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.

5. LITHOLOGY, ORIGIN AND AGE OF THE SEDIMENTS IN THE NA JAZACH LAKES

5.1. LITHOLOGY AND AGE OF THE SEDIMENTS IN THE NA JAZACH LAKES AND ADJACENT AREAS

Kazimierz Więckowski, Leszek Starkel, Anna Pazdur, Mieczysław F. Pazdur† & Tomasz Goslar

The characteristics of sediments of Lake Gościąż and its surroundings are based on more than 50 borings (Fig. 5.1). The coring sites cover Lake Gościąż, its shore zone, other lakes in the system of the Ruda valley and closed depressions. For the studies of coastal zone of Lake Gościąż, the cores from several cross-sections (A–J) were retrieved. Thickness of the Lake Gościąż sediments have additionally been identified in three sections (I, II, and III) along the lake.

5.1.1. Radiocarbon age of the sediments in the Na Jazach lakes and adjacent areas

Anna Pazdur, Mieczysław F. Pazdur† & Tomasz Goslar

Radiocarbon dates of bulk sediment samples (Tab. 5.1) were obtained in the Gliwice Radiocarbon Laboratory, and these dates are used in detail in subsequent sections of this Chapter and also by Goslar et al. (Chapter 6.2). Here, only some general remarks are given.

Most of dated material was deposited in lacustrine environment. Radiocarbon dates of bulk lacustrine sediments are, as a rule, affected by reservoir effect (Olsson 1986). In waters rich in carbonate ions the reservoir effect is especially strong, and it is called “hard-water” effect. It makes radiocarbon dates older, and the difference

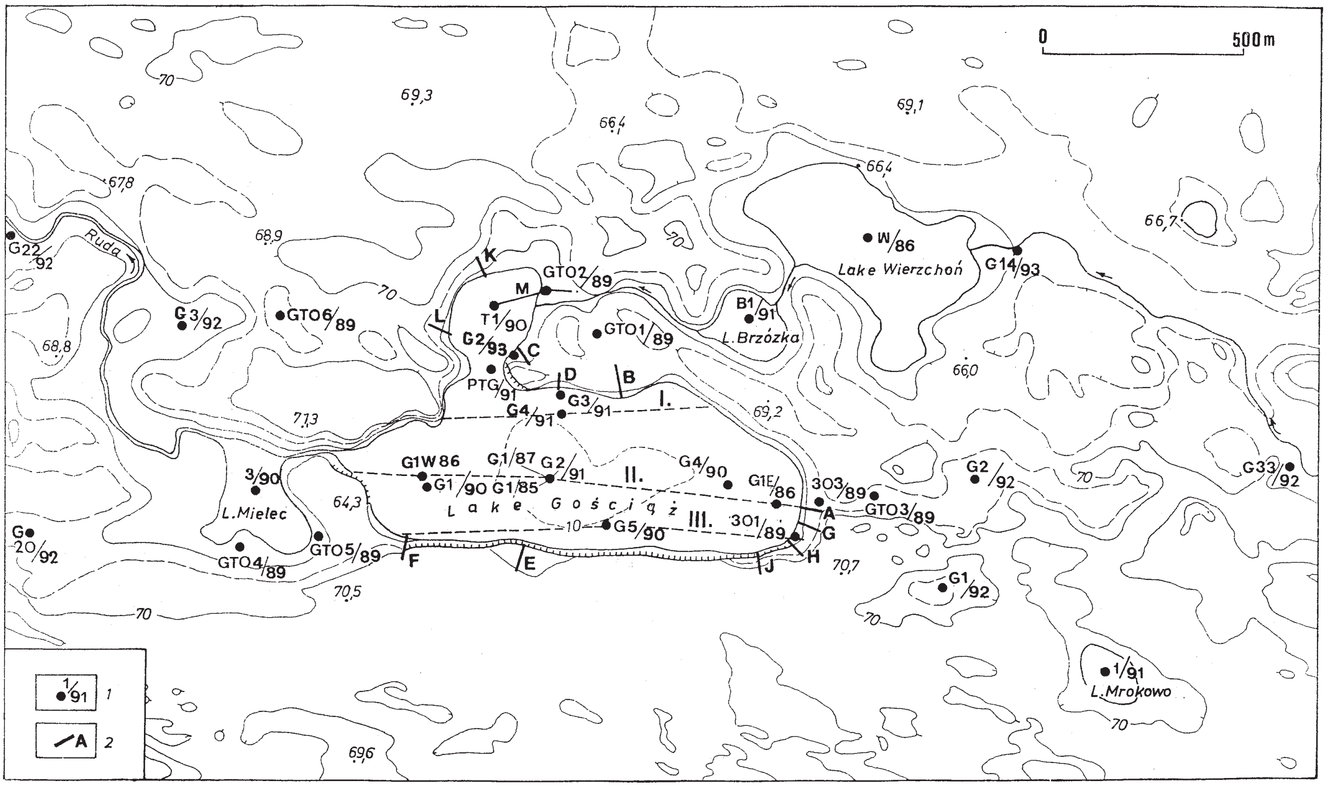

Fig. 5.1. Location of the lake-bottom borings and shore profiles used for reconstruction of deposition history. 1 – borings made between 1986 and 1993 by B. Wicik and K. Więckowski. 2 – Cross-sections of the coastal zone with several borings made in 1992 by L. Starkel and B. Wicik. The cross-sections where sediment depths were measured are also indicated (I–III).

Table 5.1. Radiocarbon dates of the sediments of Lake Gościąż and its surroundings. C – carbonate fraction; O – organic fraction; PDG – peaty detritus gyttja; PG – peaty gyttja; P – peat; CG – calcareous gyttja; DG – detritus gyttja; Ch – charcoal; WCh – wood and charcoal; CDG – coarse detritus gyttja; BMP – brown moss peat; AOM – amorphous organic matter; GOD – gyttja with organic detritus; FS – fossil soil; OS – organic soil; CT – carbonate tufa; SOM – sand with organic matter; AG – algal gyttja; PD – plant detritus; OD – organic detritus; DG – detritus gyttja; WP – wooden peat; MP – moss peat; G – gyttja; RP – rotten peat.

Lab. ^{14}C No.	Sample	Material	Age ^{14}C BP
	A. Lake Gościąż, cores from central deep		
2583	G1/85/1.5–1.6m/C	C	2100 ± 90
4066	G1/85/1.5–1.6m/O	O	1730 ± 100
3230	G1/85/2.65–2.75m/C	C	2200 ± 40
2649	G1/85/2.65–2.75m/O	O	2340 ± 80
5008	G1/85/3.05–3.15m/C	C	3660 ± 50
2571	G1/85/3.05–3.15m/O	O	2730 ± 120
5082	G1/85/3.9–4.0m/C	C	3880 ± 70
2620	G1/85/3.9–4.0m/O	O	3050 ± 80
2618	G1/85/4.9–5.0m/C	C	4680 ± 120
2621	G1/85/4.9–5.0m/O	O	3800 ± 90
3277	G1/85/6.1–6.2m/C	C	5350 ± 50
2527	G1/85/6.1–6.2m/O	O	4230 ± 120
5086	G1/85/6.9–7.0m/C	C	5690 ± 80
2623	G1/85/6.9–7.0m/O	O	5040 ± 110
5094	G1/85/7.9–8.0m/C	C	6280 ± 80
2626	G1/85/7.9–8.0m/O	O	5530 ± 100
5088	G1/85/8.9–9.0m/C	C	7390 ± 190
4100	G1/85/8.9–9.0m/O	O	6320 ± 120
1992	G1/85/9.60–9.65m/C	C	7930 ± 70
2564	G1/85/9.60–9.65m/O	O	6840 ± 390
5091	G1/85/10.0–10.1m/C	C	8190 ± 100
5372	G1/85/10.0–10.1m/O	O	7630 ± 120
5095	G1/85/10.45–10.55m/C	C	8420 ± 90
4105	G1/85/10.45–10.55m/O	O	7880 ± 150
5096	G1/85/11.0–11.1m/C	C	8800 ± 70
3231	G1/85/11.45–11.50m/C	C	9160 ± 50
2476	G1/85/11.45–11.50m/O	O	8960 ± 120
5098	G1/85/12.0–12.1m/C	C	10,230 ± 90
2627	G1/85/12.5–12.6m/C	C	10,710 ± 150
4103	G1/85/12.5–12.6m/O	O	10,240 ± 250
5099	G1/85/13.0–13.1m/C	C	10,830 ± 80
4104	G1/85/13.0–13.1m/O	O	10,790 ± 220
3225	G1/85/13.5–13.55m/C	C	10,640 ± 60
2464	G1/85/13.5–13.55m/O	O	10,640 ± 100
3223	G1/85/14.45–14.50m/C	C	12,100 ± 90
4067	G1/85/14.45–14.50m/O	O	11,270 ± 350
4007	G1/85/15.0–15.05m/C	C	12,570 ± 130
4013	G1/85/15.0–15.05m/O	O	11,980 ± 430
2584	G1/85/15.4–15.5m/O	O	12,650 ± 140
5048	G1/85/15.40–15.50m/C	C	13,480 ± 120
5444	G1/87/4.01–4.10m/C	C	3850 ± 70
5442	G1/87/4.31–4.40m/C	C	3720 ± 70
5441	G1/87/5.02–5.11m/C	C	3610 ± 60
5377	G1/87/6.15–6.25m/C	C	4520 ± 50
5376	G1/87/7.00–7.10m/C	C	4540 ± 70
5375	G1/87/7.90–8.00m/C	C	5430 ± 60
5374	G1/87/9.02–9.10m/C	C	6130 ± 60
2888	G1/87/9.42–9.52m/C	C	5270 ± 90
2889	G1/87/10.66–10.72m/C	C	7350 ± 120
5373	G1/87/10.93–11.0m/C	C	7620 ± 60
5372	G1/87/11.33–11.40m/C	C	7800 ± 70
5242	G1/87/16.92–16.98m/C	C	13,240 ± 120
2771	G1/87/16.92–16.98m/O	O	13,780 ± 200
6371	G2/87/16.02–16.10m/C	C	11,980 ± 170
5853	G2/87/16.10–16.20m/C	C	11,700 ± 120
4676	G2/87/16.10–16.20m/O	O	10,470 ± 180
	B. Lake Gościąż – other cores		
5049	G1W/86/11m	POG	12,120 ± 110
3305	G1E/86/17m	PG	11,960 ± 80
4683	G4/90/6.55–6.60m	P	12,980 ± 270
6386	G4/90/6.6–6.65m	P	13,070 ± 200
4691	G4/90/6.6–6.7m	P	12,800 ± 360
5857	G4/90/6.71–6.78m	P	13,300 ± 150
4688	G5/90/9.04m	CG	13,960 ± 270
4733	G3/91/0.45–0.60m	DG	3710 ± 80
4732	G3/91/0.70–0.90m	DG	4430 ± 130
4731	G3/91/1.50–1.70m	DG	7580 ± 250
4788	PTG/91/1.00–1.34m	Ch	3010 ± 120
4790	PTG/91/1.46–1.64m	Ch	5370 ± 210
4789	PTG/91/1.94–2.12m	WCh	6120 ± 120
4791	PTG/91/2.67–2.69m	CDG	13,300 ± 200
6355	G1/90/14.89–14.92/O1	CG	11,970 ± 130
4669	G1/90/14.89–14.92/O2	CG	12,350 ± 260
4845	T1/90/14.25–14.33 m	BMP	12,720 ± 500
	C. Shore zone of Lake Gościąż		
5696	GTO301/89/6.0–6.3m	CG	13,140 ± 170
6220	GTO301/89/6.30–6.35m	AOM	11,840 ± 160
5789	GTO303/89/4.5–4.7m	GOD	11,700 ± 130
6297	GTO303/89/5.3–5.4m	CG	12,280 ± 200
5778	GTO303/89/5.6–5.8m	CG	12,660 ± 130
5678	GTO2/89/1.00–1.15m	AOM	790 ± 60
5669	GTO2/89/1.37–1.59m	AOM	2070 ± 50
5670	GTO2/89/2.13–2.30m	AOM	2410 ± 60
5679	GTO2/89/3.00–3.18m	AOM	5670 ± 70
5677	GTO2/89/3.51–3.61m	AOM	8390 ± 90
5676	GTO2/89/3.90–4.12m	CG	9340 ± 100
6194	GTO2/89/4.50–4.69m	CG	13,970 ± 190
6900	G2/93/1.50–1.55m/O	CG	8970 ± 130
8054	A1/92/2.95–3.0m	OS	8100 ± 200
7187	B5/92/0.65–0.67m	CT	7730 ± 60
8053	E5/92/0.65–0.75m	FS	3650 ± 170
8054	G3/92/1.9–1.96m	SOM	4400 ± 160
8055	J3/92/0.4–0.45m	P	2330 ± 180
	D. Upper lakes and Ruda valley		
6171	GTO1/89/0.7–0.8m	P	770 ± 80
5656	GTO1/89/1.6–1.7m	P	2670 ± 60
5657	GTO1/89/2.6–2.7m	P	3350 ± 60
6174	GTO1/89/3.6–3.7m	P	4930 ± 110
6176	GTO1/89/4.6–4.7m	P	7160 ± 140
5659	GTO1/89/6.4–6.5m	AOM	10,040 ± 100
6219	GTO1/89/7.6–7.7m	CG	13,330 ± 160
6192	GTO1/89/7.7–7.8m	CG	14,140 ± 260
4549	GTO1/89/7.8–7.93m	CG	12,950 ± 310
4559	GTO1/89/7.8–7.93m	CG	13,320 ± 160
6369	Wierzchoń/86/12.4–12.5m	P	13,770 ± 150
4763	Brzózka/91/6.75–6.84m	AG	4510 ± 80
6589	Brzózka/91/11.35–11.45m	CG	11,340 ± 150

Table 5.1. *Continued.*

Lab. ^{14}C No.	Sample	Material	Age ^{14}C BP
4937	G33/92/1.8–1.9m	P	7700 ± 120
10053	G14/93/1.8–1.9m	P	2240 ± 100
10054	G14/93/2.9–3.02m	PD	3690 ± 120
10055	G14/93/3.14–3.2m	AOM	6460 ± 120
10056	G14/93/4.1–4.2m	G	8710 ± 130
	E. Lake Mielec and Ruda valley		
4679	Mielec3/90/13.90–13.95m	CG	14,380 ± 270
6370	Mielec3/90/13.95–14.0m	CG	12,590 ± 190
4692	Mielec3/90/15m	P	13,280 ± 320
4521	GTO4/89/1.22–1.37m	AOM	2720 ± 100
4542	GTO4/89/1.44–1.55m	AOM	3550 ± 110
5703	GTO4/89/2.77–2.90m	CG	5890 ± 60
6202	GTO4/89/2.94–3.15m	CG	6200 ± 130
6203	GTO4/89/3.60–3.70m	CG	10,750 ± 150
6205	GTO5/89/1.42–1.52m	P	2150 ± 100
6209	GTO5/89/2.18–2.35m	CG	4110 ± 110
6221	GTO5/89/2.48–2.60m	OG	2970 ± 100
4564	GTO5/89/2.48–2.60m	C	2480 ± 150
4557	GTO5/89/3.00–3.12m	DG	5440 ± 120
6210	GTO5/89/3.32–3.42m	CG	8200 ± 150
4565	GTO5/89/4.60–4.70m	AOM	10,280 ± 300
4558	GTO5/89/5.30–5.45m	SOM	13,400 ± 260
6215	GTO5/89/5.57–5.77m	CG	12,480 ± 170
4936	G20/92/4.80–4.85	P	13,240 ± 150
7227	G3/92/2.34–2.38m	P	8680 ± 70
6783	G3/92/4.53–4.60m	P	13,020 ± 160
4935	G22/92/2.0–2.12m	P	4020 ± 70
	F. Other closed depressions outside the Na Jazach lake system		
5681	GTO3/89/1.05–1.25m	WP	5660 ± 70
6200	GTO3/89/1.55–1.71m	AOM	10,560 ± 180
4522	GTO3/89/1.84m	AOM	10,930 ± 520
6201	GTO3/89/1.94–2.05m	P	11,510 ± 150
6212	GTO6/89/1.0–1.1m	MP	5300 ± 130
6214	GTO6/89/2.0–2.1m	MP	9910 ± 140
6217	GTO6/89/2.2–2.3m	AOM	11,230 ± 150
6754	G2/92/1.50–1.59m	P	7090 ± 120
6759	G2/92/4.12–4.31m	P	12,750 ± 150
6753	G1/92/4.0–4.1m	P	8160 ± 120
6764	G1/92/4.27–4.33m	P	11,250 ± 120
6684	L.Mrokowo/91/7.9–8.0m	G	7760 ± 110
6685	L.Mrokowo/91/11.9–12.0m	G	8530 ± 110
6720	L.Mrokowo/91/12.9–13.0m	RP	9480 ± 120
6721	L.Mrokowo/91/14.0–14.1m	P	12,030 ± 130

between ^{14}C age of dated samples and "true" radiocarbon age is known as "apparent age". In general, apparent age of organic fraction of lacustrine sediment is lower than that of carbonate fraction.

The magnitude of apparent age could be recognized in detail for the sediments in the Lake Gościąż central deep, where an independent age control was available due to AMS ^{14}C dating of terrestrial macrofossils (Goslar et al., Chapter 6.2) and due to the varve chronology (Goslar, Chapter 6.4). The apparent age of carbonate fraction was variable along the profile, what was attributed to the changes of the mean depth of the Lake Gościąż water body (Pazdur et al. 1994a). The mean value of apparent ^{14}C age of carbonates for the whole profile was estimated to 2000±120 yr, and the observed scatter of apparent ages of individual samples might be characterized by standard deviation of ±360 yr (Pazdur et al. 1994b). The apparent age of bulk organic matter from the Lake Gościąż central deep is ca. 500 yr lower. One might expect that the apparent age of calcareous gyttja found in other sites does not exceed 2000 yr.

In many cores from the lake shore and surrounding, lacustrine sediments (e.g. calcareous gyttja) were alternated by those of terrestrial origin (e.g. peat). The main goal of ^{14}C dating was to delimit the age of boundaries between those two formations and, where possible, the peat or charcoal fragments adjacent to boundaries were sampled. The age of such samples is free of apparent age. Many profiles, however, consisted almost exclusively of lacustrine sediments. In such cases the samples affected by apparent age were dated, and their ^{14}C ages must be interpreted with caution. The ageing of such samples is e.g. evident for the youngest sample of detritus from the core G3/91 (0.45–0.60 m) dated to 3710±80 ^{14}C BP or for calcareous gyttja in the core GTO301/89 (6.0–6.3 m) which was dated as 1300 ^{14}C yr older than underlying sample of amorphous organic matter. On the other hand, young age of the topmost sample from the core GTO2/89 (1.00–1.15 m) – 790±60 ^{14}C BP – indicates that the apparent age of samples identified as amorphous organic matter is low or completely absent.

5.1.2. Sediments of lake Gościąż

*Kazimierz Więckowski**

Lake deposits have been studied in several tens of borings (Fig. 5.1), and their thicknesses have additionally been identified in three cross-sections (Figs 5.2 and 5.3). Selected core profiles have been arranged according to their age (Fig. 5.4, Tab. 5.1) and their elevation above the lake level (Fig. 5.5).

In the sediments filling up the basins of Lake Gościąż and connecting lakes as well as in the nearby peat-filled depressions and in the shore zone, the following lithological types of deposit have been distinguished:

1. carbonate gyttjas, usually grey-olive but also light grey and ivory in colour; these deposits contain 50–95% $CaCO_3$ and 5–30% of organic matter; various types of these deposits are most common.

2. sulphide-carbonate gyttjas, which predominate in lake deeps; when fresh, they are intensively black (large

* This part of text describes initial investigation of lake sediments performed by K. Więckowski and B. Wicik before the complex studies started after 1987.

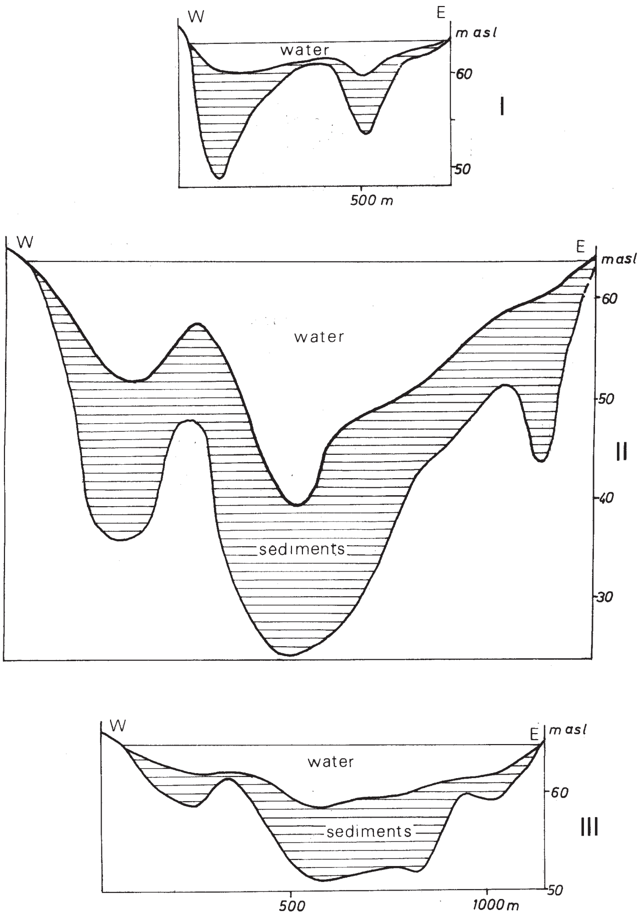

Fig. 5.2. W-E cross-sections of the northern (I), middle (II), and southern (III) parts of Lake Gościąż (after Więckowski 1993).

content of hydrotroilite); after oxidation they are brownish green with spotted, reddish coating; these gyttjas are commonly laminated and contain 50–70% $CaCO_3$ and 10–20% organic matter.

3. detritus gyttjas and algal-detritus gyttjas containing 50–85% organic matter, usually carbonate-free or with little carbonate.

4. brown-black organic gyttjas, compact and strongly bituminous, with a high content of methane.

5. peats: brown-moss, sedge, reed, and others.

6. sands of various origin: alluvial-deltaic, littoral-beach, deluvial, landslide, sometimes with an admixture of organic detritus.

7. layers of fossil soils.

8. layers of limestones and carbonate tufa.

The fundamental deposits filling up Lake Gościąż are grey-olive carbonate gyttjas of the type common to lakes formed within the extent of the last glaciation (Więckowski 1978). Only in the central and western deeps specific sulphide-carbonate gyttjas are found. Their characteristics are presented with the core G1/85 as example, being the first one of five cores obtained from the central deep. This core covers the full cycle of accumulation of lacustrine organic deposits (15.73 m), with a thin peaty layer at the base (15.73–15.87 m) above 10 cm of grey sands with chunks of brown coal.

After recovery, fresh deposits are intensively black (large content of hydrotroilite) and release hydrosulphide. As oxidation progresses the colour of the deposits changes into various shades of brownish-green with more or less reddish coating, and lamination becomes apparent (Wicik & Więckowski 1991).

At the top part to a depth of ca. 2.5 m the deposits are soft, amorphous, and jelly-like, while in the middle and lower parts they are increasingly compact. In the whole profile, numerous tiny blue spots or thin layers of vivianite even up to 1 mm are visible. Sands are lacking. The content of organic matter ranges from 10 to 18% of dry matter, and the smallest amount occurs in the middle 4–11 m part of the sequence, where the content of $CaCO_3$ reaches 75% of dry matter. A very low content of $CaCO_3$ occurs in the basal layers of sediments, which correspond to the initial stage of development. A drastic decrease in $CaCO_3$ in the top layers, which likely embody no more than a few recent centuries, is supposedly associated with human activity, i.e. forest clearing and development of agriculture. That caused increase in deflation and supply of mineral substances as well as decrease in supply of carbonates to the lake (Wicik & Więckowski 1991).

Except for the upper layer of sediments, the percentage of iron compounds is high when compared with that of the deposits of other lakes of the last glaciation, and very high (to 7.9% of dry matter) in the lower part (11–15 m) of the sequence. It probably results from the inflow of Tertiary waters, which are rich in iron (Wicik 1993). Under conditions of permanent oxygen deficit in the benthic waters of the deepest parts of this lake, iron sulphides are formed. They might favour formation and preservation of laminae, as is the case of Lake of Clouds (Anthony 1977).

From the central deep of Lake Gościąż 4 cores of sediments were recovered: G1/85, G1/87, G2/87, and G2/91. Two of them (G1/87 and G2/87) reached ca. 1–2 m deeper than the core G1/85 discussed above and revealed in their basal part, under a sand layer about 60 cm thick, a layer of gyttja about 30 cm thick containing up to 294 laminae couplets (core G2/87) (Goslar 1993, Goslar, Chapter 6.1). According to the author this sand layer resulted from a singular rapid gravitational flow that caused only a slight destruction of the top layer of the gyttja. The above was confirmed by correlation of laminae in both deeps by Goslar (1993).

The most spectacular feature of the deposits of the central deep is their lamination, representing the full period of the lake existence. Light and dark couplets correspond to annual cycles of accumulation. The thickness of laminae ranges from 0.2 to 0.8 mm. In the core G1/85 ca. 12,600 pairs of such laminae were counted by eye on a fresh core with an estimated error of ±600 years (Ralska-

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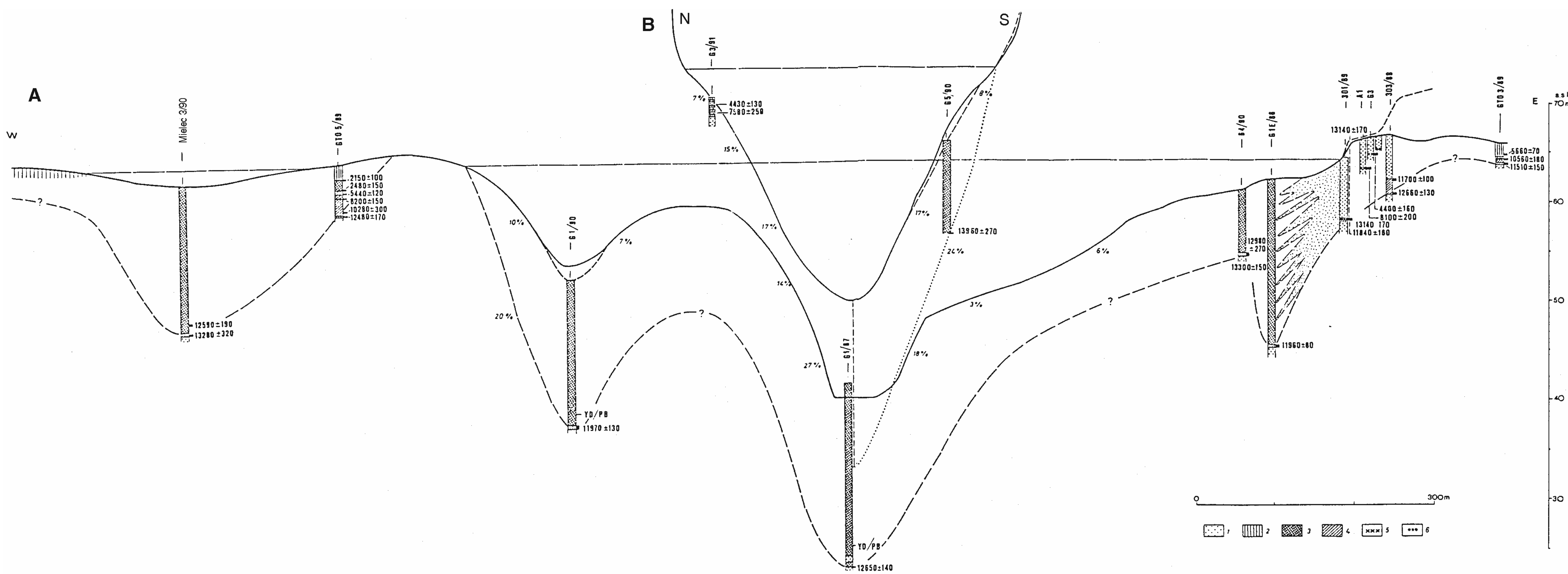

Fig. 5.3. Longitudinal (A) and transverse (B) cross-sections of Lake Gościąż and Lake Mielec with indicated main ^{14}C dated profiles (compiled by L. Starkel and K. Więckowski). 1. sand, 2. peat, 3. calcareous gyttja, 4. detritus gyttja, 5. buried soil, 6. gravely horizon. Please note the high slope of the bottom (up to 27%). Numbers of profile symbols like on Fig. 5.1.

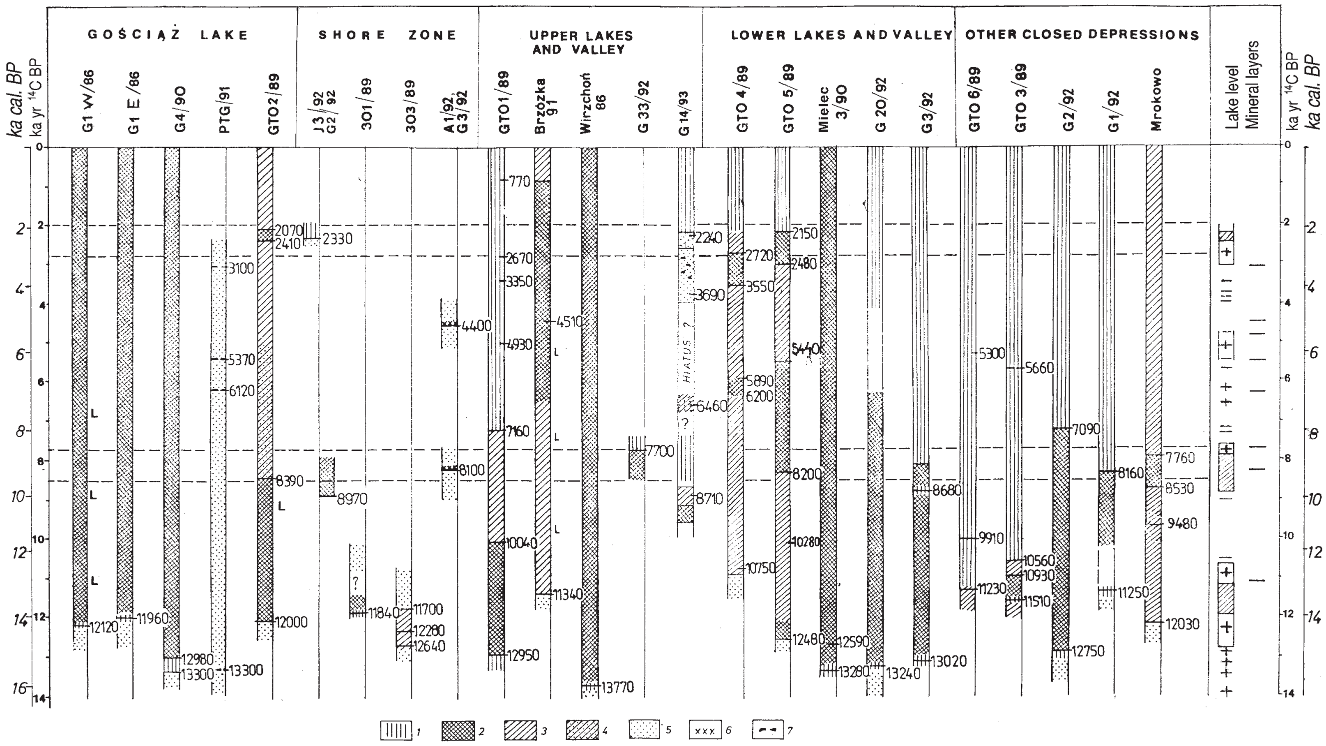

Fig. 5.4. Chronology of core profiles in Lake Gościąż and their surroundings (compiled by K. Więckowski, A. Pazdur, M. F. Pazdur, and L. Starkel). 1 – peat, 2 – calcareous gyttja, 3 – organic gyttja, 4 – lacustrine deposits with admixture of allochtonic-mineral deposits, 5 – sand, 6 – fossil humus horizon, 7 – charcoal and coarse organic detritus. Phases of higher water level (well documented ones marked with hachure) and dated horizons of sand flows and sand slumps in the lake and coastal profiles are indicated in the last column to the right. Dates on profiles are given in ^{14}C BP. At the both sides of figure, the scales of ^{14}C as well as of calendar ages are shown.

Jasiewiczowa et al. 1987). The ^{14}C date obtained from the peat layer at the base of this core – 12,650±140 ^{14}C BP – confirmed the annual nature of the laminations (Pazdur et al. 1987). Later on the studies of the laminated sediments were continued with more precise methods (Goslar 1993 and Chapter 6).

Differentiation of the laminae thickness arises from the changes in the accumulation rate of sediments and from their compression. It reflects also indirectly the changes in environmental conditions in the vicinity of the lake that controlled changes in thermic and biochemical regime of the water body. In the case of Lake Gościąż it is visible already on the preliminary thickness measurements of particular tens of laminae couplets. In the period from ca. 12,500 to 9000 years ago the accumulation rate was rather high, of the order of 1 mm per annum, with periodical substantial declines in the period between 11,500 to 11,000 years ago. Between 9000 and 7000 years ago the rate was rather low and stable, and then it started to increase and became more variable. It was most variable between 5200 and 2800 years ago. A large increase in laminae thickness during the last 3000 years is partly because the deposits have not yet been subjected completely to processes of diagenesis and compaction. A more detailed discussion is given by Goslar (Chapter 6.3).

There is a substantial differentiation of sediments in different parts of Lake Gościąż. Black, very homogeneous carbonate-sulphide gyttja in the western deep (cores G1/90 and G1/91, length 16 m, water depth 11 m) is similar to the deposits described in the central deep, but it is only partly laminated. First traces of lamination appear sporadically in the sediments five meters below the top and become more and more distinct downwards. From 10 m down to the base at 16 m the lamination is continuous, exceptionally regular, distinct, and very fine. At the base there is the peaty layer 10 cm thick dated at 12,120±110 ^{14}C BP, formed on grey, fine sand. In these sediments occur some light-grey clayey layers with distinct interfaces 7 mm thick each. The oldest of them occurs 1.84 m above the basal peat, the second 18 cm higher, and the next one another 16.5 cm higher. They are subdivided by about 230 pairs of laminae each. The fourth insert of this type occurs 45 cm higher, and the last insert (much less pronounced) 20 cm upward. The similar thickness and character of these interlaminations provide evidence of a similar intensity and duration of the process that formed them – long-lasting and strong water turbidity caused by clayey particles.

The scale and the rate of processes that affected the lake basin in the past are evidenced by the core G1E/86, which was recovered 75 m from the eastern shore, at the site where currently no pronounced deep occurs and where the water depth is only 3 meters. The thickness of

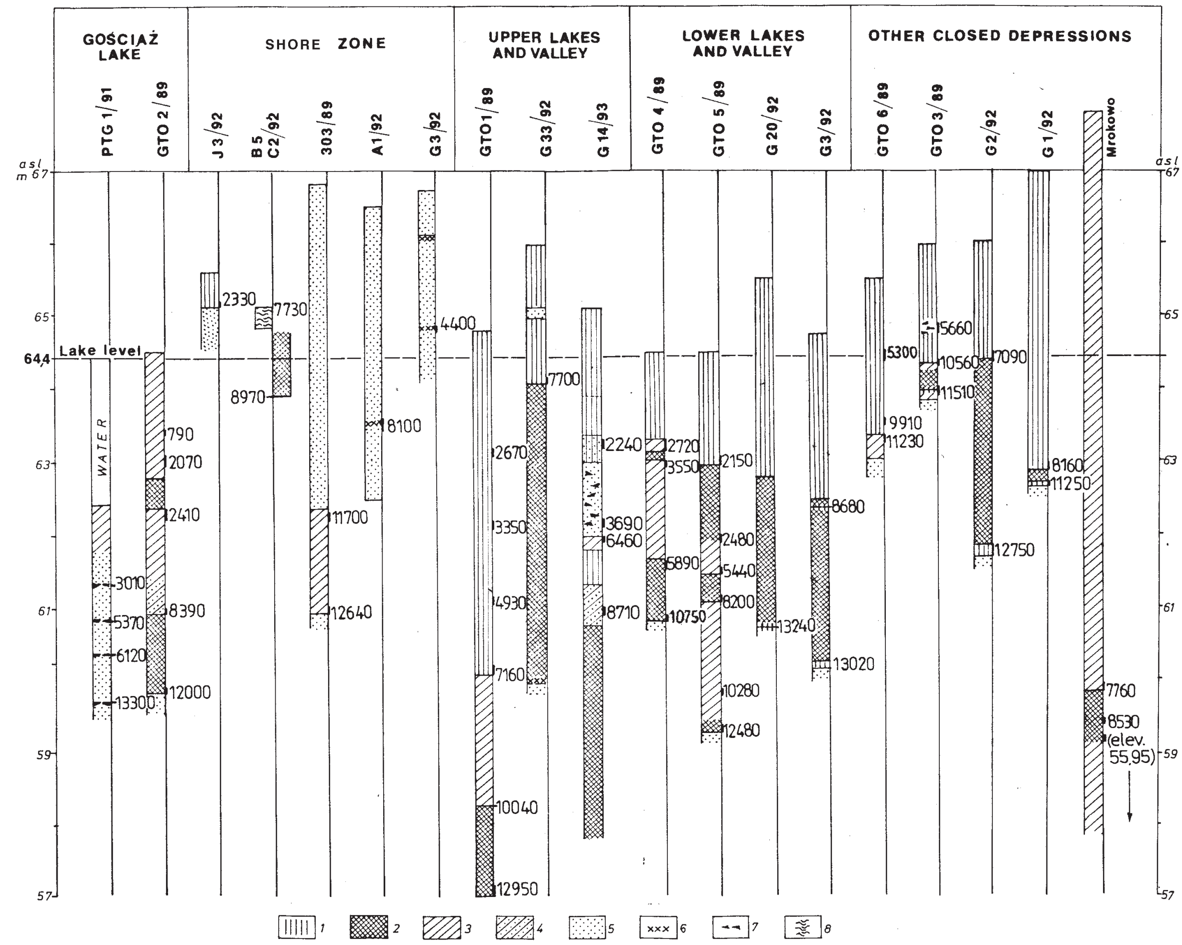

Fig. 5.5. Vertical positions of investigated profiles in relation to present lake level. 1–7 see explanations to Fig. 5.4, 8 – horizon of calcareous concretions in cross section B (see Fig. 5.1) dated at ca. 7700 ^{14}C BP (after Starkel et al. 1996).

sediments reaches up to 17.5 m. This indicates that in the past the eastern basin was originally 20 m deep. The base of this profile is formed by grey sand, overlain by strongly disturbed peaty layer 10 cm thick (dated at 11,960±80 ^{14}C BP). Above is a very differentiated sandy and clayely gyttja of variable dark grey colour, with numerous perturbations by gravitational flows, sandy interbeddings, plentiful pieces of wood, and coarse organic detritus. The depression had been filled up due to the long lasting intensive landslides and denudational processes that took place during the early phases of the lakes existence. These processes developed in the beach zone. It is striking that in the core G4/90, located ca. 100 m NW from there, at the site with the similar water depth, the thickness of the sediments is only 6.7 m, and their character indicates stable accumulation conditions (Wicik & Więckowski 1991). Core G5/90 (length 9.5 m) recovered 60 m from the southern bank of the lake (water depth 7.7 m), presents the type of sediments formed on the slopes of the lake basin. Because of the bottom slope and vicinity of the beach zone, the accumulation conditions were very variable, as expressed by the high differentiation in contents of organic matter, $CaCO_3$, macroscopic plant remnants, and sand and clay in the sediments as well as by the appearance of sporadic laminations, perturbations, and changes in the inclination of layers. A similar variability of accumulation conditions is depicted by the sediments covering the opposite, northern slope of the lake basin below the sandy cliff, documented in core G3/91. The 2 m series of sediments is here composed of numerous layers of sandy gyttjas with plentiful macroscopic plant remnants, and of varigrained sands with abundance of tiny coal pieces and macroscopic plant remnants dated to 4430±130 and 7580±250 ^{14}C BP. Accumulation of sandy deposits also predominates on the shallow passage between Lake Gościąż and the Tobyłka Bay (core PTG/91). The sandy, carbonate-detritus gyttja is 0.6 m thick and is underlain by a series of sands of various grain sizes over 2 meters thick with gravels, plentiful pieces of coal, and macroscopic plant remnants dated to 3000–6100 ^{14}C BP. Below is clayey gyttja 0.4 m thick with macroscopic remnants dated to 13,300 ^{14}C BP, and grey sands at the base of the series (Fig. 5.4).

The sediments of the Ruda stream delta zone are represented by core T1/90 (length 14.5 m) recovered from Tobyłka Bay at a depth of 1.9 m (Fig. 5.8). These are carbonate gyttjas or carbonate-detritus gyttjas of variable striped colouring, providing evidence for frequent changes in the relation among the proportions of organic matter, $CaCO_3$, macroscopic organic remnants, clays, and sands. Accumulation conditions were influenced by the stream Ruda and were very variable here. The present-day mouth of the Ruda is now located ca. 100 m from the site of the core T1/90 but in the past it could have been much closer during the low-water stages in the lake.

5.1.3. Sediments of the neighbouring lakes

Kazimierz Więckowski

Although the bottom deposits of the Na Jazach lake complex belong to the same type of carbonate gyttjas, each of them exhibits individual properties. The deposits of Lake Wierzchoń are richest in $CaCO_3$ (ca. 90%) and their homogeneity in the whole profile is the evidence of very stable conditions of accumulation. The thickest sediment found in the lake is 12.3 m. The radiocarbon date of the basal layer of peat – 13,770±150 ^{14}C BP – is undoubtedly modified by the reservoir effect. These sediments fill up ca. 90% of the original lake-basin capacity.

The sediments of Lake Brzózka are similar in character, although much less homogenous. Frequent changes in the organic-matter content are expressed by a shift in colour from light grey to grey brown, and plentiful macroscopic plant remnants indicate variability in the biochemical regime of the water body. The sediment thickness reaches 11.5 m, and the age at the base is 11,340±150 ^{14}C BP. The sediments fill 90–95% of the lake basin (Fig. 5.3).

The carbonate-rich (80–90% $CaCO_3$) deposits of the shallow Lake Mielec (water depth 1 m) are 14.2 m thick, and their base is dated to 12,590±150 ^{14}C BP. They fill 90–95% of the original lake-basin capacity. These deposits, from the level of 5.3 m down to the base, are more or less laminated (with some discontinuities). The uppermost layer, 2.6 m thick, has an unusual mauve colour (grey after oxidation).

All three lakes are now in their final stage of development. Their depths decrease very rapidly due to intensive accumulation of sediments, while their areas diminish because of progressing peat growth in the shore zones.

Ca. 0.75 km SE from Lake Gościąż in a separate meltwater basin is a small isolated Lake Mrokowo, fed almost exclusively by groundwater. The deposits of this lake are organic entirely carbonate-free plankton-detrital gyttjas which are typical of the intra-forest dystrophic lakes. In the upper part these sediments are very soft, of a jelly-like structure, with plentiful thick partially decayed fibrous plant remnants. In the lower part of the series the sediments are brownish-black and medium-compact, and have a lamellate structure and highly bituminized organic matter. The formation of lacustrine deposits started here

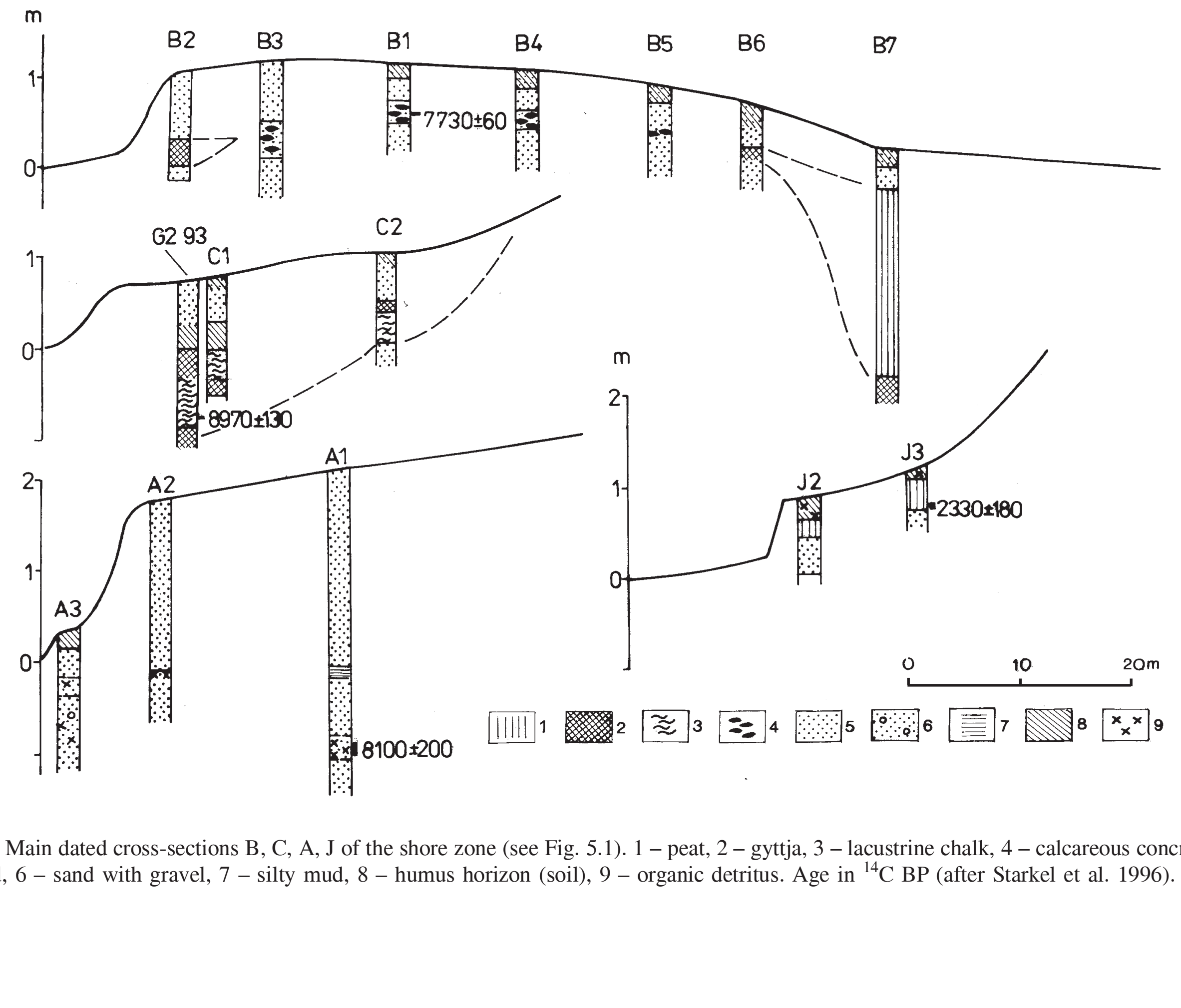

Fig. 5.6. Main dated cross-sections B, C, A, J of the shore zone (see Fig. 5.1). 1 – peat, 2 – gyttja, 3 – lacustrine chalk, 4 – calcareous concretions, 5 – sand, 6 – sand with gravel, 7 – silty mud, 8 – humus horizon (soil), 9 – organic detritus. Age in ^{14}C BP (after Starkel et al. 1996).

with a layer of black organic gyttja 72 cm thick, above which is a grey-brown carbonate gyttja 35 cm thick. Usually in dystrophic lakes the sequence of sediment is opposite. The character of the deposits suggests a very stable hydrochemical regime of the water body. Only the layer of olive-grey carbonate-detritus gyttja (ca. 59–60 m a.s.l., Fig. 5.5), laminated in the middle part, indicates that the lake was fed very intensively by the groundwaters rich in carbonates between 8530±110 ^{14}C BP and 7760±100 ^{14}C BP. At present this lake is in the atrophic stage. The sediments, which reach a thickness of 12.6 m, fill 90–95% of the lake-basin capacity, and the water depth does not exceed 1 m.

Altogether 50 cores of lake and peat deposits from the area have been obtained, including 16 cores from Lake Gościąż. The thickness of sediments has been measured at 24 additional points. The data allowed to recognize the original surface of mineral bottom of the lake basin and to determine that the eastern depression was entirely filled up with the sediments. At present the sediments fill 50–60% of the original Lake Gościąż basin.

The basins of the other lakes are filled up to much larger extent (up to 90–95%), so the lakes are currently entering their final stage. The average rates of accumulation of the sediments in all the lakes exceed 1 mm per year, which is higher than in the majority of lakes in other regions of Poland (ca. 0.7 mm per year).

The occurrence of laminated sediments, even in the lakes that are shallow at present (1–2 m), e.g. in Lake Mielec from the base to 6 m, in Lake Wierzchoń to 5 m, and in Lake Brzózka to 9 m below the sediment/water interface, appears more frequent than in the lakes of other regions of Poland. It suggests the pronounced inclination for the formation of anaerobic conditions in the benthic water layers of these lakes in the past. The most probable reason for that was a significant supply to the lakes with the waters rich in iron and sulphur compounds (Wicik 1993).

5.1.4. Sediments of the shore zone of Lake Gościąż

Leszek Starkel

Deposits of the shore zone are differentiated depending on morphology and evolution of the shores (Figs 5.1, 5.6 and 5.7; Tab. 5.1C).

The southern shore forms a scarp 6–8 m high, built of the glaciofluvial sands. It is undermined by a line of active springs and modified by niches and landslides entering into the lake. On transect E (Fig. 5.7) are preserved landslide walls overlying a fossil soil horizon dated at 3650±150^{14}C BP. The fan-deltas starting from the springs and partly submerged are built of laminated sands and gravels. A higher deltaic level on transect J was found at ca. 70 cm above the present lake level, buried by peat. Its base was dated at 2330±180 ^{14}C BP.

The eastern shore, with remains of a low coastal wall, is formed by the terrace 10–30 m wide and 1.8–2.5 m high. Above it rises a scarp up to 5 m high. In the deeper

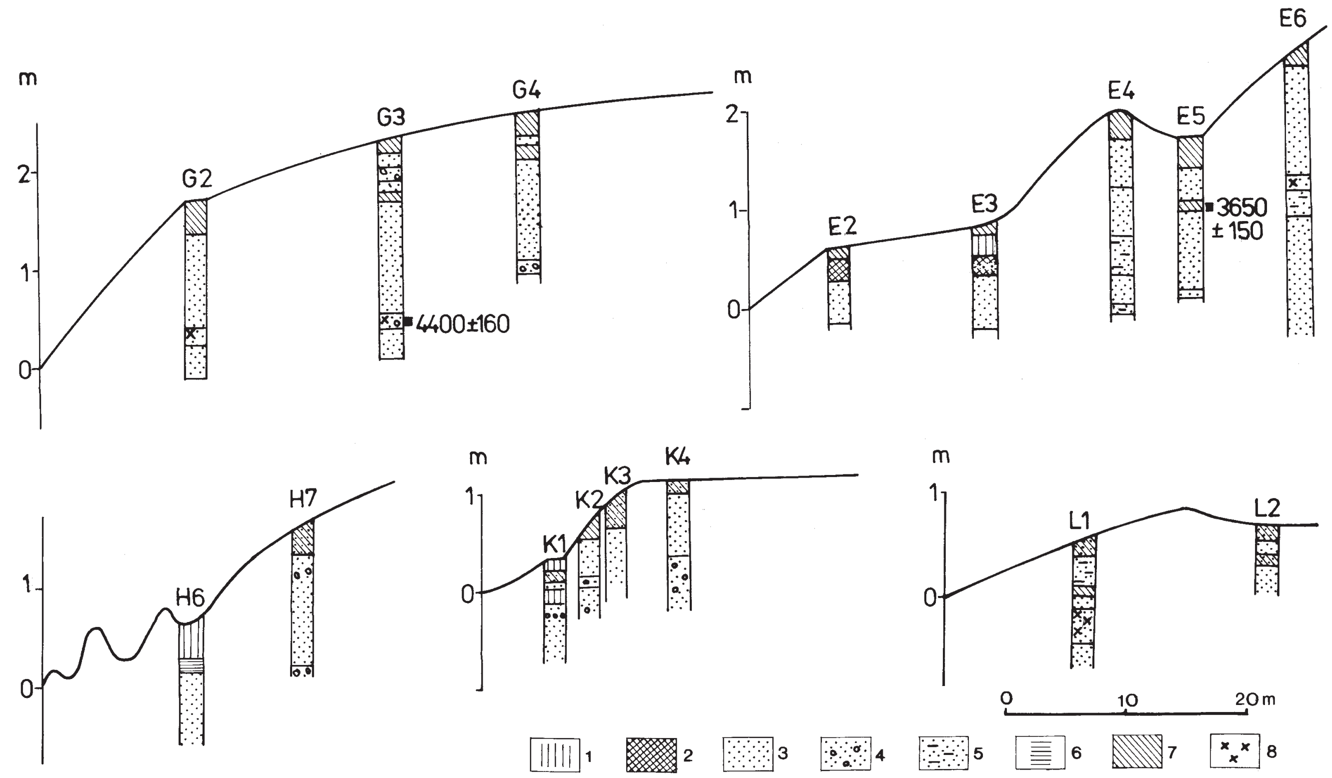

Fig. 5.7. Other cross-sections G, E, H, K, L of the shore zone (see Fig. 5.1). 1 – peat, 2 – gyttja, 3 – sand, 4 – sand with gravel, 5 – silty sand, 6 – silty mud, 7 – humus horizon (soil), 8 – organic detritus. Age in ^{14}C BP.

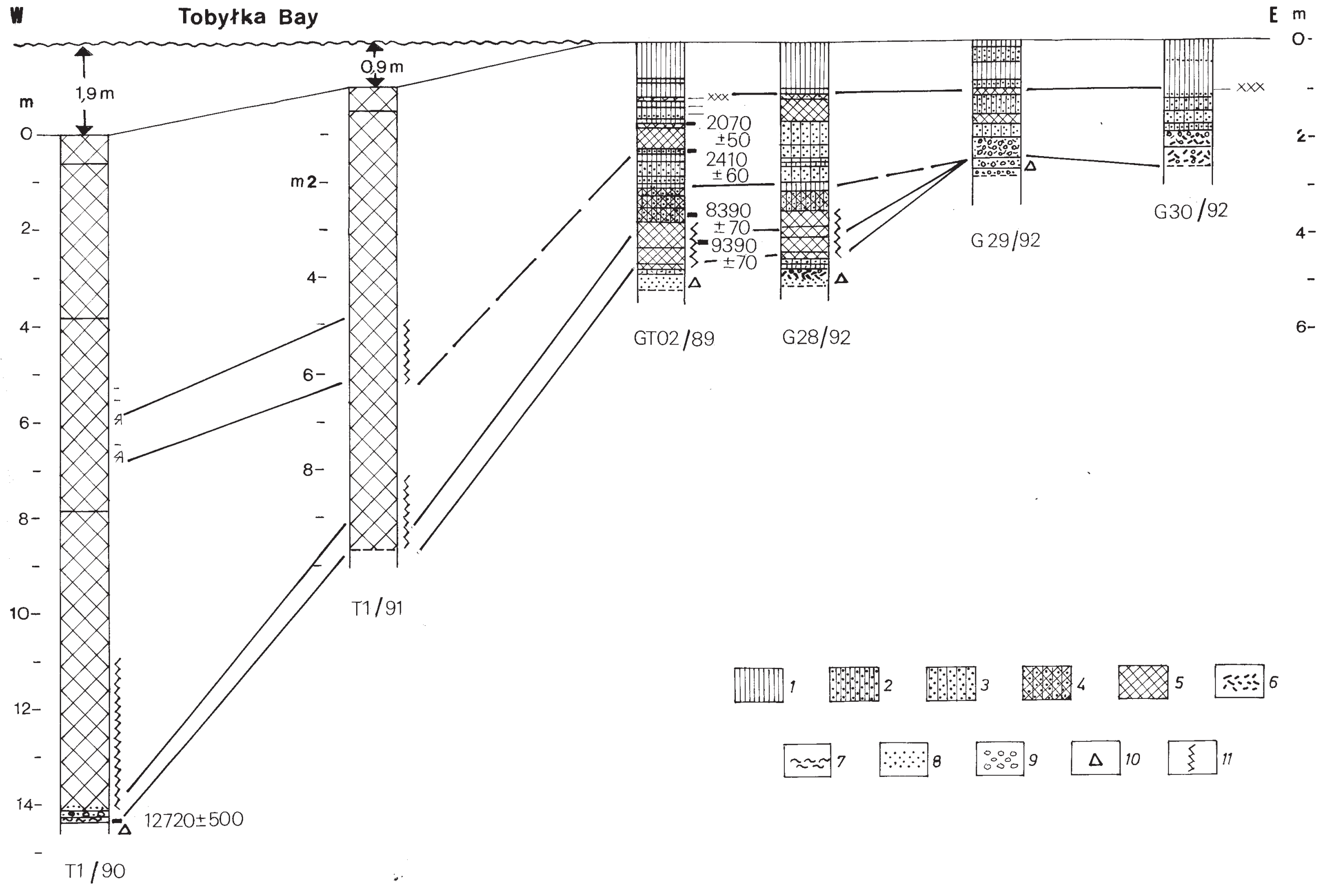

Fig. 5.8. Transect from centre of Tobyłka Bay across the delta of the Ruda River (compiled by D. Demske 1995). 1 – peat, 2 – peat with sand, 3 – sand with peat, 4 – peaty gyttja with sand, 5 – calcareous gyttja, 6 – organic detritus, 7 – mossy peat, 8 – sand, 9 – gravel, 10 – calcareous horizon, 11 – lamination. Age in ^{14}C BP.

borings (301/89 and 303/89) below the sands, gyttja and peat were found at 5–6 m depth. The datings go back to the early Allerød and correspond with the base of filling of the eastern deep (GE/86). According to Więckowski (1993), big slumps from the margin of the lake depression occurred during the Younger Dryas. However, the 2 m sandy terrace at the A and G transects (Figs 5.3, 5.6 and 5.7) includes organic horizons 1 m below present lake level dated at 8100±200 ^{14}C BP and at 0.4 m above the lake level dated at 4400±150 ^{14}C BP. This means a gradual upbuilding of the terrace.

The northeastern shore is generally steep, and the terrace bench ca. 1 m high is present only on the side of the Tobyłka Bay (transect C). The lacustrine chalk is buried in this terrace below 0.4 m of sand that was probably caused by soil erosion activated by deforestation. The base of this chalk at 0.5 m depth below lake level was dated at 8970±130 ^{14}C BP. A layer of calcareous concretions was found in sand at 40–70 cm depth (and up to 70 cm above the present lake level) in transect B (Fig. 5.6) at the isthmus between lake and small bog, investigated by Demske (1993). It is probably connected with the late Boreal – early Atlantic water-level rise. At the NW margin of lake the only bench 1.2 m high is present at the western shore of the Tobyłka Bay. It is built of sand with a layer of gravel (transect K). At transect L a ridge 0.9 m high is visible (Fig. 5.7).

At the outlet of Ruda stream to Tobyłka Bay the typical deltaic deposits (GTO2/89) overlie calcareous gyttja (Fig. 5.8), with change into organic gyttja mixed with sand. This transition was dated at 8390±90 ^{14}C BP. Above the sandy peat the calcareous gyttja appears again between 2410±60 and 2070±50 ^{14}C BP, indicating the rise of the lake level above the present one. The topmost part is peaty with some sandy intercalations.

5.1.5. Sediments in the Ruda valley floor

Leszek Starkel

About 1 km upstream from Lake Wierzchoń in the flat Ruda valley floor, 3 m of calcareous gyttja is covered by 2 m of peat (core G33/92) (Fig. 5.4). This indicates a much greater upstream extent of the lake in the past. The valley floor was overgrown before 7700±120 ^{14}C BP. At the Ruda outlet to Lake Wierzchoń at ca. 7 m depth in boring G14/93, calcareous gyttja is covered by the detritus gyttja (dated at 8710 ^{14}C BP at the base) and then by peat. The upper part of the profile is formed by sandy-organic deltaic deposits with two horizons dated at

6460±120 and 3960±120 ^{14}C BP. Above the horizon dated at 2240±100 ^{14}C BP *Carex* peat changes into *Sphagnum* peat.

The Ruda valley reach between Lake Brzózka and Tobyłka Bay is 450 m long and covered by peat. It is joined with a closed dead-ice depression also filled by 8 m of peat over lacustrine gyttja (core GTO1/89), dated at the base at 12,950±310 ^{14}C BP (Demske 1993).

The shallow Lake Mielec downstream from Lake Gościąż is bordered by a wide zone of bogs overlying buried calcareous and detritus gyttjas (GTO4/89, GTO5/89, G20/92), deposited from ca. 13,200 to 12,500 ^{14}C BP. In these profiles two distinct horizons of calcareous gyttja occur after 8200 ^{14}C BP and between 2480 and 2150 ^{14}C BP.

During the earliest high-water stage the big lake extended about 1.5 km downstream from Lake Mielec. In the widening of the valley floor ca. 0.8 km from Mielec (core G3/92) the calcareous sediments were deposited between 13,020±160 ^{14}C BP and 8680±70 ^{14}C BP. Then after a brief overgrowth and the next temporary transgression, the peat was deposited continuously from ca. 8000 ^{14}C BP to the present. Farther downstream (core G22/92, 7 m deep) the change from lake to bog happened as late as 4020±70 ^{14}C BP.

5.1.6. Deposits of small depressions without outflow

Leszek Starkel

Beyond the small Lake Mrokowo at elevation of 67.8 m a.s.l. (3.4 m above the Lake Gościąż level) several depressions without outflow occur. They are not incorporated in the main system of lakes Na Jazach drained by the Ruda, but nevertheless they are filled with the lacustrine deposits covered by peat (Figs 5.1 and 5.4). The most distinct is the swampy sinuous channel running towards east from Lake Gościąż. Its surface is ca. 1.5 m higher than the lake level. The filling is 2–4.3 m thick. The bottom peat layer was dated at 12,750±150 and 11,510±150 ^{14}C BP. It is covered by the calcareous gyttja, deposited until the Younger Dryas (core GTO3/89) or until the Atlantic (G2/92).

Another small depression to the south of that described above is 160x60 m in size. In the boring G1/92, 1.6 m below the present Gościąż water level, a peaty layer dated at 11,250±120 ^{14}C BP was found. It is overlain by lacustrine sediments which change to peat up to 4 m thick about 8160±120 ^{14}C BP.

Another oval depression, ca. 200 m in diameter, is located north of Lake Mielec. Its peaty floor is elevated ca. 1 m above the water level of Mielec. Lacustrine sediment was found in boring GTO6/89 below 2.2 m of peat (dated at the base at 9910±150 ^{14}C BP). This indicates that also there at the close of the Allerød the groundwater table rose above the bottom of the depression, which was 1.3 m below the present level of Lake Mielec.

All the characteristics of lacustrine and bog sediments and their datings presented in this chapter are discussed in the successive chapters describing various features of sediments but especially in the reconstruction of hydrological changes through time.

5.2. CHEMICAL COMPOSITION OF THE SEDIMENTS OF NA JAZACH LAKES

Bogumił Wicik

Bottom deposits of the complex of lakes Na Jazach are formed of carbonate, sulphide-carbonate, and algal-detritus gyttjas. Characteristic properties are presented in Figs 5.9–5.12. In lakes Wierzchoń and Brzózka calcareous gyttjas occur, in lakes Mielec and Gościąż ferruginous-calcareous ones, and in Lake Mrokowo algal-detritus gyttjas (Więckowski et al., Chapter 5.1).

The sediments of Lake Gościąż are characterized by strongly reducing conditions (H_2S present in the top deposits). Also the top deposits in Lake Mrokowo are oversaturated with H_2S (Więckowski et al., Chapter 5.1).

Constant accumulation of carbonates in lakes Wierzchoń, Brzózka, and Mielec (Figs 5.9, 5.10 and 5.11) shows that the variations in hydrothermal conditions during the Holocene were very weak. In lakes Wierzchoń, Brzózka, and Mielec only single episodes of decreased $CaCO_3$ content are marked at depths of 4.5 m, 7.5 m, and

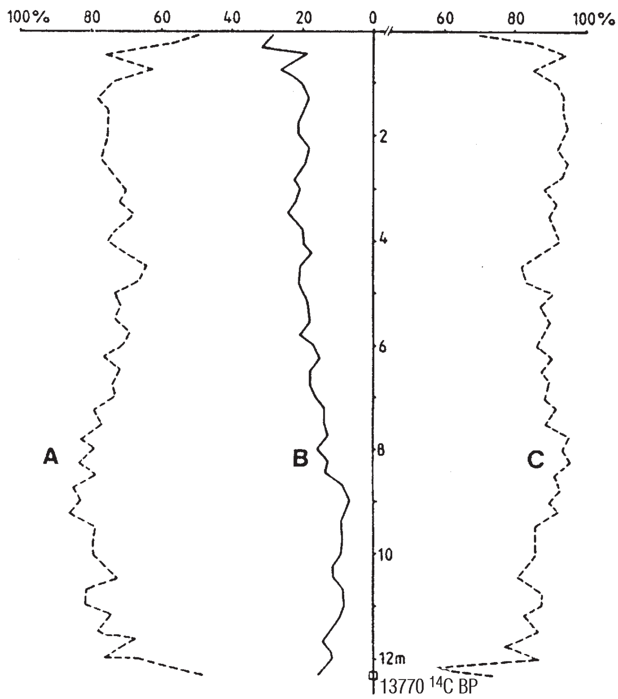

Fig. 5.9. Main sediment components of the Lake Wierzchoń profile: A. $CaCO_3$ content in sediment, B. loss on ignition, C. $CaCO_3$ content in the ignition residue.