The Usè of Laminated Sediments to Test Methods of Dating and Palaeoenvironmental Reconstruction

In previously published studies, laminated sediments have been used to confirm the chronological significance of the sedimentary record of radionuclides, especially ^{137}Cs, from weapons testing fallout (Livingstone and Cambray, 1978) and to explore the validity of alternative models of lead-210 dating. Appleby *et al.* (1979) were able to show that in the laminated sediments of three Finnish lakes (Laukunlampi, Lovojärvi, and Pääjärvi) the dates and changes in dry mass sedimentation rate calculated from assuming a constant flux of unsupported ^{210}Pb to the sediment corresponded rather well with the true dates and rates established from varve counts. By contrast, alternative assumptions led to misleading chronologies. This study helped to establish the utility of the so-called CRS model of unsupported ^{210}Pb accumulation in lake sediments as one of the more important dating tools at sites of varying sedimentation rate.

More recently, much interest has been aroused by the possibility that caesium deposition from the radioactive cloud emanating from the Chernobyl accident in 1986 might provide a new chronological marker for future palaeolimnologists. The recent postgraduate research of P.R.J. Crooks, (1991) shows that fine resolution analysis of laminated sediments, using low background gamma detectors, can be used to establish the behaviour of ^{137}Cs and ^{134}Cs incorporated in lake sediments as a consequence of the Chernobyl accident. At both Nylandssjön in N. Sweden and Blelham Tarn in the English Lake District, the Chernobyl-derived caesium peak is located in material deposited during spring/summer 1986. At Nylandssjön, diffusion below this peak is clearly indicated (Fig. 1) and can be monitored in cores from successive years, thus providing an empirical basis for modelling the process. Chernobyl- derived ^{137}Cs activity in the Nylandssjön cores so greatly exceeds that resulting from earlier weapons testing that one eventual effect of downward diffusion will be the obliteration of the pre-Chernobyl profile which, prior to 1986, was a reliable stratigraphic record of the history of

^{137}Cs deposition. By contrast, at Blelham Tarn, the weapons testing and Chernobyl ^{137}Cs inventories are more nearly comparable. Here, by measuring the remaining Chernobyl-derived activity of short-lived ^{134}Cs, (half-life 2.06 years), it has been possible to partition the ^{137}Cs deposition at each depth into activity derived from Chernobyl and that derived from weapons testing (Fig. 2). The results confirm that at this site, even after ^{134}Cs activity has been reduced to levels below the limit of detection, it will still be possible to identify both the 1963 weapon testing and the 1986 Chernobyl ^{137}Cs peaks.

Studies now in progress, are designed to use the varve chronology for the last 1000 years as a basis for testing alternative approaches to dating within that time interval, in view of its growing importance in palaeoenvironmental research. The methods envisaged include « wiggle-matched » AMS ^{14}C (cf. Fig. 3), ^{226}Ra disequilibrium, palaeomagnetic secular variation and tephrochronology. The reference site is Kassjön in N. Sweden, from which multiple cores were obtained in April 1991. The « varve » chronology has been established in these and can be replicated in counts between cores to an accuracy of ± c. 5 years in the last 1000. Two time intervals have been selected for preliminary AMS dating of different organic components in the sediment (975-1025 AD and 1390-1440 AD). This is regarded as a necessary precursor to attempting any eventual test of dating by « wiggle-matching » AMS ^{14}C dates. The time intervals chosen for this preliminary study are therefore on relatively straightforward, monotonic parts of the dendrocalibration curve. This should allow unambiguous confirmation of the suitability or otherwise of particular aquatic and terrigenous organic components in the sediments for ^{14}C dating. There are at least 20 possible Icelandic tephra layers over the last 1100 years and small sub-samples for pilot study have been taken from time intervals spanning each of these. Additional oriented core material has also been obtained for palaeomagnetic measurements. The main aim of the research, funded by NERC as part of its « Palaeoclimate » Special Topic, is to provide guidance on the best approach to fine resolution dating of peats and sediments within the timespan of the last 1000 years.

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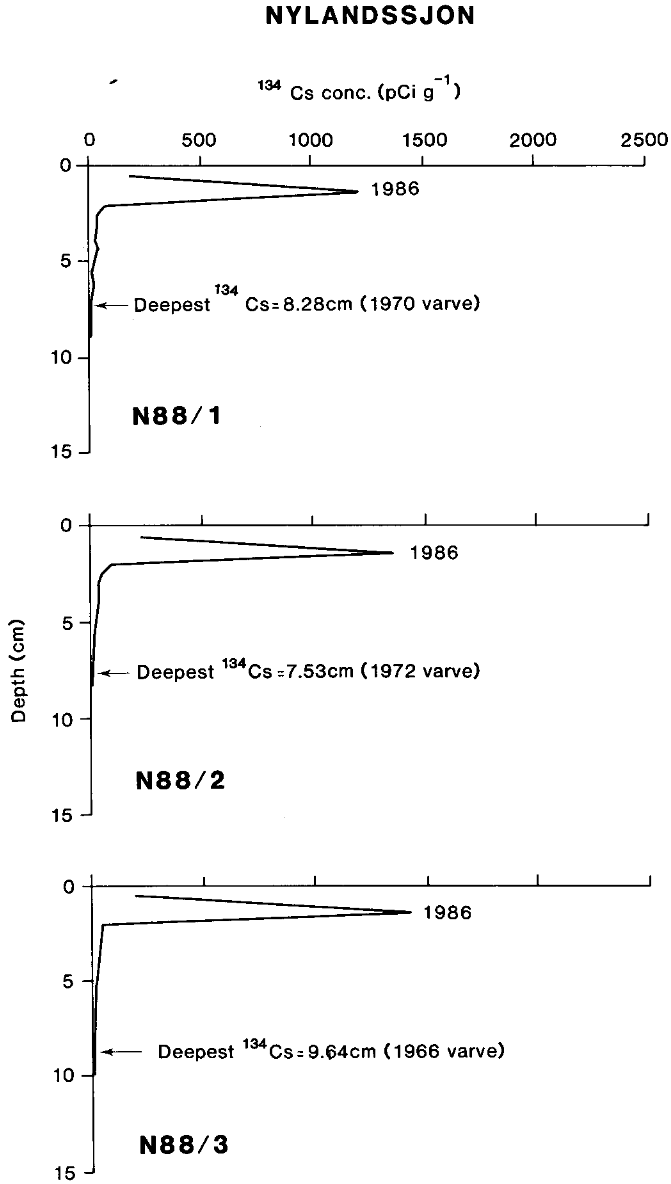
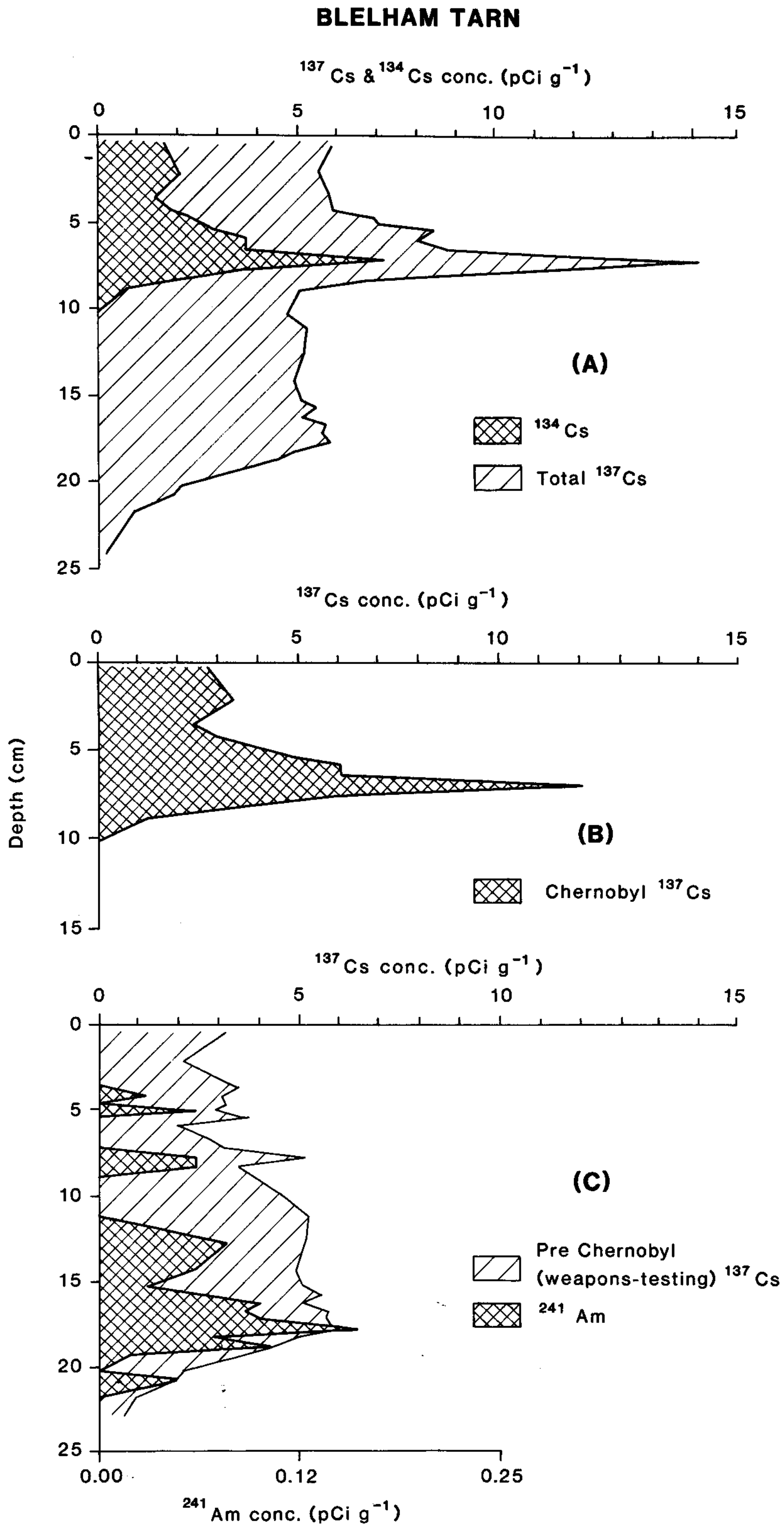


Fig. 1. The distribution of Chernobyl derived ^{134}Cs in 3 crust-freeze cores obtained in April 1988 from varved sediments in Nylandssjön, N. Sweden (Crooks, 1991). The results show peak deposition in the 1986 (Spring/Summer) varve as well as downward diffusion into the older sediments. After only 2 years, measurable ^{134}Cs (½ life 2.06 years) had penetrated into sediments 15-20 years older than the year of deposition. Comparable and continuing penetration by diffusion of the more abundant and persistent Chernobyl derived ^{137}Cs (½ life 30 years) will obliterate the record of late 1950's and early 1960's weapons testing ^{137}Cs.


BLELHAM TARN
137 Cs & 134 Cs conc. (pCi g-1)
0
5
10
15
(A)
134 Cs
Total 137 Cs
137 Cs conc. (pCi g-1)
(B)
Chernobyl 137 Cs
Depth (cm)
137 Cs conc. (pCi g-1)
(C)
Pre Chernobyl
(weapons-testing) 137 Cs
241 Am
0.00
0.12
0.25
241 Am conc. (pCi g-1)

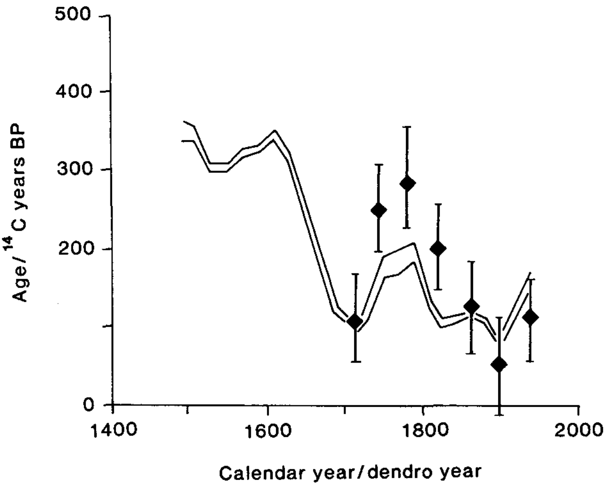


Fig. 3. An example of dating by wiggle-matched ^{14}C in recent ombrotrophic peats from Ellergower Moss, Galloway, Scotland, (Clymo et al., *1990). A sequence of seven ^{14}C dates on contiguous 2 cm thick slices of peat is superimposed on the Stuiver and Pearson (1986) ^{14}C - dendrochronology calibration wiggles. The pattern of ^{14}C 'dates' maps onto the calibration wiggles, though the amplitude of variation is greater. The research project described in the text aims to explore the feasibility of adopting the same approach to lake sediment, using AMS dates. The first stage is to establish the extent to which dates on particular organic fractions and extracts are compatible with varve-derived age.*

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Fig. 2. Caesium and Americium records from the recent laminated sediments of Blelham Tarn in the English Lake District. In (A) both the ^{134}Cs Chernobyl deposition and the combined (Chernobyl and weapons-testing) deposition of ^{137}Cs are plotted. From the former and the ^{134}Cs : ^{137}Cs deposition ratio in Chernobyl fallout of 0.614, it is possible to calculate the Chernobyl contribution to the total ^{137}Cs profile. This is shown in (B). Subtraction of this Chernobyl contribution from the total ^{137}Cs makes it possible to calculate and plot the weapons testing ^{137}Cs and this is shown in (C). For comparison, ^{241}Am derived from weapons testing fallout is also plotted (cf. Appleby et al., *1991). The « Chernobyl » peaks in (A) and (B) correspond with the 1986 varve (the origins of which are still obscure) and the peak ^{241}Am and ^{137}Cs values in C correspond with 1963 according to algal records in the underlying non-varved sediments (Haworth 1984 and pers. comm.).*

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