than 11.79 is approximately M (M = 5600) times higher (Barnett & Lewis 1978):

$$P(Sumt_{\max M} > 11.79) \approx 1 - (1 - \alpha)^M \approx \alpha \cdot M \approx 0.06$$

This would mean that the correlation observed for T_{FVC} = 3211 cal BP could be obtained by chance with the probability of 0.06, so presumably it is not incidental. It must be stressed that the estimation is highly approximate, mainly because the actual distribution of Sumt is not exactly known. It must be also stressed that calculated in the same way the probability for the second highest value of Sumt: $M \cdot P_{rnd}(Sumt > 9.53) = 1.4$ agrees with the expectation that the second highest value happened by chance. The level of significance of the product of 't' values was not estimated.

6.4. ABSOLUTE AGE OF FLOATING VARVE CHRONOLOGY OF LAKE GOŚCIĄŻ

Tomasz Goslar

According to varve counting in the upper part of the Lake Gościąż sediments (Fig. 6.12, see Goslar, Chapter 6.1), the age of the floating varve chronology (FVC) could be estimated with a relatively large error, i.e. 2900^{+500}_{-200} cal BP. More precise dating was possible by radiocarbon dating and dendro-match. Both evidences point to a shift of FVC towards the older ages:

1. The wiggle match of AMS radiocarbon dates to calibration curve fixes the FVC at 3140±120 cal BP, (Goslar et al., Chapter 6.2), which means that the dating of FVC is older by 240±120 yr. It should be pointed out that the lowest minimum in the S-square curve in Fig. 6.6a (Chapter 6.2) occurs for T_{FVC} = 3216 cal BP.

2. The correlation between 2638 yr long series of laminae thicknesses and sequences of tree-ring widths of German oaks (Goslar, Chapter 6.3) suggests the dating of the younger end of FVC to 3211 cal BP, corresponding to the shift of FVC towards the older age by 311 yr.

The close agreement between results given by both methods allows us to believe that the dendro-match is real. Therefore the calendar age of younger end of floating varve chronology was determined to T_{FVC} = 3211 cal BP, and this age has been used in all reconstructions presented in this book, unless clearly stated otherwise. The ^{14}C – and dendro-match of FVC enabled reliable dating of two events reconstructed by palynological analysis, which, previously dated by varve counting only, appeared too young in comparison with independent estimates:

1. The maxima of *Secale cereale*, *Cannabis* cf. *sativa*, and other taxa in the first half of first millennium AD

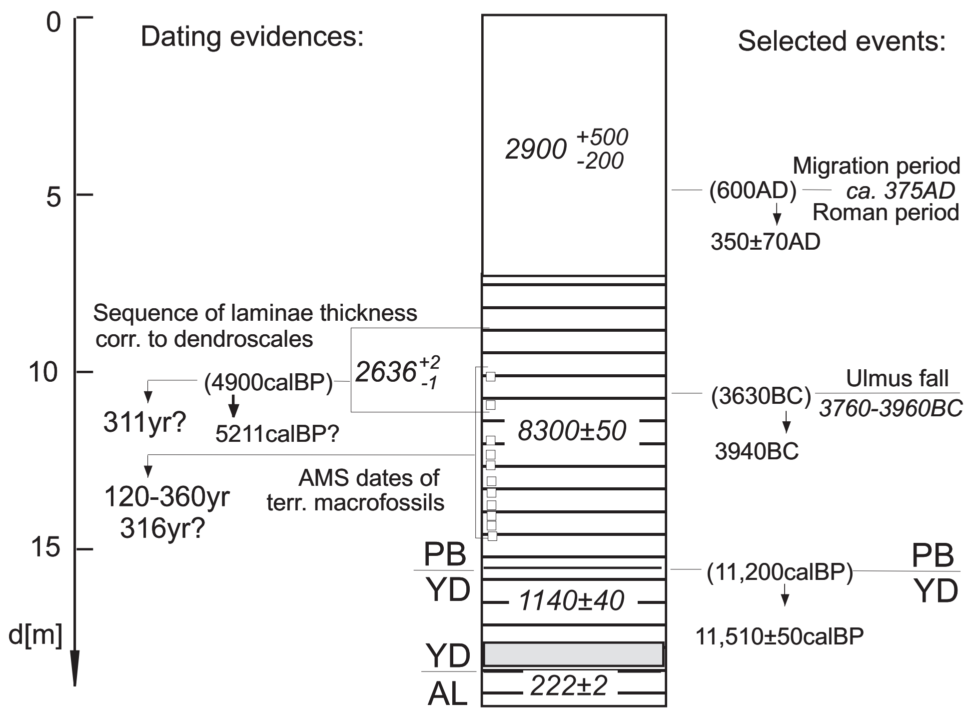

Fig. 6.12. Diagram illustrating the absolute dating of floating varve chronology (FVC) of the Lake Gościąż sediments in comparison to the age resulted from varve counting in the upper part of profile. The numbers of varves in the Allerød, Younger Dryas, and Holocene sections of FVC and in the upper part of profile are shown inside the column. Two kinds of evidence (left-hand side) point for the correction of the age of FVC by 311 yr or by 120–360 yr with respect to the age predicted by varve counting alone. At the right-hand side of figure, the ages of selected events derived from varve counting alone (shown in parentheses) and from the corrected absolute chronology, are compared with independent age estimates (shown in italics). Small open squares show the approximate positions of terrestrial macrofossils dated by radiocarbon.

were ascribed to the increased human activity during the time of Roman influences (Ralska-Jasiewiczowa & van Geel, Chapter 9.1.3). They occur in the upper part of sediment, and by varve counting its most probable age was determined to be ca. AD 600. The abrupt termination of this phase of human occupation could be related to the beginning of the Migration Period, commonly dated to ca. AD 375 (Godłowski & Kozłowski 1979), appeared then much older. Due to the dendro-dating of FVC, the chronology of the upper part of sediment has been revised (see Goslar, Chapter 8.1). Accordingly corrected estimate for the age of the above mentioned event – AD 350±70 – corresponds well to archaeological dating (Fig. 6.12).

2. The so-called "*Ulmus* fall", the abrupt distinct decline of *Ulmus* pollen, is well recognized in the Holocene pollen diagrams from Europe (see Troels-Smith 1960; Hirons & Edwards 1986). This phenomenon, dated by radiocarbon in many sites, appears to be rather synchronous, with the majority of dates falling around 5000–5100 ^{14}C BP (Latałowa 1992), which corresponds to a calendar age of 3760–3960 BC. The "*Ulmus* fall" record in the Lake Gościąż sediment was described and interpreted by Ralska-Jasiewiczowa and van Geel 1992 (also Goslar, Chapter 8.1), and according to the dendro-match of FVC it is dated to 3940 BC, in agreement with dating from other sites.

In order to ensure the dendro-match, the sequence of varve thicknesses was compared with 15 local chronologies available in tree-ring laboratories of B. Schmidt and H. H. Leuschner (pers. comm.). The chronologies of Schmidt were: Bronzezeit MWK7, Bronzezeit MWK10, and Neolithic Schleswig-Hollstein containing oaks from the archaeological excavations and bogs in northern Germany, close to the coast of the Baltic Sea; the 12 chronologies of Leuschner contained oaks from the German coast of North Sea, growing on the marine or fluvial deposits at the mouths of Elbe, Weser, and Ems rivers. The comparison with 15 chronologies has not confirmed the correlation described earlier. Though it is possible that the correlation with local chronologies is not viable and appears only after combining them, the described match with dendroscales is not high enough to date the FVC with absolute certainty. The date 3211 cal BP should be rather interpreted as the most probable from the range 3140±120 cal BP given by radiocarbon dating. It has to be mentioned, however, that the dendro-match leads to the date of the Younger Dryas/Preboreal boundary of 11,510±50 cal BP, which agrees very well with the ages obtained in the studies of ice cores GRIP – 11,550±50 cal BP (Johnsen et al. 1992) and GISP2 – 11,640±250 cal BP (Taylor et al. 1993) from Greenland summit. The problems of dating the YD/PB transition are discussed in separate chapter (Goslar et al., Chapter 7.7).

6.5. STATISTICAL ANALYSIS OF THE SEQUENCE OF LAMINAE THICKNESS

Adam Walanus

Laminae thickness

Continuously laminated sediment of Lake Gościąż comprises almost 13,000 varves (Goslar, Chapter 6.1). The thickness of ca. 3000 uppermost varves were not measured because of poor quality of the lamination. For almost 10,000 varves from the lower part of the sediment, the thickness of light (summer) and dark (winter) laminae were measured using the dendrochronological measurement device (Goslar 1987) on photographic negatives twice reduced in size. Such a procedure allowed much easier handling than if containers with the sediment are used, especially if two cores are to be compared. Besides, the sediments are then saved from the heating and drying. Precision of measurement is high enough for laminae 1 mm thick. Some attempt was also made to measure laminae thickness by computer image analysis (Walanus & Goslar 1993).

In the youngest 100 varves, taken by the freezing method (Walanus, Chapter 4.1.2) the layers corresponding to the individual seasons were measured. However, they are much thicker than deeper varves, and not comparable to them because they are not compacted.

Instead of the separate thickness of light and dark laminae, the total (= light+dark) varve thickness is mainly used in the analysis. The information given by two measurements performed on one varve couplet is carried by the ratio of light/total thickness, which seems to have some climatic interpretation (Goslar, Chapter 6.3). The average varve thickness is 1.02 mm, and standard deviation is rather low. As may be seen in Fig. 6.13, only a few varves are thinner than 0.5 mm, and not many are thicker than 1.5 mm. The histogram is asymmetric, as is obvious for the non-negative quantity, which has no upper limit. Logarythmic transformation makes the varve-thickness distribution symmetrical to the Gaussian

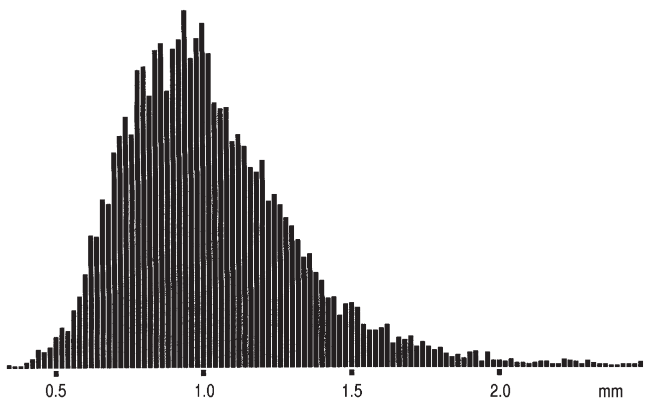

Fig. 6.13. Histogram of varve thickness. Almost 10,000 varves from 12,500 to 3200 cal BP are included.