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HIGH RESOLUTION ^{14}C DATING OF SURFACE PEAT USING THE AMS TECHNIQUE

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In an AMS (accelerator mass spectrometric) determination of ^{14}C from moss-increment dated samples from a *Sphagnum fuscum* hummock, a clear peak representing the time of high ^{14}C activity in the atmosphere due to nuclear bomb tests was found. The ^{14}C activities in the peat profile at deeper levels, corresponding to the period down to 1600 BP, showed similar variations as the atmospheric values. The time-scale obtained from radiocarbon dating fitted well with results from moss-increment counting, pollen analysis and dendrochronological dating of a fire horizon. Using the bomb activity peak, the fraction of carbon emanating from deeper layers and refixed into growing peat was estimated. The fraction of soil carbon dioxide taken up by the contemporary *Sphagnum* sward was thus found to be in the order of 20%.

Keywords: Moss increment dating, peatlands, radiocarbon, *Sphagnum*

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INTRODUCTION

Precise dating of surface peat is essential in studies of carbon budgets of peatlands. Conventional radiocarbon dating has severe limitations on samples less than a few hundred years old. Dating using ^{210}Pb has been successful at some sites but doubtful at others, and it can only be applied to ages up to about 100 years. Pollen stratigraphy gives an age estimate usually for single levels only and, as a relative method, needs support from absolute dating. Recently, accelerator mass spectrometric (AMS) ^{14}C dating using "wiggle-matching" has demonstrated the possibility to date surface peat (van Geel & Mook 1989, Clymo et al. 1990).

In the present study, the AMS technique has been utilised to study the nuclear bomb-produced radiocarbon peak in a peat profile. After the observation of this peak in the profile further AMS dating of deeper levels in the profile were performed. The results were compared with the datings of the same peat profile by means of the moss-increment counting method, dendrochronological dating of a fire horizon, and pollen analysis.

MATERIAL AND METHODS

Peat samples were cored from a *Sphagnum fuscum* hummock at Lakkasuo eccentric mire complex, Orivesi, Finland (61°48′N, 24°19′E; c. 150 m a.s.l., cf. Laine et al. (1986) for the description of the mire). For sampling, a steel cylinder (length 60 cm), a 8 x 8 cm box corer (length 100 cm) and a Russian peat sampler (10 x 50 cm) were used. The different cores were correlated by means of the fixed surface level and a fire horizon found at 58 cm. Each core was sliced into 1.0–2.5-cm thick subsamples and dated by counting moss-increments of *Polytrichum strictum* (Tolonen et al. 1988) down to 40 cm. A well-defined charcoal layer at 58 cm was dated to AD 1845 by means of dendrochronological correlation of fire scars in two standing pine stumps on the same mire, about 50 m north of the site (Alm et al. 1992a, b). Pollen analysis below 55 cm was carried out in 5 cm intervals, counting 300–400 AP at each level.

In order to have well-defined material for the AMS analysis, about 20 stems of *Sphagnum fuscum* (from a 2.5 to 25-cm depth) and *S. magellanicum* (from a 55 to 140-cm depth) were carefully extracted from horizontal layers not thicker than 5 mm. These stems were cleaned in weak hydrochloric acid, washed in distilled water and dried before being submitted for AMS analysis at the accelerator laboratory in Uppsala, Sweden. No further chemical treatment was applied before combustion and reduction to graphite.

RESULTS AND DISCUSSION

Results for the uppermost part of the profile covering the time of the nuclear bomb peak are presented in Table 1 and for the lower part of the profile in Table 2. The ^{14}C activity (as given in Table 1) is plotted against depth in Fig. 1. Maximum activity (+564 per mil) was found at a depth of 19 cm. For comparison, the atmospheric ^{14}C activity during the period 1959–1983 is plotted in Fig. 2. The activity values used are the "clean air" values proposed by Levin et al. (1985) for the Northern Hemisphere. These values agree with the ^{14}C activity of annual plant material from corresponding years, e.g. tree-rings from a southern German pine (Levin et al. 1985) and a Swedish oak (Olsson & Possnert 1992), and

Table 1. Results from analysis of the uppermost 25 cm of the peat profile at Lakkasuo. T_m is the date of the sample based on moss-increment counting and ΔT_m gives the time span of the sample based on the same method together with the standard deviation. The ^{14}C values are based on AMS measurements and expressed as the relative difference between the sample activity corrected for age and the absolute international ^{14}C standard (Stuiver & Polach 1977). $\delta^{13}C$ values are given versus the PDB standard.

Sample	Depth, cm	T_m	ΔT_m (a)	$\Delta^{14}C$, ‰	$\delta^{13}C$, ‰ PDB
A1	2.50–5.00	1985–1988	3.1 ± 1.2	149.1 ± 8.7	–26.8
A2	12.50–15.00	1969–1973	4.7 ± 0.6	341.1 ± 9.7	–26.3
A3	15.00–17.50	1963–1969	5.5 ± 1.1	445.2 ± 10.1	–26.9
A4	17.50–18.75	1960–1963	3.2 ± 0.6	501.7 ± 10.9	–26.5
A5	18.75–20.00	1957–1960	2.8 ± 0.4	564.0 ± 11.1	–24.8
A6	20.00–21.25	1954–1957	2.6 ± 0.5	317.1 ± 8.9	–24.9
A7	21.25–22.50	1951–1954	3.1 ± 0.8	180.8 ± 8.4	–24.2
A8	23.75–25.00	1942–1946	3.8 ± 0.9	98.9 ± 7.9	–24.3

Table 2. Carbon isotope data for the lower part of the peat profile at Lakkasuo. The $\Delta^{14}C$ values are from AMS measurements. The $\delta^{13}C$ values flagged with * were measured at the Dating Laboratory in Helsinki on parallel samples.

Sample	Depth, cm	$\Delta^{14}C$, ‰	$\delta^{13}C$, ‰ PDB	^{14}C Age, BP
B1	55	7.3 ± 9.3	–26.9	–20 ± 70
B2	70	–62.8 ± 6.5	–26.6	480 ± 55
B3	75	–9.6 ± 8.6	–27.3	35 ± 70
B4	80	–40.9 ± 8.1	–25.5	295 ± 70
B5	90	–36.5 ± 6.5	–25.1	260 ± 55
B6	110	–43.0 ± 7.9	–26.3	310 ± 65
B7	115	–49.3 ± 8.1	–26.7	365 ± 70
B8	121	–86.3 ± 7.9	–27.0*	680 ± 70
B9	125	–123.2 ± 9.7	–26.4*	1015 ± 90
B10	130	–145.8 ± 8.5	–27.5*	1225 ± 80
B11	140	–184.2 ± 6.7	–28.2*	1595 ± 65

Danish cereals (Tauber 1967). Since the time span, ΔTm, covered by each sample studied varied from 2.6 to 5.5 years according to the moss-increment method (Table 1), a smoothed mean-value curve is included in Fig. 2. According to this curve, maximum ^{14}C activity occurred in 1965. Detailed measurements of tropospheric ^{14}C activity show a maximum for August–September of 1963 (Nydal & Lövseth 1983).

Maximum ^{14}C activity at a 19-cm depth (Fig. 1) dates to 1958 based on moss-increment counting. There is thus a discrepancy of the order of 5–10 years between the moss-increment dating and the dating based on bomb-induced ^{14}C activity. This minor discrepancy is mainly thought to be due to problems in increment counting in the very topmost layer. The very steep rise in the activity around 21 cm in Fig. 1, together with the rise between 1960 and 1965 in Fig. 2 indicates that a good time resolution can be obtained from moss increments.

The measured ^{14}C activity in the peat was lower than the atmospheric mean activity (Figs. 1, 2). If the time span for each peat sample studied is comparable to the five-year mean in Fig. 2, the activity peak values in Figs. 1 and 2 can be compared to give an indication of the fraction of soil CO_2 taken up by the peat during growth. The activity of the emanating soil CO_2 is not known, but as the lowermost layers of the bog have been dated to about 3500 BP we can assume the $\Delta^{14}C$ activity to be within the limits 0 to –350‰. The amount of soil CO_2 as a fraction of the total CO_2 taken up by the peat around 1965 would thus be in the order of 20 ± 5%. In a study of ^{14}C concentration in the annual growth rings of a Sitka spruce, Grootes et al. (1989) obtained a value of between 13% and 28% for the addition of biospheric CO_2 to the canopy air CO_2 used by the tree for stem cellulose production. This result gives good support for our values from peat described above. We hope that measurements of gas emissions and their ^{14}C activity at the site will give more information on this important question.

A well-defined charcoal layer at 58 cm (Fig. 3) was dated at AD 1845 by dendrochronology (Alm et al. 1992a, b). As the moss-increment counting could not be extended to these depths, we have no independent dating for this part of the profile and therefore wiggle matching can not be applied directly. However, the curve in Fig. 3 shows many similarities with the ^{14}C calibration curve for this time span (Fig. 4), indicating a fairly constant growth rate for the peat. Thus, the depth at 70 cm may be correlated with the peak around AD 1800 in the calibration curve, depth 75 cm with the dip around AD 1700, and the depths 80–120 cm with the plateau in the calibration curve at AD 1450–1600. In pollen spectra (Fig. 5), a distinct decrease in *Picea* can

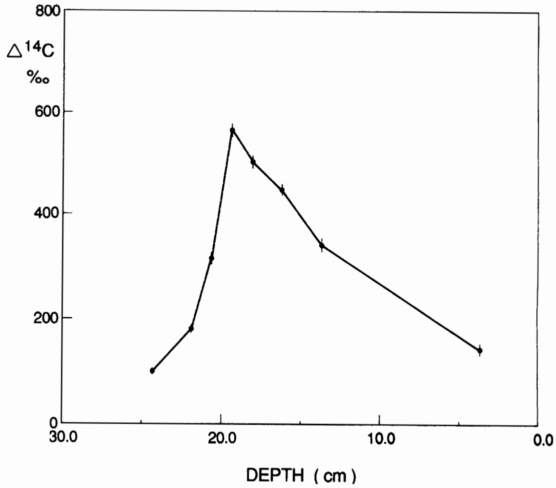

Fig. 1. Core 4L27, Lakkasuo mire, September 1991. A plot of ^{14}C activity (mean with S.D. bars) vs. depth for the uppermost 25 cm. $\Delta^{14}C$ is the relative difference between the 'normal value' ie. the absolute international standard and the age corrected sample activity according to Stuiver and Polach (1977).

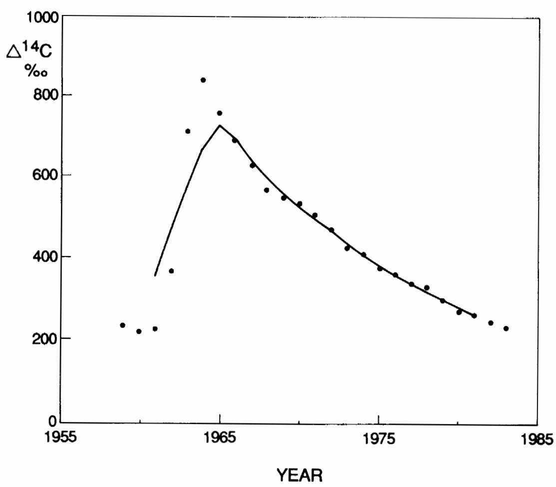

Fig. 2. The atmospheric ^{14}C activity for the period AD 1959–1983. Dots represent "clean air" yearly mean values according to Levin et al. (1985). The curve indicates a 5-year running mean as calculated from their values.

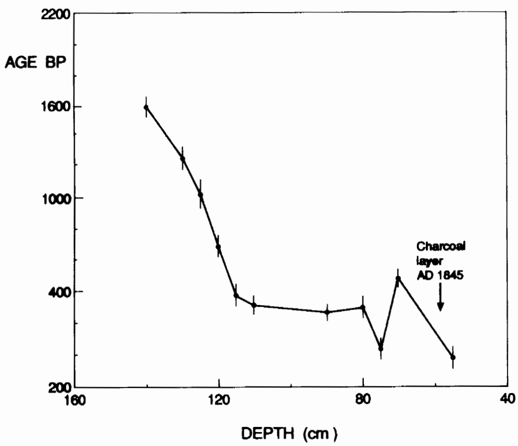

Fig. 3. Core 4L27, Lakkasuo mire, September 1991. ^{14}C ages (mean with S.D.) measured for the *Sphagnum* mosses of the samples from the depth interval 55–140 cm.(see Table 2).

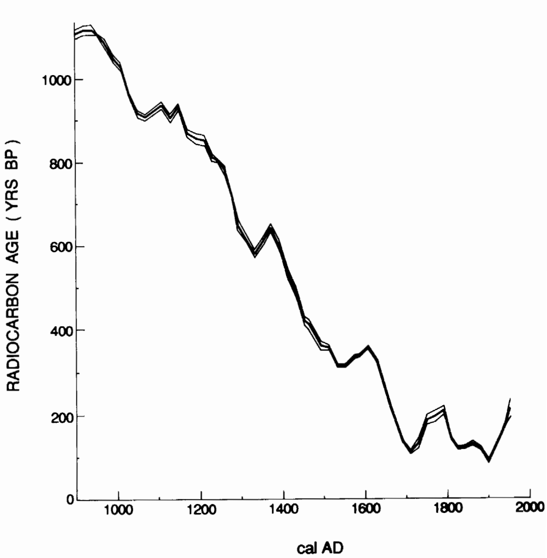

Fig. 4. The calibration curve for ^{14}C dates in the time interval AD 1950–1000. Redrawn after Stuiver and Pearson (1986).

be observed at 130 cm. This change in the pollen diagram from the southern part of Lakkasuo mire, about 600 m south from 4L27, has been ^{14}C-dated to AD 840 ± 100 (Hel-3129), well in agreement with the present result. Several cultural pollen types start to appear just above this level (Fig. 5).

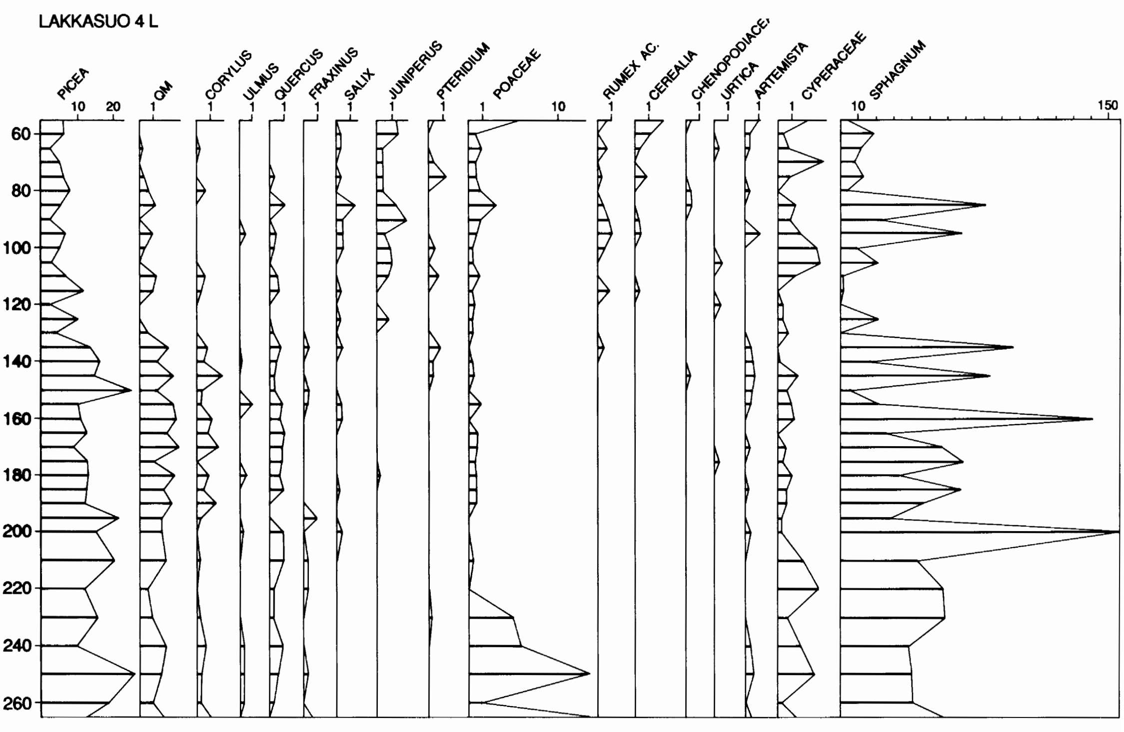

Fig. 5. Core 4L27, Lakkasuo mire, September 1991. Relative pollen and spore frequencies for selected taxa.

There is a distinct change in the $\delta^{13}C$ values given in Table 1 at a depth of around 20 cm. This depth corresponds to the mean water level at the site, and the change in isotopic composition may be connected to the methane production below this level (Martikainen et al. 1992).

CONCLUSIONS

Polach and Singh (1980) demonstrated strongly enhanced ^{14}C activity in the surface peat of Bega Swamp, Australia. However, they had no independent dating control and the interpretation of their results is therefore hampered. In our study, where the ^{14}C peak from bomb tests was encountered from strata dated independently *a priori* by the moss increment method, encourages us to believe that AMS can be applied to date the moss material of peats. We have many examples of peat datings which are stratigraphically inconsistent and younger than expected. The reason for this is the transport of younger carbon downward, either by living subsurface parts of plants or water flow or both.

A successful dating of surface peats can be done by means of AMS ^{14}C-technique from cleaned *Sphagnum* moss material. Further comparative studies are needed to elucidate whether this is true for other mosses and parts of vascular plants, such as fruits and seeds preserved in peats.

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