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A COMPARISON OF ASH DATING AND MOSS-INCREMENT DATING IN *SPHAGNUM* HUMMOCKS

Tuhka-ajoitusmenetelmän ja sammalvuosikasvainajoituksen vertailu rahkamättäissä

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A comparison of two methods for dating recent ombrotrophic peat hummocks was made at three mires. For depths approximately below 10 cm, acid insoluble ash dating gave greater ages than moss-increment dating; for depths above 10 cm, the methods showed more similar ages. The moss-increment dates were assumed to be generally correct since there was a good correlation between several independent dating results and moss-increment ages at one of the study sites. Despite the declining accuracy of moss-increment dating with depth, it should be the method chosen for dating recent peat in areas where the assumption of constant acid insoluble ash deposition is invalid. Increment dating is practically useful only in the moss hummocks, except for when the moss stems have been compressed into a horizontal position.

Keywords: Dating, mineral dust, peatlands, Sphagnum, surface peats

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INTRODUCTION

Accurate dating of recent peat profiles is essential for growth and production studies and in studies examining nutrient budgets, as well as recent increases in anthropogenic inputs (see Tolonen 1989 and references therein). Many methods for dating have been developed using a variety of factors such as pollen grains, moss growth increments, isotopes of C, Pb, and Cs, and ash.

Carbon-14 was the first element used for dating peat, but has been found to be unsuitable for material less than 200 years old (Livett et al. 1979). The examination of pollen profiles has proved useful for identifying periods of major vegetation changes, such as the onset of cultivation in an area (M. Tolonen 1985). Since changes in plant community structure are usually not instantaneous, pollen analysis at best allows one to assign a range of years to a particular peat stratum. Also, in the past 100–200 years there may not have been any radical vegetation changes in an area. Isotopes of Pb and Cs have been widely used for dating recent deposits in lakes and bogs. However, ^{137}Cs is no longer considered useful for the bog environment (El-Daoushy et al. 1982) since it is mobile and actively taken up by plants (Pakarinen & Tolonen 1977). The use of ^{210}Pb has been considered successful in some studies (Oldfield et al. 1979, Hemond 1980, El-Daoushy et al. 1982), although others feel that there may be wash down of Pb (Aaby et al. 1978) or redox control of Pb profiles (Damman 1978).

Two other dating methods with fewer limitations were examined in the present study. Moss-increment dating involves counting annual growth markers on *Sphagnum* and *Polytrichum* stems to determine the age of peat in a particular stratum (Pakarinen & Tolonen 1977, El-Daoushy & Tolonen 1984, Tolonen 1984). Dating, using the acid insoluble ash (AIA) fraction of peat, was proposed by Urban (1983) and also used successfully by FitzGerald (1986). The technique assumes that the AIA fraction is immobile and that deposition rates have remained relatively constant over the past 100–200 years.

The purpose of this study is to compare moss-increment dating and AIA-dating in terms of the comparability of the results and the ease of use, and to assess the suitability of each for dating recent peat.

METHODS

Study sites

The sites studied were Kunonniemensuo in Kitee (62°05´N, 30°10´E), Paritsansuo in Joensuu (62°36´N, 29°55´E) and Kaurastensuo in the Lammi commune (60°01´N, 24°58´E). Based upon the classification of mire complex zones by Ruuhijärvi (1982), Kaurastensuo lies on the boundary between the concentric and eccentric raised bog region, while Kunonniemensuo and Paritsansuo are in the region of eccentric raised bogs (Fig. 1). All sites are ombrotrophic raised bogs with scattered *Pinus sylvestris*. Hummock vegetation consists of a *Sphagnum fuscum* moss carpet with *S. magellanicum*, *S. nemoreum* and *Polytrichum strictum* as the major moss species, and *Calluna vulgaris*, *Empetrum nigrum* and *Eriophorum vaginatum* as the major vascular plant species.

Fig. 1. Location of study sites. 1 = Kunonniemensuo, 2 = Paritsansuo, 3 = Kaurastensuo. The thick line separates raised bogs from aapamires.

Kuva 1. Tutkimuskohteiden sijainti. Kuvaan on merkitty myös koho- ja aapasoiden välinen raja.

Sampling procedures

Cores were collected using a thin-walled steel corer 12 cm in diameter. Cores from adjacent hummocks were collected for moss dating and AIA determination. They were cut into slices 5 cm thick and wrapped in Saran Wrap. to determine the annual input of AIA at each site. Moss capitula were collected at the end of the growing season.

Laboratory procedures

Procedures for moss-increment dating are described in Pakarinen and Tolonen (1977) and Tolonen et al. (1988). The average peat layer age is calculated by dividing the mean stem length by the mean annual increment length. Moss-increment dates for Kunonniemensuo were published previously (El-Daoushy & Tolonen 1984, Tolonen 1984).

The AIA fraction of the peat is determined by the following method. Peat is ashed at 450°C for 4 h and then extracted in 10 ml of a 1:1 $HCl:HNO_3$ mixture. This mixture is diluted with distilled water and filtered through ashless hardened filter paper. The remaining residue and filter are ashed at 450°C for 4 h and the resulting material is the AIA fraction.

The age at the base of a peat segment equals the amount of AIA in the segment divided by the AIA deposition rate. The AIA deposition rate equals the annual *Sphagnum* production multiplied by the concentration of AIA in the capitula.

For this study, *Sphagnum* productivities of 260 g/m^2/yr (El-Daoushy & Tolonen 1984) for Kunonniemensuo, 254 g m^{-2} yr^{-1} (Silvola & Hanski 1979) for Kaurastensuo, and 161 g/m^2/yr for Paritsansuo were used to calculate annual input of AIA. The production at Paritsansuo was determined from the moss-increment lengths and bulk density of the top-most layer using the model derived by Pakarinen (1978).

RESULTS

AIA input

Based on moss productivity and AIA content of the capitula, the annual input at Kunonniemensuo is 0.621 g AIA/m^2/yr; at Paritsansuo, 0.488 g AIA/m^2/yr; and at Kaurastensuo, 0.306 g AIA/m^2/yr.

Moss age distribution

At Kaurastensuo and Paritsansuo the moss-increment ages of the core segments were relatively uniform, varying from approximately 4–8 years of accumulation per 5 cm of peat (Table 1). The cores from these two sites represent about 30 years of peat accumulation. For Kunonniemensuo, however, the ages of the core segments varied about 10-fold; ranging from approximately 6–60 years of accumulation per 5 cm of peat. The number of years per interval increased with depth. This core reflects about 200 years of peat formation.

AIA content

The amount of AIA present in each core segment varied tremendously, from approximately 1.5–55 g AIA/m^2/5 cm (Table 1). At Kaurastensuo the AIA content of the 15–25 cm interval is 2–3 times greater than for the peat above. The amount of AIA in the 15–20 cm interval at Paritsansuo is more than twice that present in the rest of the core. At Kunonniemensuo, the first and last core segments have similar AIA content, while the remainder of the core contains more than twice as much.

AIA and moss-increment dates vs. depth

At all three sites, the AIA age is greater than the moss-increment age for a given depth. However, the ages derived by the two methods are more similar for the upper

Table 1. Summary of the data of moss-increment and AIA-dating for the three sites. A = moss age of segment (yrs), B = cumulative moss age (±SD), C = accumulation of AIA (g m^{-2} 5 cm^{-1}), D = AIA age of segment, E = cumulative AIA age (±SD).

Taulukko 1. Yhteenveto sammalvuosikasvainajoituksen ja AIA-ajoituksen aineistosta. A = kerrostumisaika (vuosissa) sammalajoituksen mukaan, B = kerroksen alarajan ikä vuosikasvainajoituksen mukaan, C = kerroksen AIA-pitoisuus, D = kerroksen vuosien määrä AIA-menetelmällä, E = kerroksen alarajan ikä AIA-ajoituksen mukaan.

Depth/*Syvyys*, cm	A	B	C	D	E
Kunonniemensuo					
0–10	12.3	12.3±1	16.34	26.3	26.3±0.4
10–20	20.2	32.5±5	35.86	57.7	84.0±1.3
20–30	33.6	66.1±10	37.96	61.1	145.2±2.2
30–35	29.9	96.0±15	55.99	90.2	235.3±2.6
35–40	55.2	151.2±20	41.60	67.0	302.3±4.1
40–45	62.8	214.0±30	19.27	31.0	333.4±4.4
Paritsansuo					
0–5	6.0	6.0±0.9	2.98	6.1	6.1±0.0
5–10	5.4	11.4±1.4	5.90	12.1	18.2±0.4
10–15	7.6	19.0±2.1	9.94	20.4	38.6±0.7
15–20	8.2	27.2±2.7	17.92	36.7	75.3±1.0
20–25	6.6	33.8±3.3	9.00	18.5	93.8±1.3
Kaurastensuo					
0–5	5.4	5.4±0.9	2.42	7.9	7.9±0.1
5–10	4.9	10.3±1.5	1.58	5.2	13.1±0.2
10–15	3.9	14.2±1.9	4.08	13.3	26.4±0.2
15–20	5.3	19.5±3.3	8.99	29.4	55.8±0.3
20–25	8.0	27.5±3.8	11.72	38.3	94.1±0.5

10 cm of peat. At Kunonniemensuo (Fig. 2), the AIA and increment lines are similar in shape, though the slope of the AIA curve is steeper. Each line curves upward indicating a greater change in age per unit depth in the deeper peat. For Paritsansuo (Fig. 3) and Kaurastensuo (Fig. 4), the slope of the AIA curve is much greater than the moss curve, indicating a greater change in predicted AIA age per unit change in depth.

DISCUSSION

Before an assessment of each dating method can be made, it must be determined which set of peat ages is most accurate. El-Daoushy et al. (1982) compared moss-increment (*Polytrichum strictum* and *Sphagnum fuscum*) dates with lead-210 dates at Kunonniemensuo (using the same *Sphagnum fuscum* hummock we obtained the core for the present study) and found good agreement between these two methods. Furthermore, these datings corroborated the radiocarbon datings and detailed pollen analysis very well (Tolonen 1984). Therefore, we will accept the present moss-increment dates as generally correct and use them as a reference.

The within-core variation of moss-increment ages per peat segment was of a much smaller magnitude than the variation

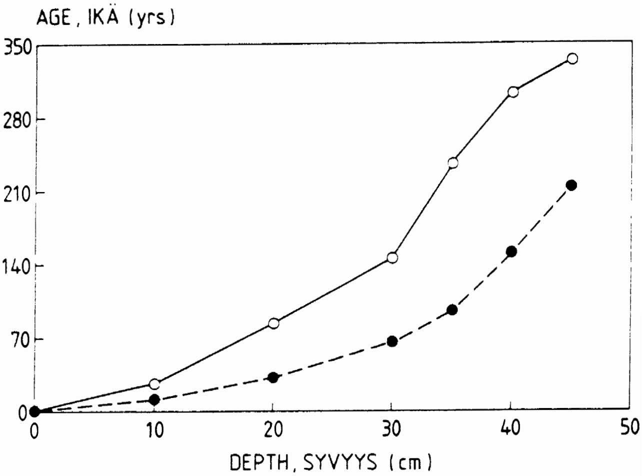

Fig. 2. Kunonniemensuo bog, Kitee. Ages obtained by means of AIA-dating (solid line, crosses) and by moss-increment dating (interrupted line, triangles) plotted against depth (cm).

Kuva 2. Kunonniemensuo, Kitee. Tuhka-ajoitusmenetelmän (kokoviiva, ristit) avulla saatujen ikien vertaaminen samojen kerrosten sammalvuosikasvainajoitukseen (katkoviiva, kolmiot).

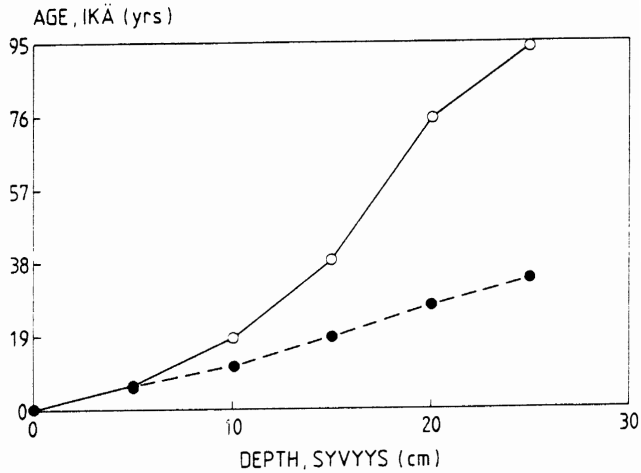

Fig. 3. Paritsansuo, Joensuu. Age vs. depth curves. Symbols as in Fig. 2.

Kuva 3. Paritsansuo, Joensuu. Ikä/syvyysjakaumat. Merkkien selitykset samat kuin kuvassa 2.

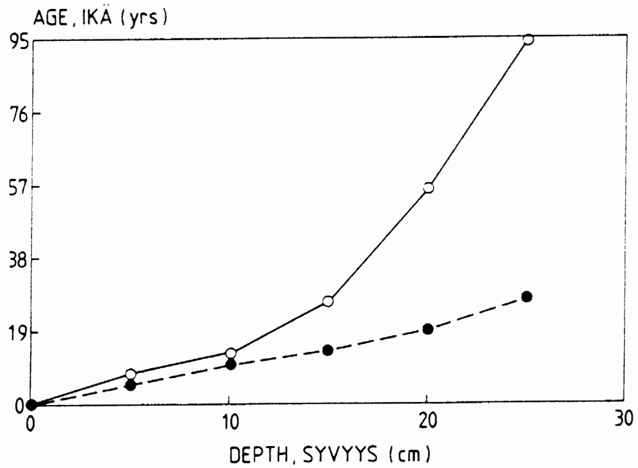

Fig. 4. Kaurastensuo, Lammi. Age vs. depth curves. Symbols as in Fig. 2.

Kuva 4. Kaurastensuo, Lammi. Ikä/syvyysjakaumat. Merkkien selitykset samat kuin kuvassa 2.

in AIA content. The input of AIA is dependent upon the amount of clearance, fires, road building, and other disturbances which occur in an area. At Kunonniemensuo, in particular, the elevated AIA levels in the peat at the 10–40-cm-depth are probably due to extensive slash and burn agriculture in the area in the past (Vuorinen 1978, Tolonen 1984). Kunonniemensuo also had the highest annual input of AIA, which is most likely caused by a nearby gravel pit.

Kunonniemensuo

In the first segment at Kunonniemensuo, the predicted AIA age is twice that of the moss-increment age (Fig. 2). This may be due to a very loose hummock *Sphagnum fuscum* carpet with scattered *S. nemoreum* and *S. magellanicum*, where the concentration of AIA is probably much higher in the living lower parts of mosses than in the capitulas. Malmer (1988) found about a two times higher AIA content in the lowest segments of *Sphagnum magellanicum* (a hummock species) than in the uppermost 1.5 cm segments. He concluded that it resulted from a continuous accumulation during the whole period the moss plants were functioning since there were no losses in organic matter. As depth increased, the AIA age overestimated the moss-increment age to a greater and greater extent. This is due to an increase in AIA accumulation with depth, probably caused by higher AIA inputs in the past. Slash and burn practices had generally ended by the beginning of the 20th century (Huttunen 1980), resulting in a reduction in AIA input in the recent past.

The Kunonniemensuo core represents much older and deeper peat than the other two, and the effect of compaction on the age/depth curve is well illustrated. Although the predicted ages are different, both lines curve upward, indicating that loss of organic matter and compaction prevents age/depth curves from being linear.

Paritsansuo

At Paritsansuo (Fig. 3) the increment age vs. depth curve is linear, and it encompasses about 30 years of accumulation. The predicted increment and AIA ages for the first core segment are identical. In the deeper peat, however, the AIA age overestimates the increment age; the magnitude of difference between predicted dates increasing with depth. Here, also, it is likely that past AIA input was greater than current input, since the amount of AIA is greater at deeper levels and relatively little peat compaction has taken place. Paritsansuo is adjacent to a major road that was paved approximately 10–15 years ago. Road construction and the former dirt road would have contributed much more AIA input than the present paved one.

Kaurastensuo

According to the measurements by Lindholm (1979), the mean annual height growth of *Sphagnum fuscum* in 1970–1977 was 11.6 mm ± 0.9 SD/a in hummocks of Kaurastensuo and the adjacent raised bog Laaviosuo. The figures are in good agreement with ours (Table 1). At our site (Fig. 4), the predicted increment and AIA ages are similar down to a 10-cm-depth. Below that level, the AIA age overestimates the increment age by a greater and greater magnitude. The increment age vs. depth curve is linear, again representing about 30 years of peat accumulation. The AIA content of the peat increases with depth, reflecting the higher accumulation rate of AIA in the deeper peat. In the area around Kaurastensuo there are likely to be fewer dirt roads and less active wind erosion of surrounding mineral soils than in the past.

Increment dating utilizes growth markers on the moss stems. These markers are relatively distinct within certain *Bryales* species, like *Polytrichum strictum*, but within *Sphagnum* stems they are not always obvious, especially in older peat. Removing moss stems from a core slice is sometimes difficult, as well. The method is useful for hummocks at depths where the moss stems are still in a slightly vertical position. For this reason, the increment dating method is restricted in moss hollows and in lawn vegetation to the topmost (usually less than ten) centimetres. Very little equipment is required; scissors, forceps, and a dissecting scope. Samples can be collected at any time during the growing season, and the time to process the material, and the accuracy of the method will depend upon the moss species present and the skill of the person doing the measurements.

AIA-dating relies upon accurate measurement of the weight of the AIA fraction. Especially in surface layers, the weight of the AIA fraction is very low and technical difficulties can effect the results. Cores, and especially capitula, should be collected near the end of the growing season so that all of the annual input is included. A 50 cm long core and capitula can be completely processed within two weeks of collection. The major drawback of AIA-dating is that the assumption of constant AIA deposition is probably not valid, at least in areas which are influenced by anthropogenic factors. The accuracy of AIA dates also depends upon the correct determination of annual input, and thus upon the correct production values applied for the sites. It is well known that production varies from one hummock to another (e.g. Vasander 1981). Therefore, it would be much better to measure the actual production from the same hummock rather than use any general values for this mire site type in the given area.

The major drawback of moss-increment dating is that the work is quite tedious and annual increments can be missed. Also, the accuracy of increment dating decreases with depth, since it becomes more difficult to count the annual increments. Moss-increment dating is, however, probably the best overall method because possible changes in moss growth due to anthropogenic inputs do not affect its accuracy.

CONCLUSIONS

In summary, because of unpredictable variations in local AIA input over time, the moss-increment method should be the best method for dating recent peat. However, the approach is practically restricted to hummocks with well-developed moss cover. The method becomes less accurate with depth, and even impossible once the moss stems have been compressed into a horizontal position.

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TIIVISTELMÄ:

TUHKA-AJOITUSMENETELMÄN JA SAMMALVUOSIKASVAINAJOITUKSEN VERTAILU RAHKAMÄTTÄISSÄ

Pintaturpeiden luotettava ajoittaminen on viimeaikoina koettu tärkeäksi mm. suoekosysteemien tuotantotutkimuksissa, ravinteiden kierron selvittämisessä ja ilmansaasteiden seurannassa. Radiohiiliajoitus on lähes käyttökelvoton 200 vuotta nuoremmissa kerrostumissa. Lyijyn radioaktiiviseen isotooppiin (lyijy-210) perustuvalla menetelmällä on yleensä pystytty hyvin ajoittamaan sedimenttejä ja eräissä tutkimuksissa myös pintaturpeita aina 150 vuotta nykyajasta.

Yhdysvalloissa on viime vuosina kehitetty "paremman puutteessa" ns. tuhka-ajoitusmenetelmää (AIA, Acid Insoluble Ash) ombrotrofisille turpeille, joiden ravinnelähde on sadevesi. Menetelmä on yksinkertainen. Määritetään turvepatsaan turpeen tiheys kerroksittain ja samojen kerrosten happoon liukenemattoman tuhkan määrä sekä vielä näytteenottopaikan nykyinen mineraalipölyn vuosikertymä suon pinnalle. Kunkin kerroksen vuosien määrä lasketaan olettamalla mineraalipölyn vuo paikalla vakioksi. Nykyinen AIA:n vuosivuo saadaan esim. määrittämällä kasvukauden lopussa näytepaikan rahkasammalten latvusten AIA-pitoisuus ja kertomalla se paikan sammalkerroksen vuosituotoksella.

Sammalvuosikasvainajoitus (vuosikasvainajoitus) perustuu aitosammalten (useimmin rämekarhunsammalen) ja/tai rahkasammalten vuosikasvainten mittaamiseen turvekerroksissa. Tietyissä lajeissa ja tiettyinä vuosina vuosikasvaimet ovat luotettavasti erotettavissa. Menetelmä sopii lähinnä mättäisiin ja on niissäkin käyttökelpoinen vain niin kauan kuin versot ovat niin pystysuorassa, että versot ulottuvat läpi leikatun turvekerroksen. Kustakin kerroksesta mitataan tilastollinen määrä oikaistuja sammalversoja ja niistä havaittavissa olevia vuosikasvaimia. Kerroksen syntymiseen kuluneiden vuosien määrä saadaan jakamalla versopituuksien keskiarvo kasvainten keskiarvolla. Hajontaluvut yhdistetään.

Kolmen suon rahkamättäissä verrattiin näitä kahta menetelmää toisiinsa (Kuvat 1–4 ja taulukko 1). AIA-iät olivat kauttaaltaan suuremmat kuin sammalajoituksen antamat. Tulokset poikkesivat yleensä yhä enemmän toisistaan syvyyden myötä. Ikä/syvyys käyrien muodossa on kyllä yhteisiäkin piirteitä (etenkin Kuva 3).

Tulosta tulkittaessa lähtökohdaksi otettiin Kiteen Kunonniemensuo, jonka sammalajoitus oli aikaisemmissa tutkimuksissa todettu olevan hyvin sopusoinnussa kolmen muun itsenäisen ajoitusmenetelmän tulosten kanssa samasta turvepatsaasta: radiolyijy- ja radiohiiliajoitukset ja vielä yksityiskohtainen siitepölyanalyysi, joka viimemainittu oli kalibroitu läheisen vuosilustoisen järven siitepölyanalyysiin. Oletimme siksi sammalajoitukset lähinnä oikeiksi ja pohdimme, mikä vanhensi AIA-ikiä niihin verrattuna.

Nykyinen AIA-vuo oli arvioitu rahkasammalten latvusten AIA-pitoisuuden nojalla. Paritsansuon näytemätäs oli tiivispintainen ja siinä pintakerroksen ajoitukset veivät yksiin, toisten näytemättäiden sammalatvukset olivat löyhempiä, erikoisesti Kunonniemensuossa hyvin pehmyttä pintaa. Huomattava osa nykyisestä AIA-laskeumasta on löyhissä mättäissä voinut kiinnittyä latvuksen alaiseen sammalkerrokseen (Malmer 1988). Todennäköinen syy AIA-ikien voimakkaaseen poikkeamiseen liian vanhaan suuntaan syvyyden myötä on paikan kivennäispölyn vuon muutos turvekerrostuman syntyaikana. Kaikkien kohdesoiden välittömän ympäristön maankäytön historia voi pitkälti selittää nykyistä suuremmaksi oletettua pölylaskeumaa lähimenneisyydessä. Kolmas tuhka-ajoitusmenetelmän tuloksiin voimakkaasti vaikuttava seikka on sammaltuotoksen suuri vaihtelu mättäästä toiseen ja jo samankin mättään eri osissa. Siksi sammalkerroksen vuosituotos pitäisikin määrittää itse ajoitettavasta turvepatsaasta.

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