IV. METHODS & APPLICATIONS

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^{14}C DATING OF PLANT MACROFOSSILS IN LAKE SEDIMENT

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ABSTRACT. Macrofossils of terrestrial plants have been picked from a sediment core taken in Lake Lobsigen, a small lake on the Western Swiss Plateau. The sediments were previously analyzed for pollen composition, plant and animal macrofossils, and stable isotopes. Plant macrofossils were selected near pollen zone boundaries in Late Glacial and early Postglacial sediment for ^{14}C dating by AMS. In the same lake carbonate and gyttja (aquatic plant) samples were dated by decay counting. The dates on terrestrial material are generally younger than those on carbonate and gyttja, *ie,* material reflecting the $^{14}C/C$ ratio of dissolved bicarbonate in lake water. This is probably due to a contribution of dissolved limestone carbonate and thus a somewhat reduced $^{14}C/C$ ratio in the lake's water (hard water effect).

INTRODUCTION

It is important for Quaternary biologists to know the correlations between biozones and chronozones. A problem with dating of lacustrine sediments by the ^{14}C technique is the influence of allochthonous carbonate on the carbonates and water plant remains in the sediment. One way to avoid this hard water effect and to establish chronozones with material reflecting atmospheric ^{14}C concentration is to date recognizable macrofossils of terrestrial plants in sediments. This approach is hampered by the scarcity of sample material.

A suitable technique for measuring $^{14}C/^{12}C$ ratios on small samples is accelerator mass spectrometry (AMS). The sample sizes used to obtain the AMS results presented here ranged from 0.5 to 3mg of plant material.

MATERIALS AND METHODS

Sediment cores from the small, closed basin of Lobsigensee (47° 02′ N, 7° 18′ E), 514m asl, were investigated. The first studies on this lake were made by Haeni (1964), which also yielded the first ^{14}C date on gyttja from the Bölling period. Detailed studies of pollen assemblages, insects, mollusks, and stable isotopes have also been performed on this lake (Ammann *et al,* 1983). Aquatic plant remains (gyttja) were ^{14}C dated by conventional decay counting and results were published by Ammann (1984). ^{14}C dates of carbonates have not yet been published. Pollen zone boundaries of two cores drilled for this study were identified through pollen analysis; the cores were then sampled for remains of terrestrial plants (mainly fruits of birch trees). The material was washed in diluted hydrochloric acid and dried. The samples were burned in a closed system as described by Andrée (1984). The CO_2 obtained was converted into amorphous carbon required by the AMS technique according to the system developed by Andrée *et al* (1984). The AMS measurements were made at ETH Zürich (Suter *et al,* 1984). The errors given for the AMS dates are 1σ deviations including the statistical error of the sample and NBS oxalic acid standards and the long-term stability of the background, as well as the error of the $\delta^{13}C$ value (Andrée *et al,* 1984).

RESULTS

Figure 1 and Tables 1 to 3 show the compiled ^{14}C data of the gyttja, carbonate, and macrofossil samples. The data show generally good coherence except in two cases (11th result from top, Table 1 and 3rd, Table 2). For both cases we have no explanation yet. Remeasurement will show whether they are artifacts or real features. First the macrofossil dates were compared with those of gyttja and carbonate. Unfortunately, there are only a few carbonate/gyttja dates in the macrofossil sections and no macrofossil dates of the Alleröd where many carbonate/gyttja dates were measured. In the Bölling, where a reasonable amount of both data is available, the situation becomes complicated.

At first glance, it is obvious that the gyttja and carbonate dates are generally older than the dates of terrestrial material. The shift is on the average ca 800 yr. An explanation for this finding is hard water effect. This means that dissolved bicarbonate originating from old carbonaceous rock influences the ^{14}C concentration of the lake water which therefore has a lower ^{14}C value than at equilibrium with the atmosphere. The gyttja samples, consisting mainly of deposits from aquatic plants, show generally the same behavior. This can probably be explained by the fact that these plants derive their carbon supply from the water (dissolved CO_2 or bicarbonate) and not from the air (CO_2).

The results can be checked by comparison with known ages of reference horizons. The macrofossil data are used for this only, as the others

TABLE 1
Macrofossil dates, Lake Lobsigen*

Core	Depth in core (cm)	^{14}C age (yr BP)
170d	744–746	9910 ± 120
170d	746–748	9770 ± 120
170d	748–750	10,060 ± 120
170d	750–752	9930 ± 120
170d	752–754	9980 ± 120
160a	853–855	9880 ± 120
170d	754–756	9550 ± 130
170d	756–758	10,150 ± 130
170d	758–760	10,330 ± 130
170d	760–762	9620 ± 130
170d	762–764	11,640 ± 160
170d	764–766	10,300 ± 140
170d	766–768	10,600 ± 140
160a	887–889	10,900 ± 140
170d	768–770	10,350 ± 120
170d	775	10,900 ± 130
160a	901–903	10,860 ± 130
160b	898–900	11,060 ± 140
160a	930–932.5	11,920 ± 140
160a	932.5–936.5	12,420 ± 150
160a	936.5–939.5	12,410 ± 150
160a	939.5–943.5	12,360 ± 140
80	483–492	13,060 ± 150**
170c	901–905	12,470 ± 140

* Results are in same order as in Figure 1.
** Date on aquatic plants Characeae

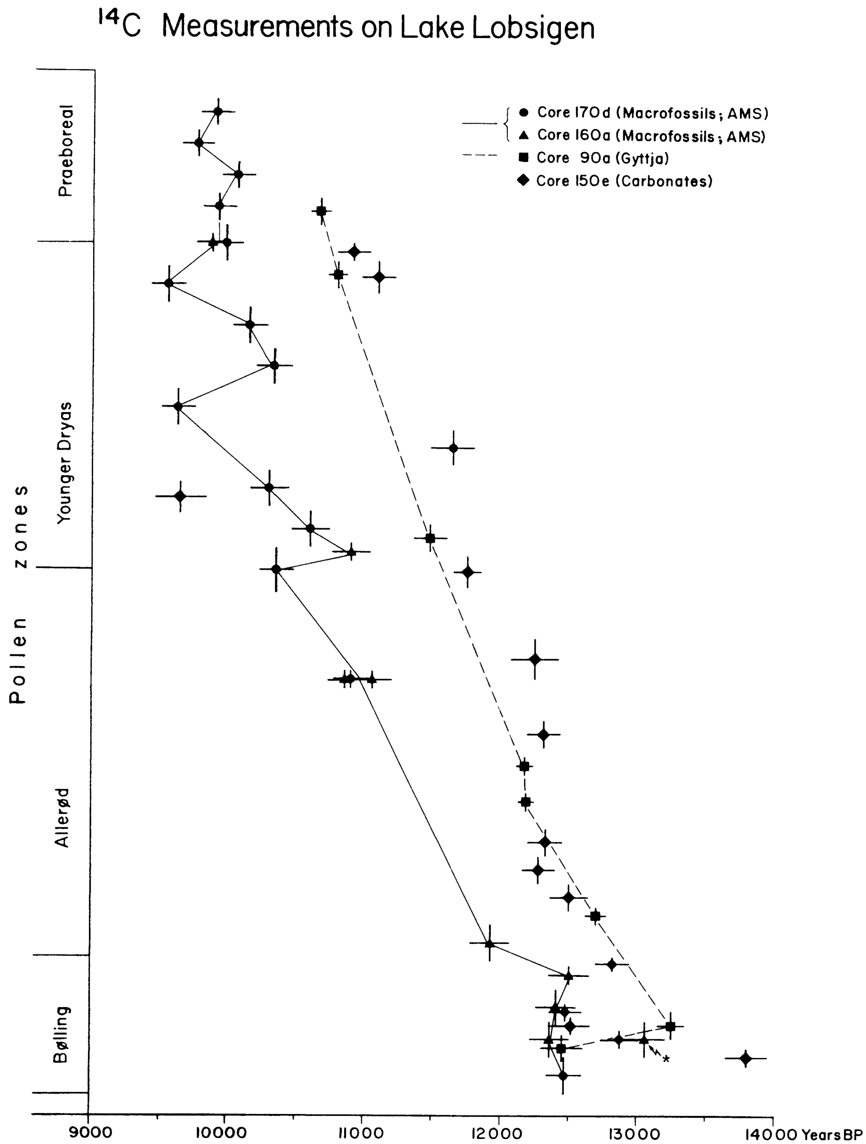

Fig 1. Plot of ^{14}C ages *vs* pollen zones. The points are plotted according to the depth scales of the individual cores. These have been correlated using local pollen zone boundaries. The horizontal bars indicate ± 1σ measurement error, the vertical bars show the depth span of the sample.

* AMS result on Characeae

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TABLE 2

Carbonate dates, Lake Lobsigen*

The depth scale of this core is shifted relative to the other cores because the sediment build-up at this littoral site stopped at the end of Younger Dryas.

Core	Depth in core (cm)	^{14}C age (yr BP)
150e	0– 2	10,910 ± 120
150e	2– 5	11,090 ± 120
150e	23–26	9640 ± 190
150e	29–32	11,750 ± 100
150e	35–38	12,240 ± 170
150e	43–46	12,310 ± 120
150e	52–55	12,320 ± 130
150e	55–58	12,270 ± 120
150e	58–61	12,500 ± 140
150e	67–70	12,820 ± 130
150e	76–80	12,480 ± 120
150e	80–83	12,520 ± 140
150e	83–87	12,880 ± 140
150e	87–91	13,800 ± 150

* Results are in same order as in Figure 1.

might have an offset due to the hard water effect. The best established reference horizon is defined by volcanic deposits of the Laacher See eruption, just below the transition from Alleröd to Younger Dryas. This eruption has been ^{14}C dated at several places in Europe to a mean age of 11,000 yr (Bogaard, 1983). In our study, the horizon was dated on three cores from two different locations in the lake (Cores LQ160a,b and LQ170d) with a mean age of 10,940 yr. Results are shown in Table 4 together with ages of other reference horizons given by Welten (1982) as a modification of the scheme of Mangerud *et al* (1974). They obtained their mean values by dating a number of samples of various materials. Agreement between these is good and no questions are raised about the reliability of the macrofossil dates. The age obtained for the early Bölling period is remarkable. Our measurements indicate 12,500 yr instead of 13,000–13,300 yr as expected from the chronozones of Mangerud *et al* (1974) and Welten (1982). A similar age (12,490 yr) for the early Bölling was reported by Mielke and Müller (1981), who also used terrestrial plant remains which they dated by conventional decay

TABLE 3

Gyttja dates, Lake Lobsigen*

Core	Depth in core (cm)	^{14}C age (yr BP)
90a	743–745	10,670 ± 70
90a	747–749	10,790 ± 70
90a	765–767	11,470 ± 120
90a	781–785	12,170 ± 60
90a	785–787	12,180 ± 60
90a	795–797	12,700 ± 80
90a	805–807	13,250 ± 100
90a	807–808.5	12,460 ± 160

* (Ammann, 1984). Results are in same order as in Figure 1.

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TABLE 4
Comparison of reference horizons

Transition	Macrofossils (yr BP)	Reported ^{14}C dates (yr BP)
Bölling/Alleröd	11,920 ± 140	12,000*
Lower boundary	10,860 ± 130	
of Laacher Tuff	10,900 ± 130	11,000**
	11,060 ± 140	
Younger Dryas/	9880 ± 120	10,000*
Preboreal	9980 ± 120	

* Ref: Mangerud (1974); Welten (1982)
** Ref: van den Bogaard (1983)

counting. However, they found a marked age step from 13,355–12,760 yr within a short distance in the Oldest Dryas pollen zone, suggesting that the atmospheric ^{14}C level might have fluctuated at that time. It will be interesting to continue the study of this early period.

The data in Figure 1 present comparatively constant ages indicated by the macrofossils during early Pre-boreal and Bölling periods. Calculating the mean ^{14}C age for the Pre-boreal samples (top six macrofossil dates) yields 9922 ± 97 yr. The error of this mean is in the order of the measurement errors of the dates (120 yr), supporting the hypothesis of almost constant ^{14}C age in this period. This observation confirms data reported by Oeschger *et al* (1980) who studied the same period of time in a peat bog from Wachseldorn, finding a sequence corresponding to peat growth of ca 500 yr with an almost constant ^{14}C age.

The finding of a constant ^{14}C age in this sequence could be interpreted as an exceptionally high sedimentation rate. An argument against this hypothesis is strong vegetational changes as indicated by the pollen profile. It is improbable that these changes would have taken place in <ca 100 yr as required by the high sedimentation rate hypothesis. Another interpretation is the assumption that atmospheric ^{14}C concentration changed in this period. A sequence of almost constant ^{14}C ages corresponds to a decreasing trend of ^{14}C in the atmosphere with time. This can be produced either by decreasing ^{14}C production rate or by dilution of the atmospheric ^{14}C with carbon of lower ^{14}C concentration. The drastic changes in the environmental system observed at this transition could, eg, have accelerated ocean circulation, involving a reduction of the atmospheric ^{14}C level (eg, Siegenthaler, Heimann & Oeschger, 1980). The constant age level through the Preboreal needs further confirmation by extending tree-ring measurements and reconstructing changes in carbon cycle dynamics. Some information on this question might arise from a program to reconstruct the history of ocean circulation described by Broecker *et al* (1984).

A similar sequence of constant ^{14}C ages is observed during the Bölling (Fig 1), with a mean age of 12,415 yr (4 samples). Mielke and Müller (1981) also found constant ^{14}C ages during this period, with a mean age of 12,515 yr in remarkable agreement with our results. Interestingly, both periods of constant ^{14}C age immediately follow a major cold period.

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CONCLUSION

Macrofossils provide an interesting and helpful means of dating distinct features in pollen and $\delta^{18}O$ profiles of lake sediments, as the results can be directly correlated with ^{14}C data from other sources, such as tree rings (from which younger lake sediments may be linked to an absolute time scale), peat bogs, archaeologic remains, and ice cores.

Another interesting application of macrofossil dates is comparison with dates on materials like carbonate through which the history of carbonate influx into the lake can be reconstructed to some extent.

The application of AMS ^{14}C dating to macrofossils found in lake sediments provides a useful tool for paleobiologists as well as climatologists.

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