

RADIOCARBON DATING THE HOLOCENE IN THE GOŚCIAŻ LAKE FLOATING VARVE CHRONOLOGY

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ABSTRACT. Terrestrial macrofossils selected from laminated sediment of Lake Gościąg were dated by AMS. Thus, part of the floating varve chronology (FVC) (Goslar *et al.* 1993) between radiocarbon ages of 4225 ± 45 and 7740 ± 85 BP can be compared and placed on the ^{14}C calibration curve. As a result of our dating, the top of the FVC is now dated between 3120 and 3300 cal BP, *i.e.*, 3210 ± 90 cal BP.

INTRODUCTION

Terrestrial macrofossils are most suitable for radiocarbon dating lake sediments because they are free of the hard-water effect (Olsson 1986). Short-lived parts of land plants provide the best ^{14}C estimate of the time when the sediment was deposited. A danger of dating reworked macrofossils still exists and cannot be avoided entirely. However, in the case of laminated sediments, this is usually limited to such events as the development of turbidites and slumps.

In many cases, laminations are of poor quality or have disturbed sequences in the upper parts of the sediment record (Hajdas 1993). Therefore, most long varve chronologies, sometimes extending to the Late Glacial period, are either floating or show large counting uncertainties. One possibility for solving this problem is to ^{14}C -date the floating varve chronology (FVC) and place it on the ^{14}C calibration curve (Hajdas *et al.* 1993, 1995.)

Lake Gościąg contains a sedimentary record of the last deglaciation (Goslar *et al.* 1993a; Ralska-Jasiewiczowa, Wicik and Wieckowski 1987), and most of it is well laminated. However, because of difficulty in varve counting, the uppermost 2900 yr were counted with an uncertainty of $-200/+500$ yr. Below this point, well-developed varves are observed, and a long varve chronology has been established (Goślar 1993; Goślar *et al.* 1993). To reduce the uncertainty after 2900 BP, we dated the younger part of the FVC to match it to the dendrochronologically based calibration curve. Sediment samples were selected to allow for coverage of the longest sequence of varves in this lake. Macrofossils from these samples were dated using accelerator mass spectrometry (AMS).

METHODS

Sediment samples containing *ca.* 100 varves (exact number given in Table 1) were treated with acid (10% HCl) to remove carbonates and facilitate washing macrofossils. Gościąg sediment contains *ca.* 40–60% carbonate, so that most of the sediment was removed in this step, followed by washing through a sieve (250-mm mesh). From the remaining residue, we selected only fragments of terrestrial plants (Table 1), so that the hard-water effect, a possible uncertainty of dating, could be ruled out (Hajdas 1993).

We applied a standard cleaning procedure of a consecutive acid/base/acid soaking of organic matter at 60°C for 1 h (Hajdas 1993). Each step was followed by rinsing to neutral pH. Combustion graphitization and sputter target preparation followed the usual procedure. The targets were measured in

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TABLE 1. AMS-Dated ^{14}C Ages and $\delta^{13}\text{C}$ Values for Macrofossils Selected from Sediment of Lake Gošćiaź

ETH-no.	Sample	Relative varve age*	^{14}C age (yr BP)	$\delta^{13}\text{C}$ (‰)	Material	C content (mg)
12417, 12418†	G(1+2)MZ	5717 ± 88	7740 ± 85	-31.5 ± 1.2	Bark, catkin scales	1.5
12423	G7MZ	5227 ± 43	7740 ± 70	-33.0 ± 1.1	Bud, twig	2.2
12425	G9MZ	4645 ± 60	7075 ± 80	-27.0 ± 1.2	Twig(s), bark	1.75
12427, 12428†	G(11+12)MZ	2860 ± 80	5505 ± 90	-18.9 ± 1.2	Catkin scales, seeds	0.6
12430	G14MZ	1790 ± 45	4225 ± 70	-24.0 ± 1.3	Needle, leaf fragments	2.4

*In years from top of FVC; macrofossils of two samples were combined into one.

†Uncertainty corresponds to the thickness of sediment sampled for dating.

a cassette with standards (Oxalic Acid I and ANU sucrose) and blanks at the ETH/PSI AMS facility. $^{14}\text{C}/^{12}\text{C}$ and $^{13}\text{C}/^{12}\text{C}$ ratios were measured quasi-simultaneously (Bonani *et al.* 1987).

RESULTS

Conventional ^{14}C ages listed in Table 1 were calculated according to the procedure suggested by Stuiver and Polach (1977). Age correction for the fractionation is based on $\delta^{13}\text{C}$ values (Table 1), which were measured for each graphite sample (see above). For each sample, the type of macrofossil and the amount of carbon is given. A comparison between the fitted chronology and tree-ring calibration curve indicates that two ages (ETH-12417 and ETH-12430) are too young and fall below the calibration curve (Fig. 2). Both samples contained >1 mg of carbon (Table 1), and contamination is unlikely here. We tried to obtain better dating resolution, but the amount of organic material selected from sediment from other depths was not sufficient for dating.

Gošćiaź FVC consists of 7000 varves counted between the uppermost, poorly laminated sediment and the massive layer deposited during the YD (Gošlar *et al.* 1993). Previously, the top of the well-laminated sediment was dated at 2900 +500/-200 cal BP. Figure 1 shows ^{14}C ages of macrofossils plotted vs. relative varve time. Intervals between macrofossil samples contain >500 varves, and the whole ^{14}C -dated varve chronology covers almost 4000 varve years.

We matched the Gošćiaź FVC with the calibration curve using the modified least-squares minimization method (Pearson 1986). We found an absolute offset of the varve age by minimizing the weighted sum of squared differences between ^{14}C ages of macrofossils and those derived from the calibration curve. The weight included uncertainties from sample sizes and AMS dating of macrofossils (Table 1) as well as uncertainties from the calibration curve. Figure 2 shows the FVC fitted to the calibration curve. The top of the FVC dates between 3120 and 3300 cal BP, *i.e.*, 3210 ± 90 cal BP.

CONCLUSION

Radiocarbon dating terrestrial macrofossils is a useful tool for the dating of lake sediments. Dating a sequence of five samples selected from the sediment deposited during a 4000-yr period allowed absolute dating of this segment. Such a strategy, called "wiggles matching" if performed with very high-resolution dating, allows more precise dating of Holocene records. In the case of the Gošćiaź FVC, higher-resolution ^{14}C dating could improve the fit with the ^{14}C calibration curve.

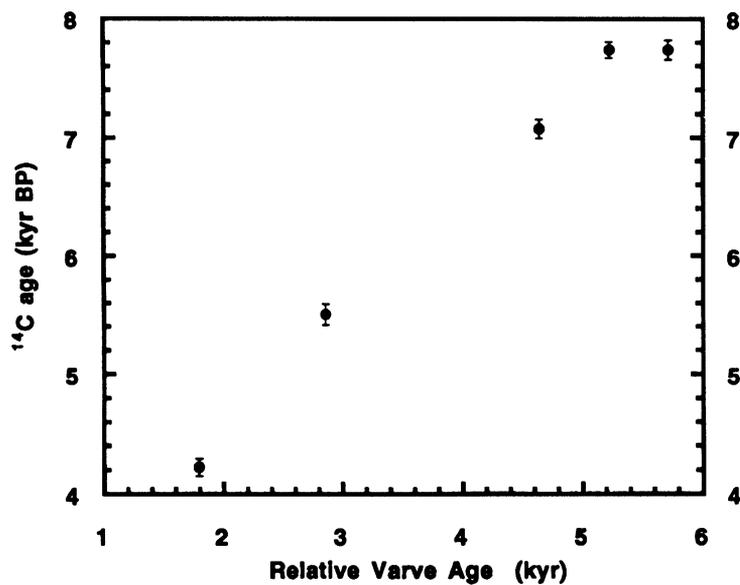


Fig. 1. ¹⁴C ages of terrestrial macrofossils plotted vs. their relative varve age derived from varve counting

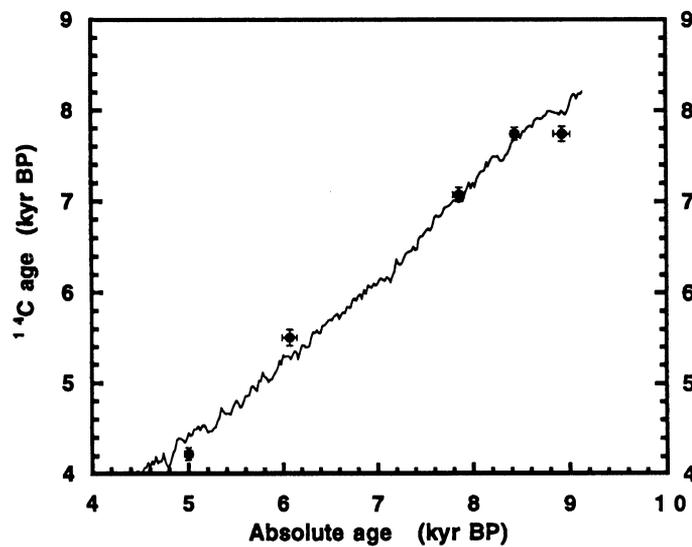


Fig. 2. The best fit of the FVC to the ¹⁴C calibration curve. The top of this chronology dates to 3210 ± 90 cal BP.

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