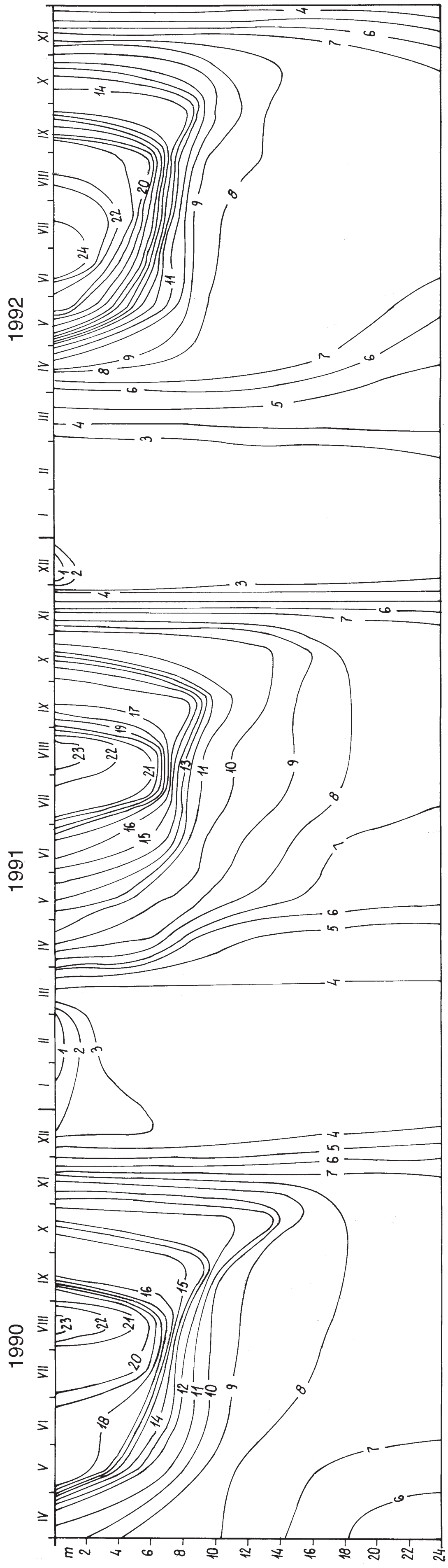

Fig. 3.7. Variability in thermal conditions (°C) in the deepest site of Lake Gościąż in 1990–1992.

accumulation of sediments was most intensive during that time of the year.

Summarizing, it can be said that the sedimentation develops best during autumn homothermal conditions and eventually during spring homothermal conditions. These periods of intensified dynamics of water movement were associated with thermal homogenization and with the increase in alimentation. Summer and winter periods are characterized by extreme calmness, interrupted only by inflow of the cool Tertiary waters. Inflow of water and dissolved substances to Lake Gościąż is controlled by variability in alimentation and is rather small in comparison to the lakes located on the plateau. Such situation results from lake location in the valley and from its intensified feeding by groundwater.

At present the basin of Lake Gościąż is filled with sediments which constitute ca. 50% of its capacity. In 1925 Jaczynowski determined the maximum depth as 25.8 m (Lencewicz 1925). At present the maximum depth is 24 m. It would indicate that ca. 2 m of the bottom deposits could have accumulated in the deepest part for 70 years, assuming that the earlier measurements were precise enough.

Due to overgrowing, the area of Na Jazach lake complex diminishes, though in Lake Gościąż, with steep slopes, this process is very slow. A larger extent of the lake in the past is evidenced by lake terraces in certain locations. The process of overgrowing is currently being stopped by artificial damming, which disturbs the rhythm of water-level oscillations in the lake and can induce changes in sedimentation conditions.

3.4. CHEMISTRY OF GROUNDWATERS IN THE NA JAZACH LAKES AREA

Bogumił Wicik

Lakes Na Jazach and the connecting Ruda stream as well as adjacent peatlands form a hydrological system fed by groundwaters of the Quaternary aquifer. The thickness of this aquifer in the area exceeds 20 m. Beneath the Quaternary aquifer are Pliocene clays and locally Miocene coals and carbonaceous sands or even Cretaceous limestones.

The pressure of the Cretaceous waters, in which mineralization does not exceed 0.5 g/dm^3, is 900–1200 kPa (Fabianowski & Olczak 1988). Near Lake Wierzchoń these waters stabilized at the level of 54 m a.s.l. in wells. Waters of the Miocene brown coal series are also weakly mineralized and are under subartesian pressure of 250–1300 kPa. When bored near Lake Wierzchoń these waters stabilize at ca. 39 m a.s.l. They contain up to 0.4 mg/dm^3 of manganese and in certain cases over 10 mg/dm^3 of iron.

The Quaternary waters in this part of the Płock Basin flow northward with an hydraulic gradient of ca. 1.5–2‰

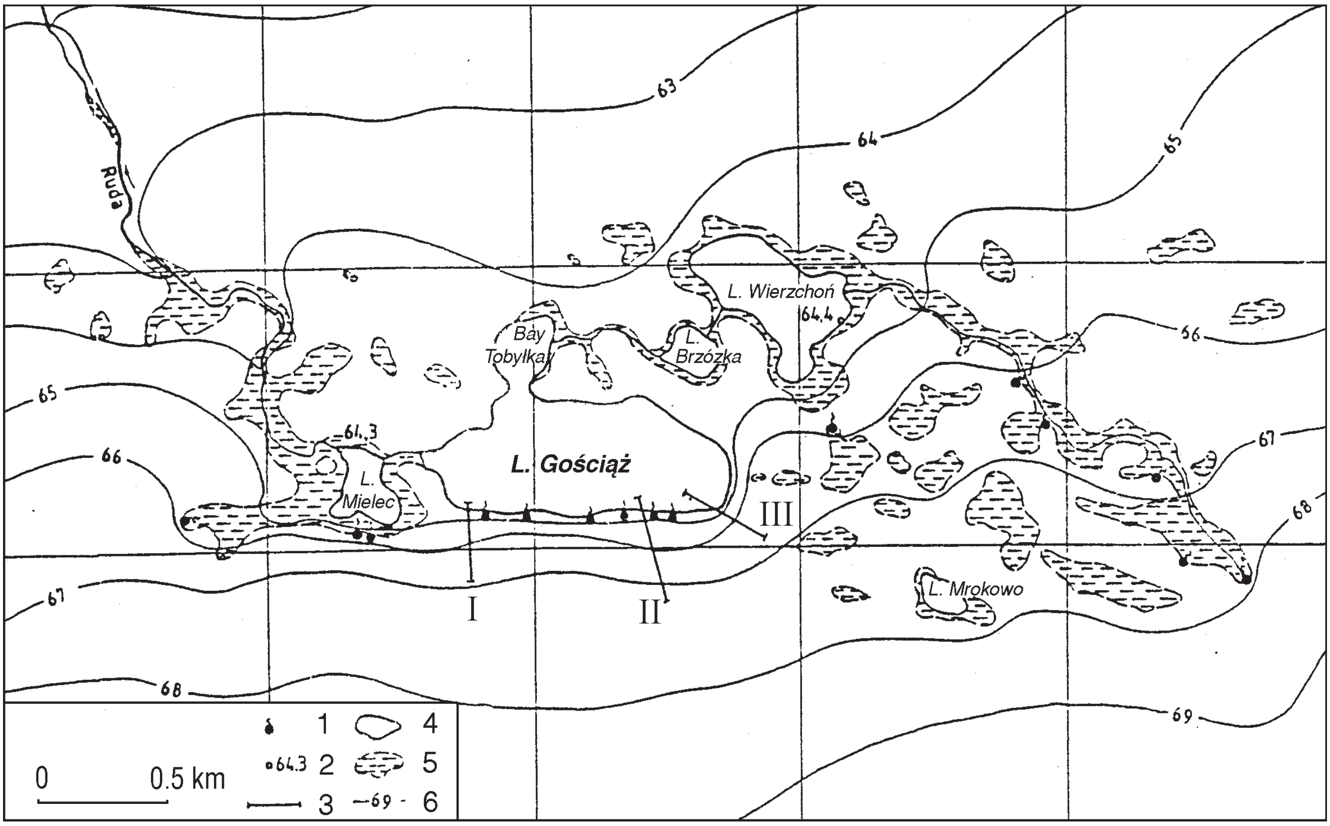

Fig. 3.8. Hydrographic sketch of the area of lakes Na Jazach. 1 – springs, 2 – elevations in m a.s.l., 3 – geological profiles, 4 – lakes, 5 – mires, 6 – hydroisohypses.

(Fig. 3.8, Churski & Marszelewski, Chapter 3.3). Thus the lakes are located on the route of the groundwater flowing from the anticlinorium ridge of the older substratum towards the Vistula valley. The discontinuities in the isolating layer of the Pliocene clays serve as hydrologic windows, where a direct contact between the Quaternary waters and confined waters of the older geological horizons occurs.

Dynamics of groundwater exchange near the lakes depends on magnitude of surface runoff. In periods of low precipitation or large moisture losses due to evaporation, the losses of groundwaters inflowing from the south are compensated through the hydrologic windows. As a result, if no significant changes occur in the thickness of aeration zone, the top part of the aquifer contains "old" waters of a long-lasting hydrological circulation and a constant temperature of ca. 7.5–8.5°C, which discharge to the lakes.

During the periods of high water levels and cessation of the drainage zone at the southern side of the lakes, the main water mass feeding the water bodies exhibits high rate of flow, similar to the mean infiltration coefficient for this part of Płock Basin (0,00036 m/s; Sierżęga & Narwojsz 1988). These are waters of seasonally variable temperature, low mineralization, and rich in substances derived from the soil zone.

The waters of the Quaternary aquifer in the lakes Na Jazach area are differentiated by their chemical composition. In the bottom parts of this aquifer at the zone of contact with the Pliocene clays the waters are alkaline, with pH 8.5–10.5 and ca. 15 mg Ca/dm^3, 55 mg Na+K/dm^3, and ca. 100 mg HCO_3 and CO_3/dm^3. Their total hardness is 2.0°Ger. They can mix with the waters of the upper parts of this aquifer. In boreholes to a depth of 12 m, waters of similar chemical properties have not been found.

In the top parts of the Quaternary aquifer, which remain in contact with the aeration zone, thin layers of natural or slightly acid waters occur, with mineralization not exceeding 0.12 g/dm^3. These waters contain colloidal humus-mineral complexes and occur locally at the northern side of the lake system Na Jazach and also west of Lake Mielec, for they contribute to Lake Mrokowo. Most waters of the Quaternary aquifer feeding the lakes and the Ruda stream exhibit diverse chemical properties. The composition of groundwaters inflowing from the south is significantly modified near the lakes.

East of Lake Gościąż, gradients of the groundwater table are from 2 to 5‰. Low values occur near Lake Mrokowo and peatlands occupying depressions north of the lake. The top part of the aquifer shows seasonal changes in temperature, it is neutral or weakly acidic, and its mineralization slightly exceeds 0.1 g/dm^3 (Fig. 3.9). The present-day bottom deposits of Lake Mrokowo are fed by such waters and consist of non-calcareous algal-gyttja saturated with methane (CH_4). An oligotrophic mire is developed beside the lake. Waters strongly over-saturated with H_2S occur in closed depressions to the NW and SE of Lake Mrokowo and in its littoral part below peat and limnic deposits at the depth of 7–9 m. Waters with no hydrogen sulphide appear in springs and seeps in the Ruda valley upstream of Lake Wierzchoń. Moreover, hydrogen sulphide is not found in groundwaters below the peat deposits near the stream valley and east of Lake Gościąż. In general within the area limited by hydroisoline of 67 m a.s.l. (Fig. 3.8), by the Ruda stream valley, and by the southern bank of Lake Wierzchoń, the groundwater without H_2S exhibits slightly reducing properties. The waters contain ca. 55 mg Ca/dm^3, ca. 180 mg HCO_3/dm^3, and 0.1–0.8 mg Fe/dm^3 at pH 7.3–7.6. Their mineralization (0.30–0.34 g/dm^3) is usually higher than that of waters feeding lakes Gościąż and Mielec (Fig. 3.10). Due to permanent feeding with such waters, gyttjas deposited in lakes Wierzchoń and Brzózka contain over 90% $CaCO_3$. High accumulation of carbonates, which has been proceeded since both the lakes were formed, is an effect of continuous supply of waters of stable physical and chemical properties. In the carbonate deposits of these lakes iron is practically lacking. Ferruginous organic soil complexes are supplied with groundwaters from the south and they have stabilized in the eastern part at the height of Lake Mrokowo.

At the northern side of the Ruda valley and of Lake Wierzchoń, the groundwaters contain ca. 0.2 g ions/dm^3, 24–40 mg Ca/dm^3, and 80–150 mg HCO_3/dm^3.

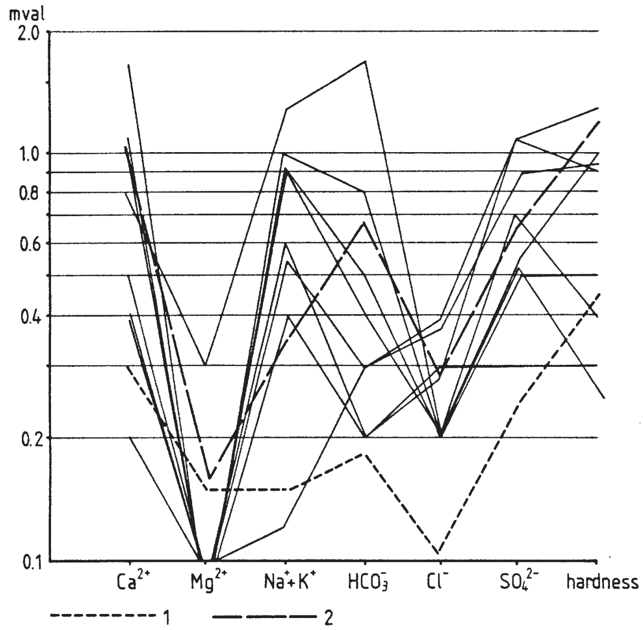

Fig. 3.9. Ionic composition of snow water (1), lake water of Lake Mrokowo (2), and groundwaters of aeration zone (continuous lines).

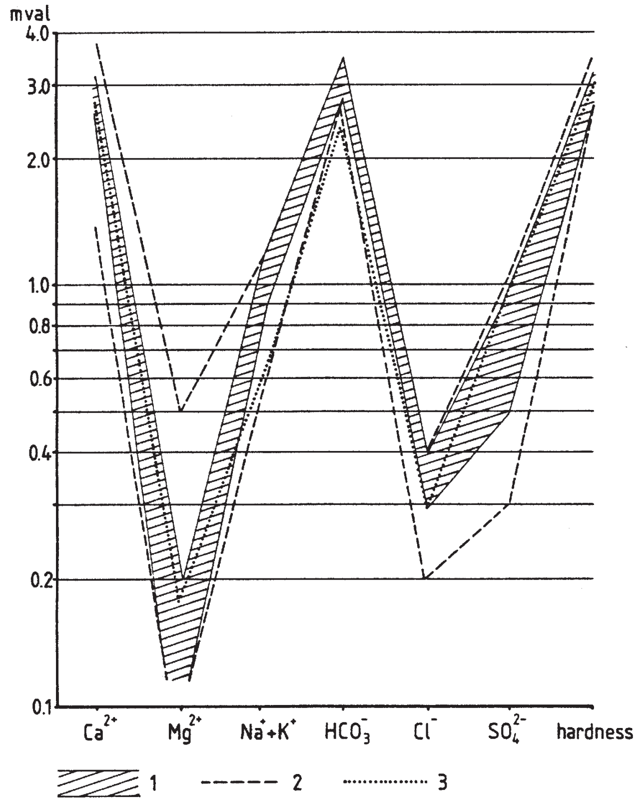

Fig. 3.10. Ionic composition of the groundwaters of saturation zone. 1 – dominant values, 2 – extreme values, 3 – springs at the shore of lakes Gościąż and Mielec.

In the western part, including lakes Gościąż and Mielec, the gradients of groundwater table are 5–12 ‰. High gradients occur also in the 200–300 m wide zone of intensive drainage that adjoins the lake in the south. Steep slopes of the lake basins cut across the aquifer at the height of ca. 65 m a.s.l. The waters outflowing there from numerous springs and seeps exihibit constant temperature (7.5–8.5°C) and constant ionic composition, regardless of season or water level (Fig. 3.10). In periods of low levels of the water table the total content of ions in spring waters is larger by ca. 25–30 mg/dm^3 than at high water levels. On the other hand, changes in acidity are significant: from pH 6.7–7.1 in spring months to pH 7.2–7.8 in the remaining seasons. In the 8 km wide belt south to the lakes the groundwaters exhibit the same properties as the waters in the springs and in the eastern part (Fig. 3.10). A relatively intensive horizontal exchange of waters in the western part, forced by the draining influence of the lakes and of the stream, does not eliminate moderate reducing conditions in the aquifer. At pH 7.2–8.2, up to 2.5 mg Fe/dm^3 occurs in groundwaters mainly in form of $Fe(HCO_3)_2$. Thus a very strong contrast exists between the properties of the aeration and saturation zones. The reduced forms of Fe, transported with weakly alkaline groundwaters towards the lakes, are subjected to intensive transformation to $Fe(OH)_3$ in the zone of contact with

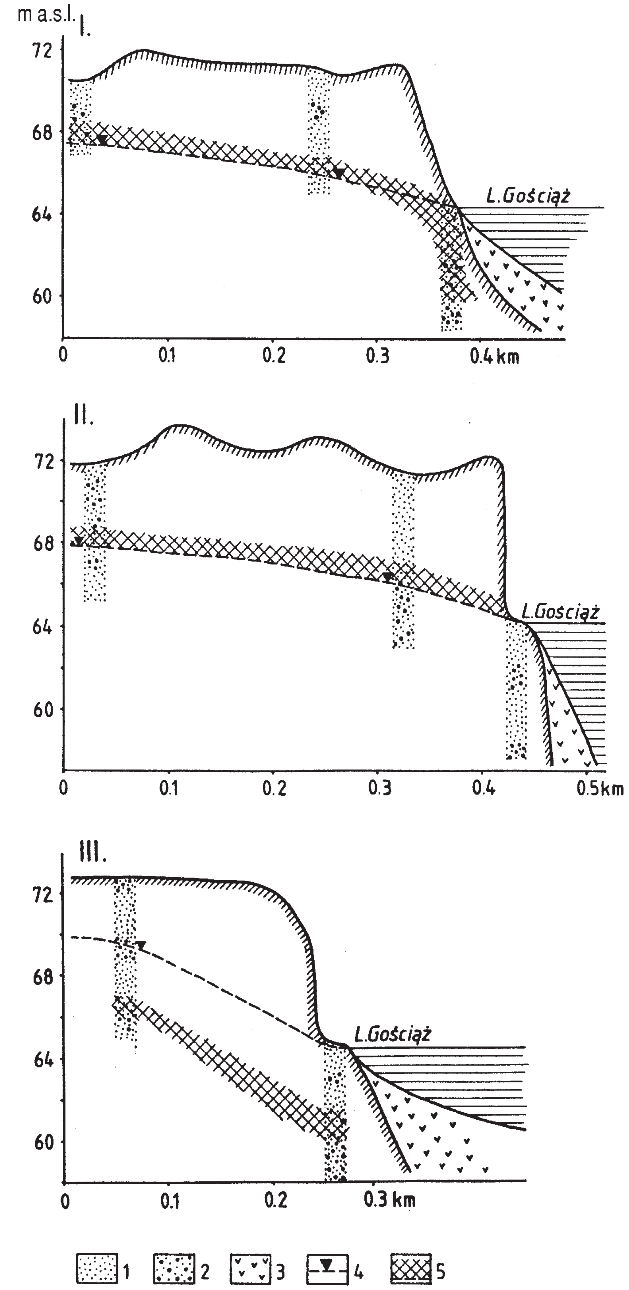

Fig. 3.11. Lithological profiles (I, II, III) of the southern shore of Lake Gościąż (see Fig. 3.8). 1 – fine-grained and medium-grained sands, 2 – coarser sands with gravel, 3 – sulphur-calcareous gyttja, 4 – level of groundwater, 5 – horizons of Fe and Mn precipitation.

the oxygenized and carbonate-free layer of aeration. In such conditions in the top parts of the aquifers the strongly ferruginous layers occur (Fig. 3.11). The abundant precipitates of iron hydroxides in form of nest-like accumulations as well as iron and manganese concretions are found there. Thickness of the oxidation layers is 0.4–1.2 m. These layers occur in the zones of seasonal fluctuations of the groundwater levels, and they are places of partial concentration of the elements leached from the soils.

Locally levels of precipitates of iron compounds, and less frequently of manganese, are found at the depth of 2–3 m below the groundwater table or lake water level (Fig. 3.11). In such situations the groundwaters exhibit slightly higher pH (7.7–7.9) and presence of gases, especially CO_2. The pressure of these waters at the depth of ca. 3 m below the water table was ca. 140 kPa and did not vary during measurements lasting up to twenty hours. The iron concretions occurring in the carbonate sands reach 3–8 mm in diameter. They are usually oval or spindle-shaped; their interior is filled with spherically arranged ochre. The concretions of iron hydroxides were forming when the groundwater table at the southern side of Lake Gościąż occurred 3–4 m below the present-day level. The waters within such horizons, after being brought to the surface, become yellow-red. They contain over 10 mg Fe/dm^3. In the samples of waters occurring below and above the layers with concretions the content of total iron is definitely smaller. The waters below the "ferrugination" zones are greenish, but after oxidation of the ferrous compounds they become rusty orange.

Waters of some springs feeding the lakes Gościąż and Mielec contain more substantial amounts of iron in autumn and spring seasons only (0.9–1.4 mg Fe/dm^3). The jelly-like precipitates of ferruginous mineral complexes deposited at seepages contain, besides iron and manganese, many other chemical elements. The substantial enrichment in other elements occurs in the beach sands (Tab. 3.3). The groundwaters infiltrating into the lake within the beach and littoral shoals feature weak hydrostatic pressure. If bored at the depth 2–6 m these groundwaters usually stabilize at ca. 0.3–1 m above the lake water table. While the temperature of the lake water is 23°C (in summer), the water temperature in shoal zone at the depth of 1.5 m is 12°C. The cold groundwaters mix there with lake waters, the pressure of gases contained in the groundwaters decreases, and $CaCO_3$ crystallizes abundantly. In Lake Mielec intensive accumulation of carbonates makes development of the underwater plants

Table 3.3. Content of selected chemical elements in deposits of littoral zone of Lake Gościąż.

Type of deposit	Loss on ignition in %	Organic C %	mg/kg of ash								
			Fe	Cd	Pb	Ni	Co	As	Zn	Sr	Mn
Beach sands	0.4	0.2	9500	0.10	0.5	0.9	0.34	6.3	0.2	2.1	270
Ferruginous deposits precipitated in spring	33.6	4.3	110050	0.24	9.1	24.2	6.10	20.6	5.9	31.0	6000

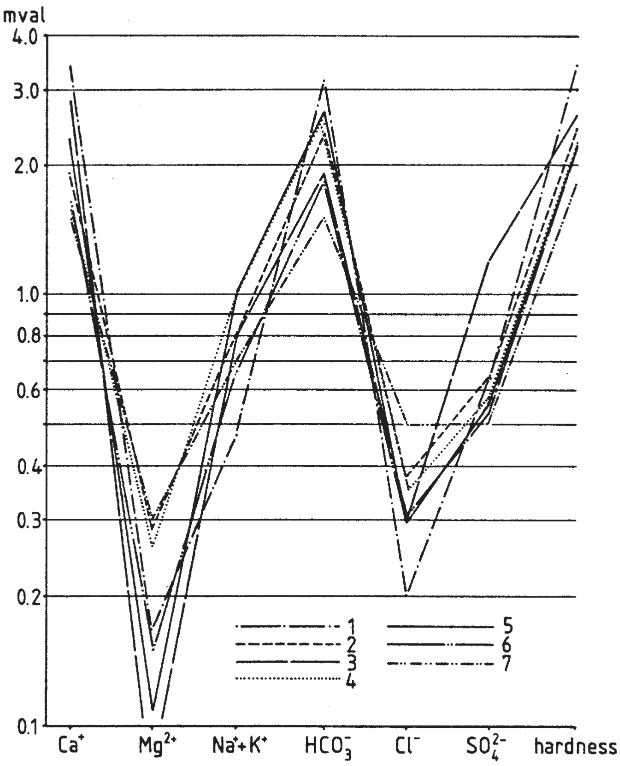

Fig. 3.12. Ionic composition of the surficial water. 1 – Ruda upstream of Lake Wierzchoń, 2 – outlet to Lake Gościąż, 3 – source area of Ruda stream, 4 – Lake Mielec, 5 – Lake Gościąż, 6 – Ruda downstream of Lake Mielec, 7 – Lake Wierzchoń.

impossible. The underwater plants covered with carbonate crust, die out in the beginning of June. Strong reducing conditions, usually with H_2S, occurring within shoals and beaches favour stabilization of numerous chemical elements (in the form of sulphides) brought here with the groundwaters. Some of these elements, e.g. Mn and Fe, after oxidation change into hydroxides. Beyond the littoral zone, in Lake Mielec the deposits are of carbonate facies, while in Lake Gościąż the deposits of sulphide-carbonate facies are accumulated (Wicik 1993). Waters of the lakes and the Ruda stream linking these lakes have strong affinity to groundwaters (Fig. 3.12). They are slightly hard, calcium bicarbonate waters. The stream waters at the inlet to Lake Wierzchoń contain more Ca and HCO_3 ions than waters being in contact with aeration zone in its source area. In lakes Wierzchoń and Brzózka the waters of the Ruda stream lose 20 mg Ca/dm^3 and ca. 70 mg HCO_3/dm^3. At the entrance to the Tobyłka Bay the total content of the main ions in the stream waters decreases by ca. 85 mg/dm^3.

In lakes Gościąż and Mielec, further transformation of chemical properties of the waters of the stream as well as of the springs takes place, and ca. 2 km downstream of the outlet from Lake Mielec the Ruda waters are poorer in Ca and sulphate ions but enriched in HCO_3 ions when compared to the stage at the inflow to the lakes.

3.5. HYDROBIOLOGICAL CHARACTERISTICS AND MODERN SEDIMENTATION OF LAKE GOŚCIĄŻ

Andrzej Giziński, Andrzej Kentzer, Tomasz Mieszczankin, Janusz Żbikowski & Roman Żytkowicz†*

The discovery of laminated sediments in Lake Gościąż has initiated interdisciplinary studies of the lake and its surroundings, including palaeoecology and ecology (Ralska-Jasiewiczowa 1993). The varved sediments contain a specific chronological record of environmental changes during ca. 13,000 years. Such a record cannot be read without profound knowledge of the modern structures and functions of the lake ecosystem, in particular the phenomena and processes determining the formation of lacustrine sediments. Sedimentation in lakes responds to external and internal forcing (Sly 1976). Giziński et al. (1992) demonstrated that the functioning of particular lake ecosystems, even in lakes of the same limnological type, appeared to be very different. The "individuality" of lakes shows that the common hydrobiological information is not sufficient for dependable description of the specific ecological situation of lakes at any given time and place.

The investigations, which have been carried out since 1988, aimed at hydrobiological recognition of the structures and functions of the Lake Gościąż ecosystem. The palaeoecological character of the whole program dictated that the main attention be given to modern sedimentation, i. e. to phenomena and processes influencing the character of sediments and lamination. Within these processes both resuspension and redeposition have not been well studied. The importance of sediment transportation and translocation was already emphasized by Żytkowicz (1982, 1989). A rapid development of interest in resuspension and its function both in the ecosystem and in the formation of laminated sediments has been observed in recent years (Wiśniewski 1995).

3.5.1. Hydrobiology

In studies of abiotic parameters of Lake Gościąż much emphasis was put on studying:

1. The effect of water dynamics on the thermal and oxygen regime.

2. The budget of the most important biogens (nitrogen and phosphorus). Such investigations are the expression of the holistic approach to the lake ecosystem as the dynamic structure. It is likely to be the most reliable source

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