum* (ErS) peat. The ash contents for *Sphagnum* vary within the range 1.0–4.2, the mean value being 1.9. For ErS the corresponding values are 0.8–9 and 2.4, two exceptionally high values (7 and 9) occurring in the surface layers.

With reference to the studies mentioned above and to the results obtained from further investigation, the present paper aims to discuss the indicative value of the ash content fluctuations in *Sphagnum* peat profiles. To do this, detailed curves for the ignition residues (ash content %) of three profiles of *Sphagnum* peat have been correlated with corresponding *Cerealia* pollen curves and with total curves for the natural indicators of open mineral soil, *Artemisia*, *Chenopodiaceae*, *Rumex* and *Plantago* (cf. Iversen 1941, Fries 1951), which may be assumed to originate from the same areas.

The bogs discussed are Retulansuo, Hattula (Nunez & Vuorela 1979), Lemunsuo, Perniö (Vuorela unpubl.) and Loimansuo, Huittinen (Vuorela 1975). Additional data on minerogenous *Carex*-forest peat derive from profiles in Vohtenkellarinsuo, Paimio (Glückert 1976, 1977, Vuorela 1983) and Perkiö, Hauho (Vuorela 1982).

All the C¹⁴ determinations were performed at the Radiocarbon Dating Laboratory, Helsinki. Two C¹⁴ datings from Lemunsuo, 600 ± 90 (Hel-1640) at the start of permanent field cultivation and 880 ± 100 B.P. (Hel-1641) at the start of an older cultivation phase, have not been published previously.

Material and methods

The material from Retulansuo, Lemunsuo and Loimansuo is *Sphagnum* peat with sporadic *Eriophorum* remains. The slight fluctuations recorded in the grade of humification of these cores have not been described as the relative pollen frequencies do not depend on this factor.

The material from Vohtenkellarinsuo and Perkiö is mainly *Carex*-forest peat with *Sphagnum* peat in the uppermost layers only.

When sampling the material for the loss-on-ignition analysis, we avoided the remains of wood fragments and *Eriophorum* leaves. The agricultural period corresponds to the *Sphagnum* peat layers in all these samples.

The samples were ashed at 550°C (2.5 h). To avoid fluctuation due to samples too small in size, the amount of dry material used for the determination was kept to about 1 g in the new determinations. Samples were weighed to an accuracy of 0.0001 g. The samples were taken every 2.5 cm or 5 cm.

The pollen data of indicator species were recorded as rates per one thousand arboreal pollen at each level.

Results

The ash content of *Sphagnum* peat is held to be »less than 5 %» (Kivinen & Pakarinen 1981: 12); in Retulansuo (Fig. 1) the mean value for the inter-agrarian periods is even less than 1 % (cf. Driessen *et al.* 1979). This should be roughly the value for clean *Sphagnum* peat, as the bog is located on an isolated island (Retula) lacking sandy or silty deposits. Most of the till in the vicinity of the bog has been washed by the lake Vanajavesi (Auer 1924; Nunez & Vuorela 1979). The ash contents that reach 4–5 % in the surface samples must therefore have been affected by secondary mineral matter.

In Retulansuo the fluctuations in these values are very small, 0.5–3 %, throughout the period of prehistoric and historic agriculture, partly because of the relatively high growing rate of ombrogenous *Sphagnum* peat (Aaby & Tauber 1974, Moore & Bellamy 1974) and partly because of the soil type – peat and clay – cleared for agriculture on Retula (Nunez & Vuorela 1979). The airborne material from the early fields consisted mostly of organic peat dust, which cannot be separated from the original material at the sampling site. From the 20 cm level upwards, the more developed agriculture has a more marked, but still modest, influence on the ash content, which now reaches 3 %. The indicators of bare mineral soil show a particularly distinct increase at the 17.5 cm level, thus indicating the clearing phase of the adjacent fields.

Right at the surface the ash content reaches 5 %; hence, the figures reported by Kivinen and Pakarinen (1981) refer to the surface layers of *Sphagnum* peat. Even if the increase in airborne mineral material in Retulansuo is no higher than 1 to 5 %, it correlates nicely with the frequency of pollen indicators of human activity, not least with *Cerealia* pollen.

The clear decrease in the indicator pollen in the topmost samples will be discussed later.

Even in the pre-agrarian deposits of Loimansuo (Fig. 1), the variations in ash content remain below 1 %. The indication of early agriculture shows up clearly in the two curves at the 160–175 cm level corresponding to the Iron Age, when the ash content rose to 3 %. Later, advances in field cultivation and permanent settlement are reflected in an ash peak at the 40 cm level together with a rise in the *Cerealia* curve and a steadily increasing ash content from the 50 cm level towards the surface. This increase, to c. 5 %, corresponds to that of *Cerealia* and indicator pollen and is very similar to the values obtained from Retulansuo.

The ignition residues from the 10–15 cm level were submitted to electron microscopy. Besides the mineral matter mentioned above, remains of the microflora of the *Sphagnum* peat were recorded (Figs. 2 and 3; cf. Nieminen 1979). The amount of this kind of material is, however, insufficient to cause the high ash values of these levels.

In the peat profile from Lemunsuo (Fig. 1), too, the fluctuations in the ash content curve correlate nicely with those for *Cerealia*. The mean value for the ash content is higher than that of Retulansuo or Loimansuo and may reflect either a shorter distance between the bog and the action area of the settlement or the different types of soil tilled, especially as the rate of peat accumulation is approximately the same in Loimansuo and Lemunsuo. All the curves show enhanced values at the 90–97 cm, 65–72.5 cm and 40–50 cm levels, the oldest phase dating back to the days of the Vikings or the Crusades. A distinct increase can be dated to 600 ± 90 B.P. (Hel–1640) at the 50 cm level.

In the Lemunsuo profile the ash content of *Sphagnum* peat is around 2–3 %, except right at the surface where it fluctuates between 5 and 7.

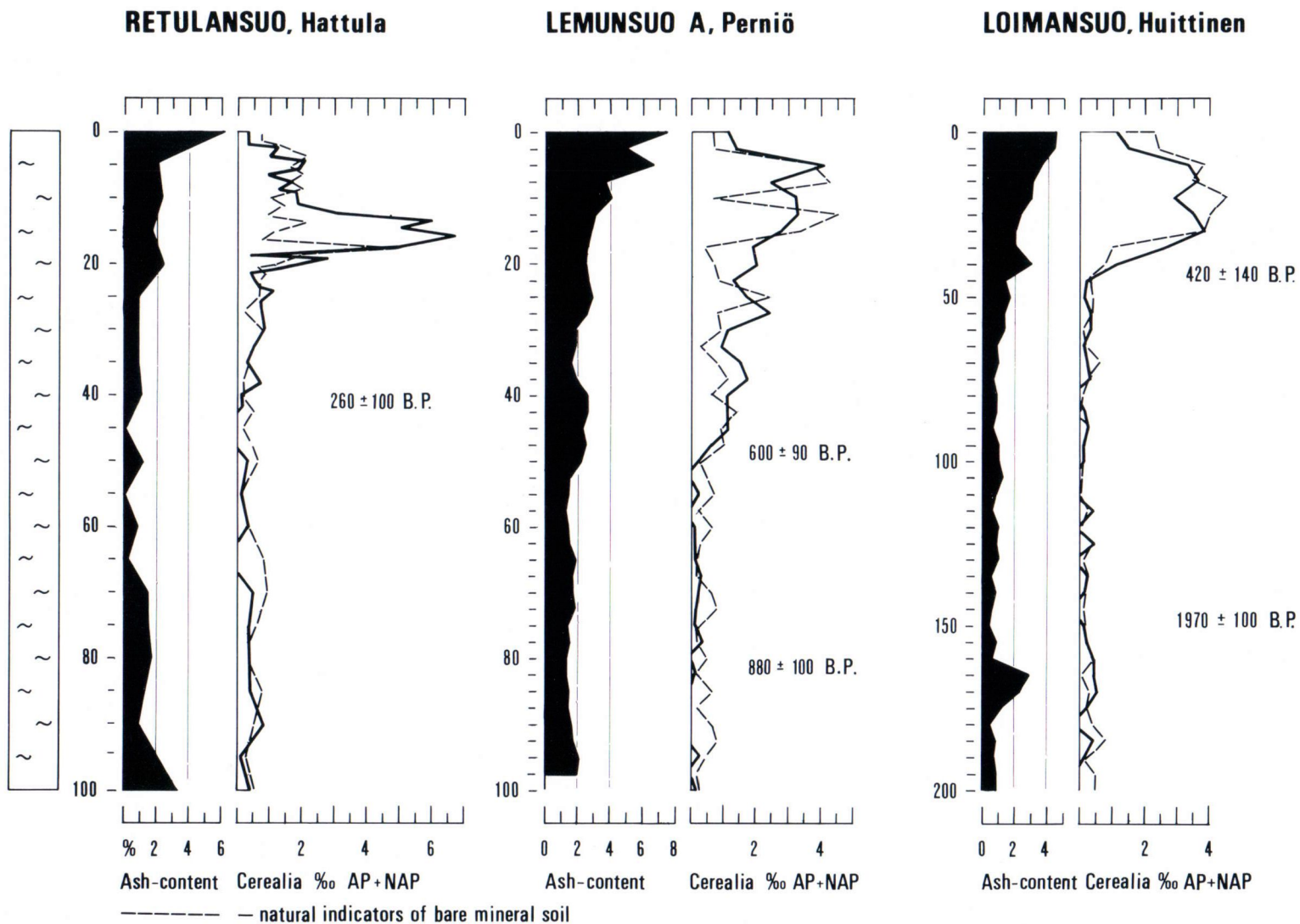


Fig. 1. A correlation between the ash content values and those of the Cerealia and weed pollen (*Artemisia*, *Chenopodiaceae*, *Plantago* and *Rumex*) in the *Sphagnum* peat profiles of Retulansuo, Lemunsuo and Loimansuo dated by C^{14} methods.

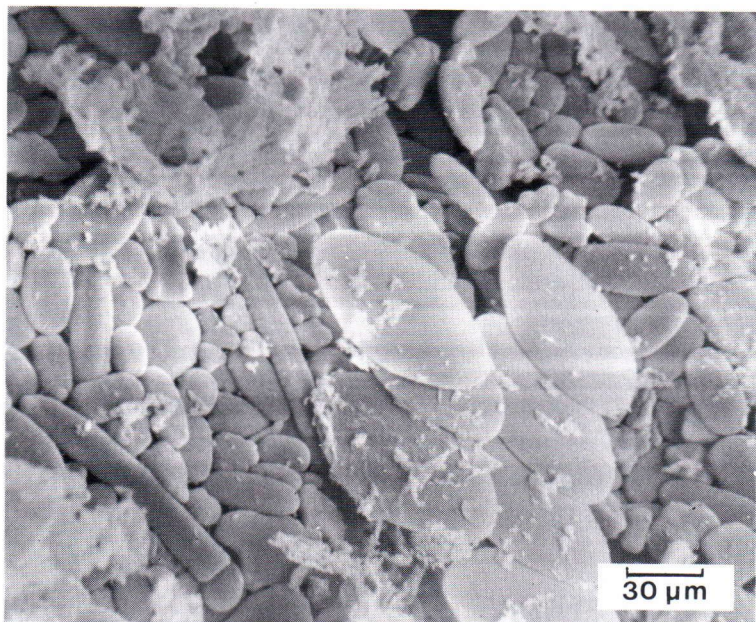


Fig. 2. Inorganic remains of the microflora found among the ignition residues of *Sphagnum* peat in Loimansuo at the 10–15 cm level. SEM, Viikki.

In all the diagrams, the surface layers show a discrepancy between the increasing ash content values and the decreasing *Cerealia* frequencies. In all these cases, however, vast modern fields with intensive agriculture are located close to the samples sites. This suggests that the ash content of peat deposits is an even more useful indicator of field cultivation (field erosion) than is *Cerealia* pollen, which is affected by varying amounts of pollen, depending on the crops cultivated. It is obvious that, the early predominance of *Secale*, for example, can be traced in the *Cerealia* curve but that the pollen values of *Hordeum* are considerably underestimated (cf. Vuorela 1973). The grade of tilling, the extent to which the land was worked and wind erosion do not substantially depend on the species cultivated. The same phenomenon is shown by the topmost samples of the curves for natural indicators of bare mineral soil, obviously as a result of the high grade of technology and the lack of weeds in modern agriculture. The maximum values for



Fig. 3. Remains of Flagellata (Chrysophyta, Chrysomonadinae) *Mallomonas* sp. (acc. to Järnefelt *et al.* 1963), found in the ignition residues of *Sphagnum* peat in Loimansuo at the 10–15 cm level. SEM, Viikki.

these herbs occur at the pre- and interphases of the *Cerealia maxima* and indicate the presence of fallow land and probably grazing.

In addition to the raised bogs described above, the ash content values were determined from two cores of minerogenic *Carex* peat. The profile from Perkiö (Fig. 4), which does not include the recent peat deposits, shows that the mean values for the ash content in »clean» *Carex* peat are c. 5%. Contamination by the underlying mineral soil – brought about by earlier wave action and later biological activity (Anderssen 1979) – increases these values towards the limnotelmatic horizon.

This sample site is located in the immediate vicinity of a Corded Ware dwelling site, dating back to 4000–4500 B.P. (Edgren 1970, Alhonen 1970). The role of agriculture in settlements of this period is still a moot point and resulted in thorough investigations at the dwelling site (Vuorela 1982) in the course

of which the ash content of the sample core was also analysed. At first sight, the conspicuous increase in the ash content at the 90–100 cm level seemed to indicate that the aeolian sand was redeposited from the dwelling site into the peat. Further examination demonstrated, however, that the anomalies in the ash content values were caused by considerable amounts of diatoms redeposited at this level and whose main species were the acidophilous *Eunotia praerupta* var. *inflata*, *Pinnularia viridis* var. *intermedia* and *Eunotia diodon*. Several other *Eunotia*, *Pinnularia* and *Nitzschia* species were sporadically encountered (analysed by H. Haila). It is interesting to note that yet one more pre-agrarian phase of local human influence – indicated in this diagram by the decline of *Picea* at the 60–80 cm level – is not reflected in the ash contents.

The stratigraphy of Vohtenkellarinsuo (Fig. 5) resembles that of Perkiö, consisting mainly of *Carex* peat with abundant fragments of wood. In this profile two layers of ash and carbonized wood indicate local deforestation by burning. Both horizons, that at the 5–7 cm level and that at the 45–50 cm level, are manifested in the ash content values. The slight decrease in these values at the *Carex/Sphagnum* peat boundary at the 35 cm level can be attributed to a change in the rate of peat accumulation.

The ash contents of *Carex* peat (4–5%) and of the *Sphagnum* peat affected by aeolian field erosion (3–4%) correlate with the corresponding values in the previous diagrams. Likewise, the uppermost samples show a sharp increase in the ash value and a decrease in the *Cerealia* values.

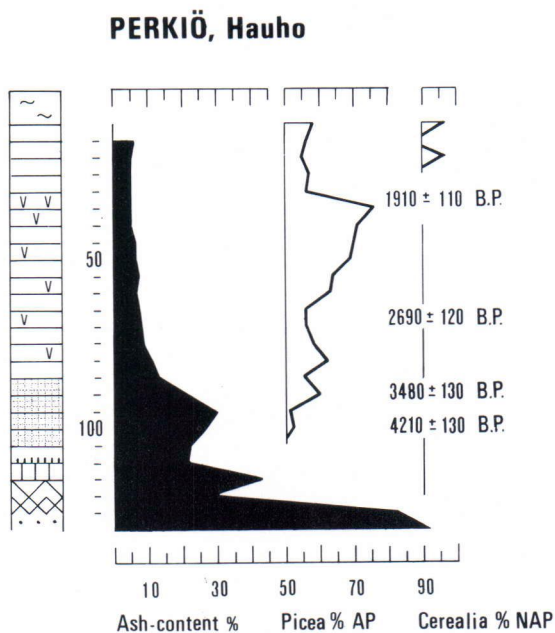


Fig. 4. The curves for the ash content values, *Picea* pollen and *Cerealia* in the *Carex* peat profile from Perkiö. The stratigraphical symbols are explained in the text.

Conclusions

The diagrams referred to above allow the following conclusions to be drawn:

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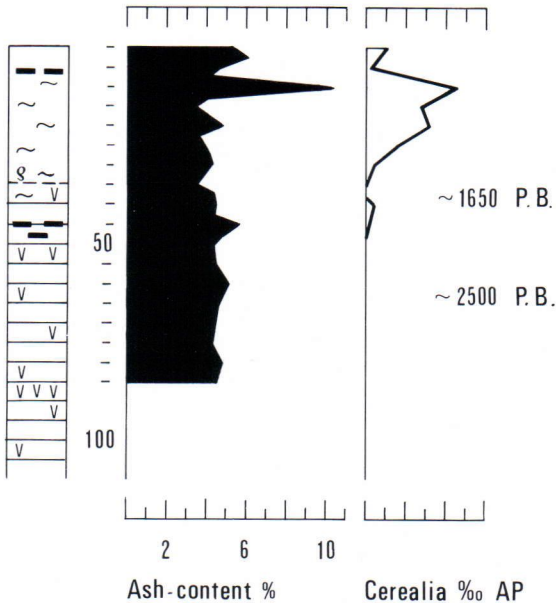


Fig. 5. A correlation between the ash content values and those of *Cerealia* pollen in the bog Vohtenkellarinsuo. The stratigraphical symbols are explained in the text.

Field erosion by wind affects the bare mineral soil surface in connection with settlement and field cultivation. This is recorded in fluctuations in the ash content values of the surrounding peat lands. The extent of field erosion may be determined by a careful loss-on-ignition analysis of *Sphagnum* peat carried out from the same material as pollen analysis. This faster method could sometimes be used as a preliminary elementary means of analysis to establish the main phases of local human activity in the profile.

The ash content of clean ombrogenous *Sphagnum* peat is c. 1%. A marked increase to 2–3% is noted in connection with early agriculture, whereas the value of 5% reached in the uppermost layers only indicates recent field cultivation. The present material shows that the ash content of nonaffected *Carex*

peat is c. 5%. The difference between the ash values for *Sphagnum* and *Carex* peat could be attributed partly to the different rates of growth, because the component of aeolian material is compared with the pollen concentration values (cf. Kramm 1978), not forgetting, however, the genetical differences between these two peat formations.

A regular discrepancy exists in the topmost low-humified peat layers between the increasing ash content values and the decreasing indicator and *Cerealia* frequencies. This may be due to the small amount of pollen in the recently predominant crops, *Hordeum* and *Avena*, as well as to the shortage of fallow fields. Since, however, neither the way nor the extent to which the land was worked nor wind erosion depend on the crops cultivated, the ash content may be considered as a more reliable indicator of field cultivation than the value of *Cerealia*. Depending on the quality of the mineral soil, the ash content of peat deposits may even act as an indicator of the distance between the sample site and the centre of activities of the settlement. Thus it could help in distinguishing the sporadic *Cerealia* pollen and other indicator pollen of primitive local slash-and-burn cultivation from the pollen transported long distances.

In *Carex* peat the ash values increase towards the limnotelmatic contact of the profile. Close to that horizon the diatoms may occasionally affect the values and result in a misinterpretation. The silicoflagellates found in the ignition residues of the surface layers of *Sphagnum* peat occur in amounts too small to affect the ash values.

The dust-input in *Sphagnum* peat may be of some importance for the determination of bulk density values (g/dm^3) as well (Karesniemi 1972). The loss-on-ignition values have then often been omitted merely because of the ombrogenous nature of *Sphagnum* (Tolonen 1977). The proportion of airborne

mineral material in the surface layers of the peat deposits could have some influence on the estimation of peat production (Pakarinen & Tolonen 1977).

With reference to the present material it seems likely that, in certain circumstances,

the ash content of peat deposits may consist of inorganic material derived from the surroundings of the bog, and that as such, it may, together with the pollen flora, help us to reconstruct human activities in the past.

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