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POSSIBILITIES FOR DETAILED DATING OF PEAT BOG DEPOSITS

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ABSTRACT. Geochemical and palynological data as well as radiocarbon dating were used to study the peat bog deposits in Niinsarre bog, northeast Estonia. The aim of this study was to establish criteria for determining a detailed chronology, which is important, for example, in studying paleoevents and historical monitoring. In some cases, we can use cumulative pollen data, as well as cumulative chemical and peat bulk density data.

INTRODUCTION

The Niinsaare mire, *ca.* 70 ha^2, is located *ca.* 10 km southeast of the town of Jôhvi on the west side of the Kurtna kame field in northeast Estonia (Fig. 1). The maximum depth of peat in Niinsarre is 5 m. The paludification of the depression between the limnoglacial kames started 6 ka BP with the formation of *Carex* peat. The development of the mire was related to the water-level changes in the depression. The appearance of a thin horizon of gyttja-bearing sediment occurred above the *Carex* peat. This was associated with the rise of the water level and widening of neighboring Lake Mustjärv. The gyttja is overlain by *Phragmites* peat, and at *ca.* 4.7 ka BP, homogeneous *Sphagnum* and *Ericaceae* layers started to form. The uppermost 3.7 m of the core feature a regular pattern of alternating *Sphagnum* and *Ericacea* peat layers.

METHODS

Material was gathered for ^{14}C dating from three parallel samples taken from cores *ca.* 10–20 cm apart using a Russian peat sampler (70 × 500 m). We used the dendrochronologically based calibration program of Stuiver and Pearson (1986) (Table 1) to calculate variable rates of peat accumulation. Samples for peat bulk density, palynological and chemical measurements were taken from the same cores. To measure peat bulk density, we sampled each botanical layer separately. For paleobotanical and geochemical analyses, we used a continuous sampling method. Sampling frequency was calculated to cover layers formed over 50 yr.

We used standard laboratory treatment of pollen samples, consisting of KOH treatment, sieving and acetolyses. Stockmarr's (1971) tablet method was employed to determine the concentration of annual pollen influx. A minimum of 500 aboreal pollen (AP) were counted from each sample. The pollen diagram was published earlier (Koff 1992).

We were able to determine 32 chemical elements by neutron-activation analysis at the Institute of Physics, Latvian Academy of Sciences (Punning *et al.* 1989). We used a standard method to determine peat bulk density. The samples were dried at 60°C and the degree of the decomposition in percentages was estimated microscopically. Ilomets (1979) and Clymo (1983) found that the accumulation rate of peat, especially *Sphagnum* peat, changes little with time. Thus, knowing the mean peat per cm^2 and the ^{14}C age of a particular layer made it possible to calculate the age of each subsequent layer through the entire peat section:

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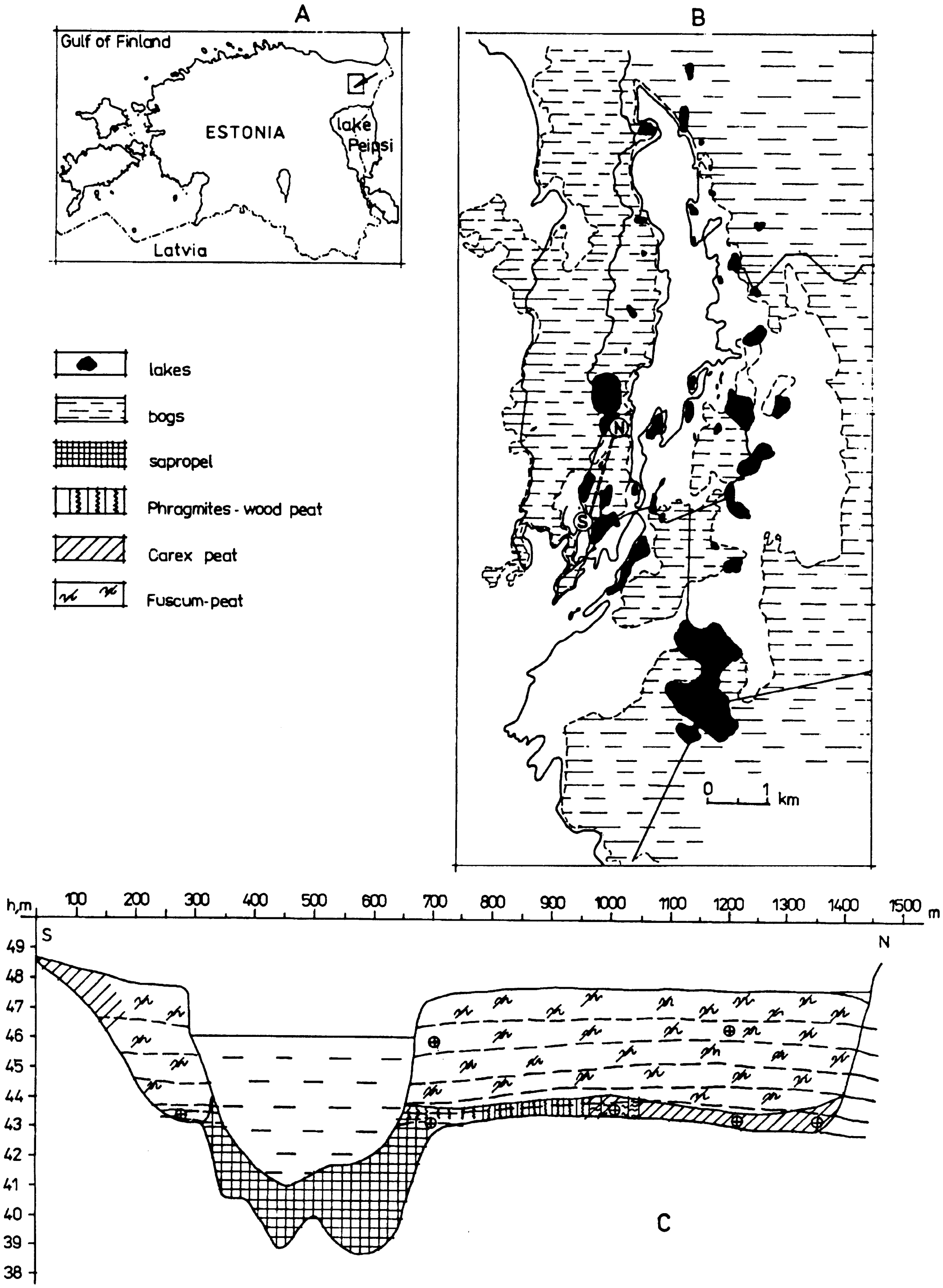

Fig. 1. Location of the study area (A, B) and cross-section of Niinsarre bog (C). In B, see N–S.

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$$A = \frac{\sum_{i=1}^{n_{^{14}C}} \sigma_i h_i}{T_{^{14}C}}$$

$$t_i = \frac{m_i}{A}$$

$$T_i = \sum_{i=1}^{n} t_i$$

where A = annual peat accumulation, g cm^{-2} yr^{-1}
σ_i = peat bulk density of layer i, g cm^{-3}
$T_{^{14}C}$ = ^{14}C age BP
$n_{^{14}C}$ = ^{14}C-dated layer, yr
t_i = formation time of layer i, yr
m_i = density of layer i, g cm^{-2}
h_i = thickness of layer i, cm
T_i = age of layer i.

TABLE 1. Radiocarbon Data Obtained for Niinsarre Peat

Laboratory number	Sample depth (cm)	Sample description	Radiocarbon age (BP)	Corrected age
Tln–825	119–126	*Sphagnum* peat	1530 ± 35	1430
Tln–823	231–238	*Sphagnum* peat	2635 ± 40	2790
Tln–826	354–361	*Sphagnum* peat	3670 ± 70	4080

RESULTS AND DISCUSSION

Although ^{14}C data from peat is quite reliable, we cannot establish a sufficiently detailed age scale for paleoenvironmental reconstruction because of the following limiting factors:

1. The inherent statistical error of ^{14}C determinations
2. The presence, in peat deposits, of organic matter of various ages (*e.g.*, rhizomes, roots), the obtained age of which characterizes the mean formation interval of the multicomponent system (Punning *et al.* 1985)
3. Continuing exchange with surroundings after the end of primary life activity (end of photosynthesis), which prevents interpretation as a closed system.

It must also be borne in mind that a considerable amount of material is needed for dating, and each date is comparatively expensive, which does not allow for many samples to be dated. In practice, the linear time scale is constructed between two ^{14}C dates, assuming constant linear accumulation

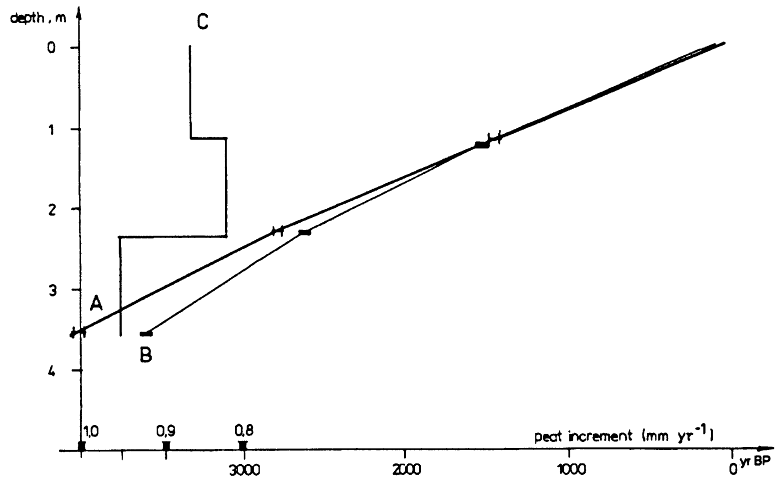

Fig. 2. Conventional (A) and corrected (B) ^{14}C data of peat increment, reconstructed with corrected ^{14}C data (C).

of peat in the given time interval. However, as also indicated by our studies (Punning *et al.* 1985), accumulation rates may differ, occurring by deposition gaps resulting from sharp changes in environmental conditions caused by hydrothermal, hydrologic or other natural or human activity. It is clear that other methods are needed to date peat deposits. In this study, we used the constant peat bulk density method (Ilomets 1980) and the constant pollen input method (Middeldorp 1984).

Figure 2 presents the depth-age curves based on conventional and calibrated ^{14}C ages, as well as a roughly determined mean peat increment between dated horizons. Figure 3 shows three curves: curve A describes the relation between depth of the investigated sample and its age calculated by the constant peat bulk density method; curve B is the peat accumulation cumulative curve; curve C shows the peat increment changes. These data indicate that the sequence of peat accumulation has changed twice – at *ca.* 3 and 1 ka BP.

To reconstruct the time scale, Middeldorp (1984) assumed a constant pollen influx over a given interval. Our studies indicate that the main factors influencing pollen influx are the change of hydrothermal conditions, the change of the surface area of the bog and anthropogenic influences (Koff 1987, 1989). Paleogeographic studies in the Kurtna kame field show that the Niinsarre bog area has changed little during the oligotrophic development phase (the last 3–4 ka) (Ilomets 1985) and that the water level has stabilized (Erg and Ilomets 1989).

Figure 4 presents the cumulative curves of arboreal pollen (AP). On this curve, we constructed successive straight lines and calculated the number of pollen grains per cm^2 on a depth scale for the interval between the break points of the lines. We then calculated the annual influx of pollen grains for the peat layers and determined the detailed time scale based on pollen quantity and calibrated ^{14}C ages (Fig. 5). This method can be applied only by constant peat accumulation and good preservation of all deposits. As the reconstruction is based on ^{14}C data, the destruction of a layer by fire would mean an anomalous increase in a certain interval.

Using neutron-activation data and our time scale, the cumulative curves of the concentrations and input of Mg were also constructed. The cumulative concentration curve refers to the intensity of

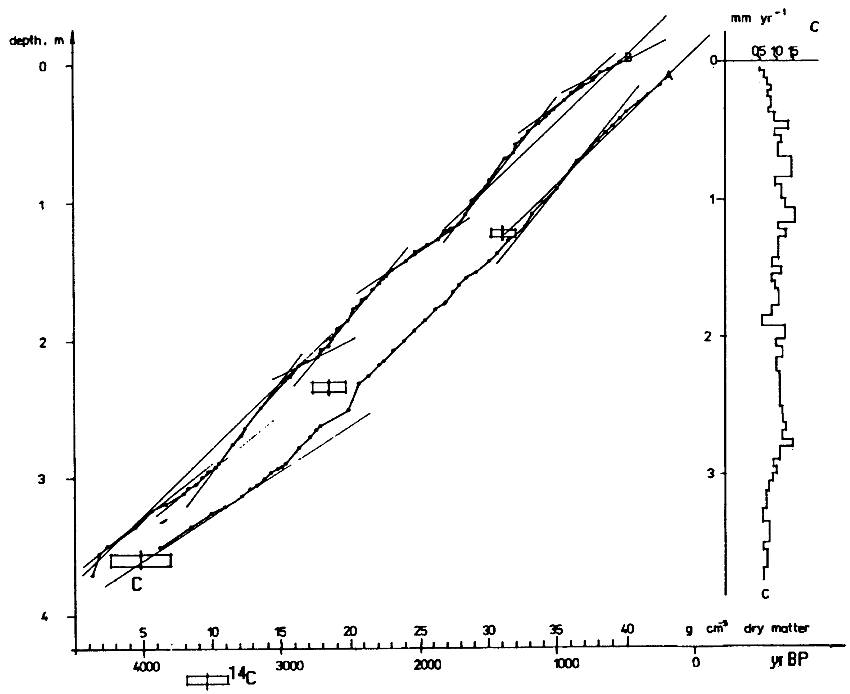

Fig. 3. Depth *vs.* constant peak bulk density age curve (A), cumulative curve of dry matter (g cm^{-3}) (B) and peat increment (mm yr^{-1}) (C) based on curve (A).

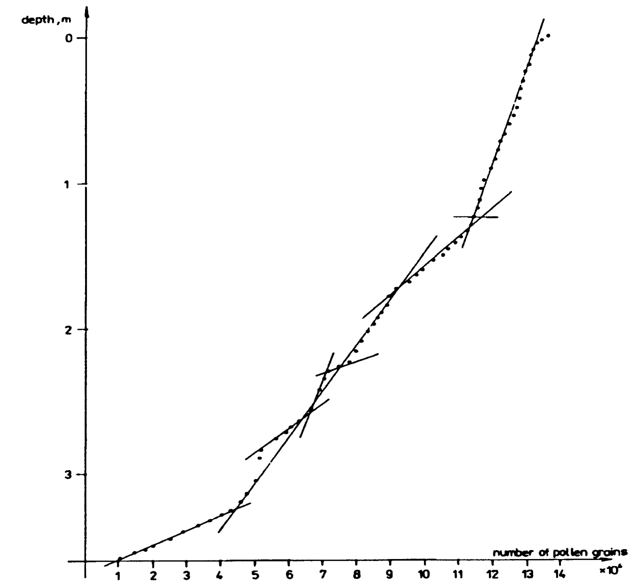

Fig. 4. Cumulative curve of AP sum

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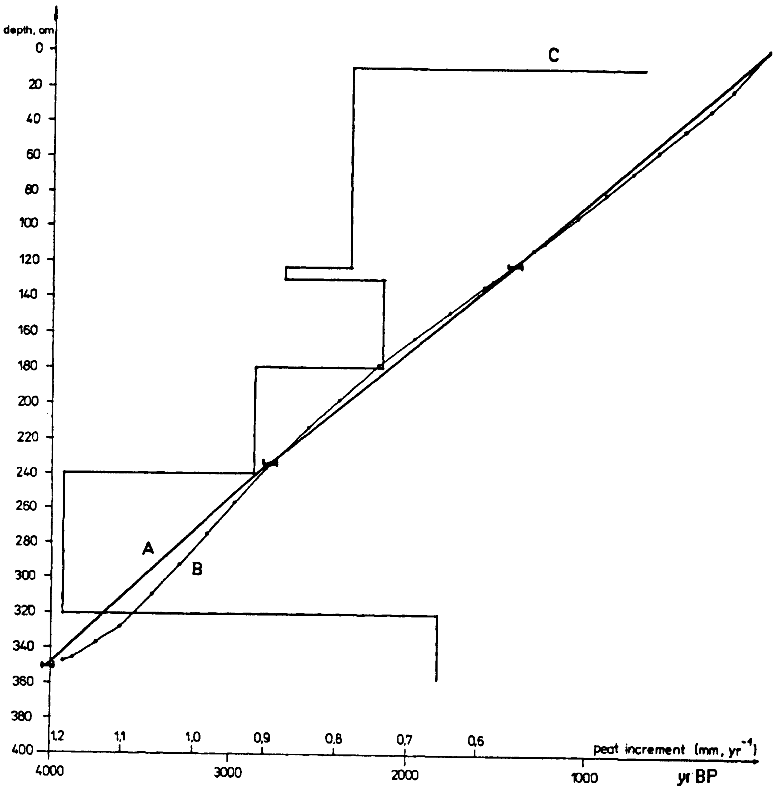

Fig. 5. Time scale based on calibrated ^{14}C age (A), constant pollen influx (B) and peat increment changes (C)

input or the change of the peat accumulation rate. Transferring the Figure 5 time scale to the vertical axis and adding the Mg input curve, one obtains a curve of considerably changed morphology. Figure 6 presents the curves for Mg influx. In the interval of 4–0.7 ka BP, a nearly straight line indicates constant Mg input. From 0.7 ka BP, Mg input increases and is especially sharp during the last 100 yr.

Menke (1987) obtained a similar curve for element distributions in a peat sequence in Schleswig-Holstein near Luebeck. Mencke believed that natural Mg input is determined by the terrigenous character of the area. Sharp changes in recent centuries may be the result of human activity.

Analogous curves may also be constructed to investigate the distribution and input dynamics of other elements. Naturally, the shapes of curves for separate elements differ greatly, *e.g.*, the shape of the quantity and temporal input curves of Zn do not change significantly. There is a slight decrease of Zn in the lower horizons; its input also decreases during the last 600–700 yr. The Al input curve does not change significantly, compared to the cumulative curve. As the main source of Al in the *Sphagnum* peat is atmospheric dust of mineral origin, the input curve also reflects the degree of vegetal cover.

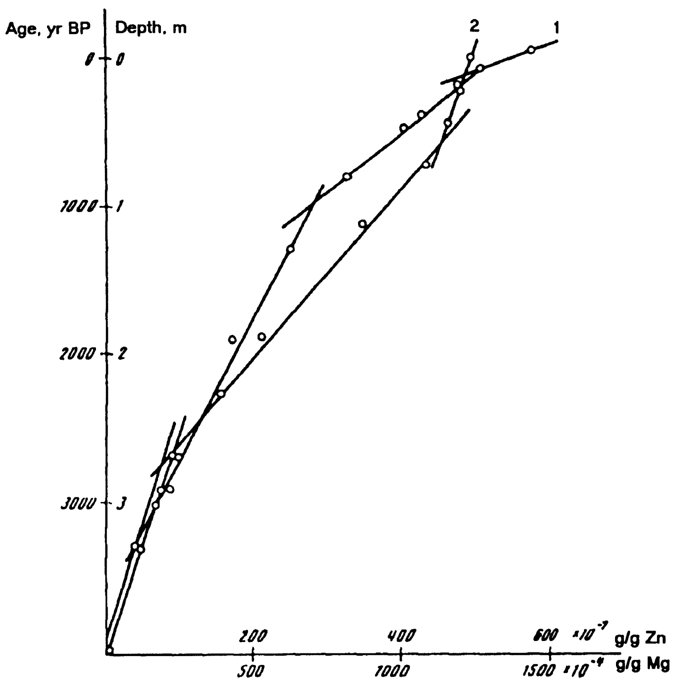

Fig. 6. Cumulative curve of Mg (1) and Zn (2)

Conclusion

An age scale based on the extrapolation of ^{14}C dates is not sufficient to study environmental conditions or to evaluate human activity over time. If major changes have not taken place in the development of the bog (*e.g.*, changes in size, hydrothermal conditions, human impact), one may use the assumption of constant pollen influx to increase time-scale precision. For analogous approximation, the time scale can also be made more precise by using Mg input dynamics. Primary deposition of pollen and chemical elements is well preserved in *Sphagnum* peat.

References

Clymo, R. 1983 Peat: Ecosystems of the world. In Gore, A., ed., *Mires: Swamp, Bog, Fen and Moor.* General Studies 4A. New York, Elsevier: 159–224.

Erg, K. and Ilomets, M. 1989 Influence of mining on the water level of Kurtna lakes – state and prognosis. In *The State and Development of Kurtna Lake System II.* Tallinn, Valgus: 47–54.

Ilomets, M. 1979 On the dynamics of fractional composition of peat forming horizon in Männikjärve peat bog. In *Physical, Isotope-Geochemical and Geological Methods in the Investigation of Anthropogenic Periods in Estonia.* Tallinn: 22–37.

_____1980 The determination of the age of peat layers based on the peat bulk density method. In *Proceedings of the Academy of Sciences of the ESSR, Geology* 29: 121.

_____1989 The development of the Puhatu mire system in the Holocene. In *The State and Development of the Kurtna Lake System II.* Tallinn, Valgus: 75–89.

Koff, T. 1987 The development of the vegetation in the Kurtna Lake district. In *The State and Development of Kurtna Lake System I.* Tallinn, Valgus: 41–46.

_____1989 The reconstruction of the natural conditions by using pollen analysis. In *The State and Development of Kurtna Lake System II.* Tallinn, Valgus: 68–74.

_____1992 Anthropogenic influence on the natural vegetation in Kurtna Lake district (Northeast Estonia). In Arrhenius, B., ed. *Laborativ Arkeologi V*, Stockholm University: 171-178.

Menke, B. 1987 Geobotanische und geochemische Untersuchungen an einem Torfprofil zur Frage natürlicher und anthropogener Elementverfrachtunger. *Geologisches Jahrbuch* A 95: 3–102.

Middeldorp, A. 1984 *Functional Paleoecology of Raised Bogs – An Analysis by Means of Pollen Density Dating, in Connection with the Regional Forest History.* Amsterdam: 124 p.

Punning, J.-M., Ilomets, M., Karofeld, E., Koff, T., Kozlova, M., Laugaste, R., Taure, I , Rajamäe, R. and Varvas, M. 1989 Technogenic changes in biochemical matter cycling. In *The State and Development of Kurtna Lake System II.* Tallinn, Valgus: 14–28.

Punning, J.-M., Ilomets, M., Koff, T., Rajamäe, R., Peterson, I. and Tiits, T. 1985 *Complex Stratigraphic-Paleographical Investigations of Lacustrine and Bog Sediments from Vällämäe Kettle-Hole (SE Estonia).* Tallinn: 58 p.

Stockmarr, J. 1971 Tablets with spores used in absolute pollen analyses. *Pollen and Spores* 13: 614-621.

Stuiver, M. and Pearson, G. W. 1986 High-precision calibration of the radiocarbon time scale, AD 1950–500 BC. *In* Stuiver, M. and Kra, R. S., eds. Proceedings of the 12th International ^{14}C Conference. *Radiocarbon* 28(2B): 805–838.