Ralska-Jasiewiczowa M., Goslar T., Madeyska T. & Starkel L. (eds), 1998. Lake Gościąż, central Poland. A monographic study. Part 1. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

6. CHRONOLOGY OF THE LAKE GOŚCIĄŻ SEDIMENTS

6.1. FLOATING VARVE CHRONOLOGY OF LAKE GOŚCIĄŻ

Tomasz Goslar

The Swedish term varve was used by de Geer (1912) to describe couplets of coarse and fine material deposited seasonally in periglacial lakes. According to Renberg (1981), however, this term means “the sediment deposited during one year”, and thus it may be used for all kinds of deposit, independently of the mechanism of layering. Such an interpretation has been adopted by O’Sullivan (1983) in his excellent review of laminated lake sediments, and now it is widely used by scientists dealing with laminated lake sediments. Varve chronology is thus equivalent to calendar chronology.

The varve chronology of the Lake Gościąż sediments has been constructed from seven cores. Four of them (G1/85, G1/87, G2/87, and G2/91) come from the central, deepest place in the lake, two (G1/90 and G1/91) from the western deep, and one (T1/90) from the shallow northern bay Tobyłka (Fig. 6.1). All cores were collected by K. Więckowski and B. Wicik. The correlation of laminated sequences of the cores is presented in Fig. 6.2. The cores were taken in 2 m or 1 m segments, but for simplicity they are presented in Fig. 6.2 as continuous.

The cores from the central deep reveal lamination throughout the whole profile. In different sections of sediment the structure of laminae couplets is slightly different, but the main pattern is the alternation of light (white) layers rich in calcite crystals and darker (yellow, light-brown) layers with more organic detritus (the details in Chapters 7.2 and 8.1). Because of the poor quality of lamination in the upper part of profile, the continuous chronology could only be constructed for the section up to 7.34 m below the present-day sediment surface (all depths given according to core G1/87).

The main gap in varved sequences in cores G1/87 and G2/87 is caused by the layer of sand (16.27–16.92 m) overlying the basal laminated fragment. Its origin has not been satisfactorily explained; the simplest cause would be slumping from the lake shore. If this was indeed the reason, it was surprisingly extensive and did not occur as a single event, as evidenced by the granulometric analysis of the sand. The coarse texture of the bottom sand would suggest strong erosion of the underlying laminated sequence, but correlation with the continuous laminated sequences in cores from the western deep and northern bay (see Goslar, Chapter 7.2) shows that only a few varves below the sand were eroded. The inclination of the varves below and above the sandy layer in both cores G1/87 and G2/87 (see Fig. 7.11 in Chapter 7.2) suggests that they were deposited on a sloping lake bottom. It seems thus possible that the sandy material, slumping along one slope of the lake bottom, was stopped at the opposite slope, in the area where the cores G1/87 and G2/87 were retrieved. The sand deposited in such a way caused only minor erosion and prevented the underlying laminated sequence from destruction by further events.

The cores G1/85 and G2/91 did not reach the laminated sediment below the sand, either because they did not penetrate deeply enough, or, perhaps, they were taken in places where the oldest laminated sequence was not covered by the falling sand and thus was totally destroyed. At the very bottom of core G2/87, another layer of sand exists which unfortunately could not be penetrated during coring. The cores from the central deep reached neither the layer of peat documenting the early stage of lake formation, nor the sequence showing the natural transition between non-laminated and laminated

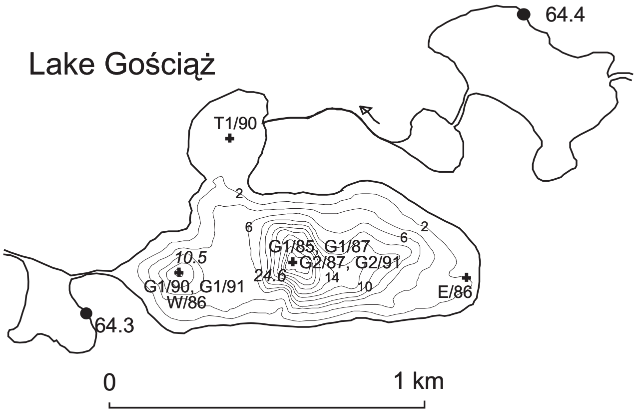

Fig. 6.1. Bathymetric map of Lake Gościąż with the coring sites (+) described in the text. The elevations of water table of adjacent lakes are also shown.

lacustrine sediment. About 2 m above the sand layer the continuous lamination in the central deep is broken by two massive layers, occurring in all cores. The correlation of different cores shows clearly that during their deposition some number of underlying varves were eroded and suggests that the gaps in continuous chronology corresponding to those layers are fortunately not longer than a few years (Goslar, Chapter 7.2). In addition to the four cores described here, the core G3/87 was taken for palaeomagnetic research (Sandgren 1993). Its lamination was not directly correlated with other cores, but approximate correlation was possible by comparison of the record of varve thickness measured by T. Goslar (main cores) and P. Sandgren (G3/87).

The lamination in the cores from the western deep (G1/90 and G1/91) reveals no gap corresponding to the sand layer. In their basal parts the lacustrine sediment is underlain by peat. In core G1/90 the lamination appears 15 cm above the peat-gyttja interface and, ca. 2 cm higher up, becomes regular and distinct enough to enable the varve counting. The regular varves in the western deep started to accumulate later than in the central deep (in the core G1/90 at least 150 years later). In core G1/91 the succession of non-laminated and laminated sections is similar, but the distinct lamination appears only 18 cm higher up (ca. 500 years later). Two massive layers are contemporaneous with those deposited in the central deep. Higher up, the massive layers in the western deep (and thus the breaks in continuous lamination) occur more and more frequently, and above the sixth massive layer, ca. 500 varves higher up, the lamination in the western deep was not analysed. The detailed correlation of laminated sequences is discussed by Goslar in Chapter 7.2.

The sediment from the northern bay (T1/90) is laminated only in its lowest part. The basal sand there is overlain by 8 cm of peat, ca. 15 cm of non-laminated gyttja mixed with sand, and a laminated section higher up. The oldest varves in T1/90 were presumably formed earlier than those found in the central profiles, but above the 10-cm-thick section of basal lamination a break occurs between the 1-m segments of the core, making the section too short and thus not correlative with the central cores. The 80-cm regularly laminated section of the next segment was correlated with other cores. Higher up, the laminated sections occur alternately with non-laminated ones, and they have not been analysed.

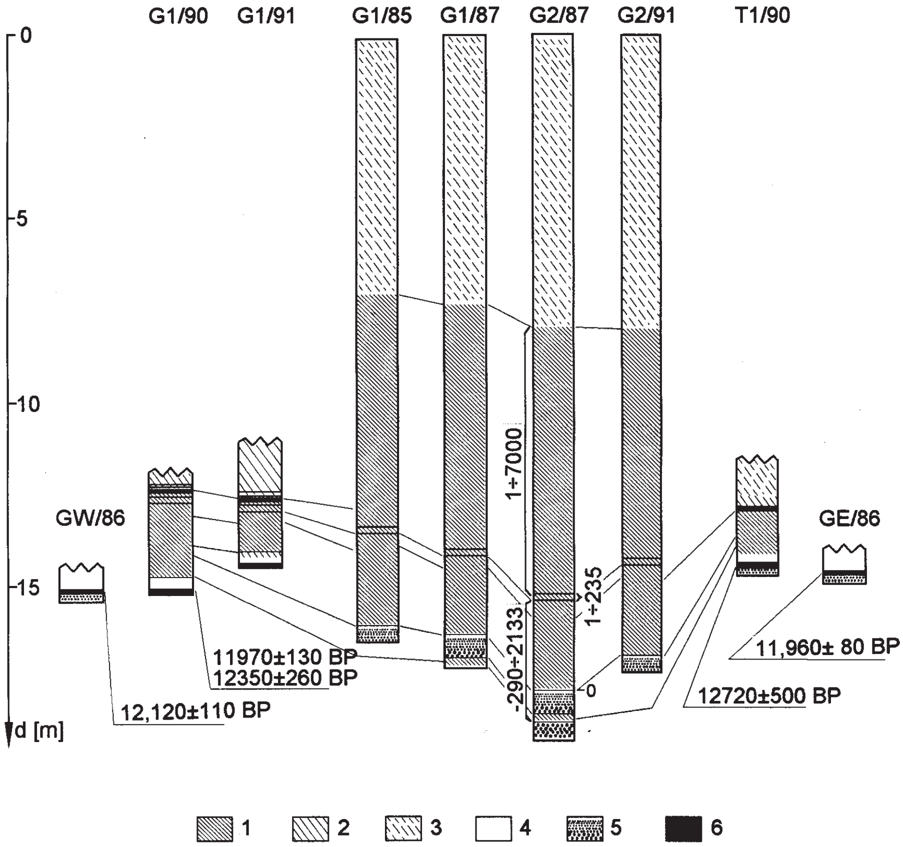

Fig. 6.2. Diagram showing the correlation of laminated sequences from Lake Gościąż. The lines between cores show corresponding levels in different cores. Two non-laminated additional cores are also displayed at both sides of the graph. All radiocarbon dates (in ^{14}C BP) have been obtained in the Radiocarbon Laboratory in Gliwice. 1 – lamination enabling the construction of continuous varve chronology, 2 – disturbed lamination, not analysed, 3 – disturbed lamination used in the construction of chronology of the upper part of sediments, 4 – no lamination, 5 – sandy layer, 6 – peat. The horizontal lines across the cores denote massive layers breaking continuous lamination. The ranges of varve numbers in separate continuous sections of floating varve chronology are given along the lower part of core G2/87.

Table 6.1. Synchronisation of core G3/87 sections with the floating varve chronology. The third and fourth columns give the number of varves in floating chronology corresponding to the ends of sections. The last column gives the difference of independent varve counting on different cores.

Segment of G3/87	No. of varves in segment (P. Sandgren)	Lower end versus floating chronology (T. Goslar)	Upper end versus floating chronology (T. Goslar)	Difference (G3/87–G1,2/87)
1	1025	1	988	37
2	1157	1178	2345	-11
3	891	2485	3390	-15
4	1164	3595	4767	-9
5	788	4807	5600	-6
6	1063	5952	7018	-4
7	688	7023	7715	-5
8	869	8035	8905	-2
9	681	8915	9594	1

The radiocarbon dates of basal peat from the cores described above, from two additional cores from the western and eastern part of the lake (Fig. 6.2), and the core G4/90 (Fig. 5.1, 12,980±270 ^{14}C BP) suggest that it was formed during the Bølling interstadial. The possible scenarios for the lake's origin are discussed in detail elsewhere (Madeyska, Chapter 2.2). The palynological and other data show that the deposition of laminated sediment in all places started in late Allerød (see e.g. Ralska-Jasiewiczowa et al., Chapter 7.4).

Combining the laminated sequences of seven cores correlated with one another led to the construction of a continuous chronology comprising 9662±90 varves for the fragment of profile between 7.34 m and 17.05 m. In the upper part of the profile (above 7.34 m) the varves are often bent, they frequently do not form continuous surfaces, and in some sections they are almost or completely invisible. The number of varves in this part could then be estimated with much less precision, i. e. to 2900 $^{+500}_{-200}$ varves. Due to significantly smaller error, the chronology of the lower part of sediments is called floating.

The general strategy of varve counting in the lower part was as follows: every 2–5 cm the correlative layers were marked, and the varves between markers were counted in all cores. Usually the results of counting in all cores were the same. In case of differences the markers were set more densely, e.g. every 10 varves, and the counting was repeated between all pairs of markers. Where necessary, this procedure was repeated for even narrower fragments, leading to precise identification of the couplet which caused the outlying counting. In most cases, couplets not clear enough to be counted in one core were well developed in other cores. Due to this procedure the error in the chronology could be reduced. The quoted error of varve counting corresponds approximately to the number of couplets not clear enough in any cores to be identified as annual varves. The relative error in the chronology is higher in the Late-Glacial (1362±40) than in the Holocene part (8300±50). The details of correlation of laminated sequences, varve structures in different parts of the profile, problems in interpretation of unclear laminae, and sources of error of varve counting are discussed in further chapters (Goslar, Chapters 7.2 and 8.1).

Another estimate of error in the varve chronology is given by the comparison with totally independent varve counting. This was possible because core G3/87 was taken for palaeomagnetic research in Lund University. The varves in nine segments of that core were counted and measured by P. Sandgren. Since the photographs of core G3/87 were not available, it was correlated with floating varve chronology using the sequences of varve thickness. In the correlation, 21-yr running means were compared. The patterns of appropriate curves were clearly correlative, and the ends of segments of G3/87 could be synchronised to the floating chronology with the precision of ca. 5 years. As shown in Tab. 6.1, except for segment 1 the numbers of varves counted in G3/87 were systematically lower than that in the floating chronology, and the total difference for the sections 2–9 is –51. This difference agrees surprisingly well with the error in the Holocene part of the floating chronology. On the other hand, in segment 1 (comprising Late-Glacial sediment) P. Sandgren counted 37 more varves than the author. This might be due to more complicated structure of Late-Glacial varves, which could result in misidentification of non-annual bands and overestimation of the number of varves when not interpreted under the microscope. The difference of independent varve counting agrees once again surprisingly well with the error of the Late-Glacial part of the chronology. This seems to confirm that the error of floating varve chronology was not underestimated.