

freshwater environment wherever total iron is in large excess over sulphur. Particulate iron hydroxides strongly interact with dissolved species, depending on pH and local redox condition (Lucotte & d'Anglejan 1988). In oxic environment ferric iron oxides are the main scavenger of phosphate and trace elements (Fig. 8.19). The reductive dissolution of iron-containing compounds under reducing condition led to the release of the adsorbed P to the pore water (Martens et al. 1978, Sarazin et al. 1993, Tessier et al. 1985, Wersin et al. 1991) or to the direct precipitation of ferric-ferrous and ferrous phosphates (Buffle et al. 1989). Such annual recycling of P within the sediment column can influence the origin of Fe-phosphate-bearing laminae within a single varve. However, stagnant periods in the development of the lake followed by sediment disturbance can cause the anomalous large influx of phosphorus to the water column (Nriagu & Dell 1974), and thus it can control algal blooms.

The chemical data of the sediment samples from Lake Gościąg presented above should be considered as a preliminary investigation, giving only general trends of the geochemical changes during the evolution of the lake. Analyses were performed on few and small samples. Nevertheless, well-marked variations of the chemical composition that can be due to the climatic changes were noticed:

1. The two orders of magnitude decrease of Mn content from 6634 cal BP was preceded by two thousand years (from 8596 cal BP) of its gradual reduction. The interval of the abrupt Mn reduction within Lake Gościąg deposits may be further limited to 7500–7000 cal BP (Fig. 8.20), if we use the relative value of Mn abundance performed by L. Chróst.

The simultaneous decrease of the Mn/Fe ratio caused by the slight increase of Fe points to the change of the chemistry of particulate matter carried by the groundwater. This variation could arise from the gradual changes of the climate from subarctic to warmer and humid that resulted in the formation of a thick soil horizon.

2. The sediments formed from 8596 to 6634 cal BP are unusually enriched in iron. This may also be related to the climatic changes resulting in a eutrophic or/and a stagnant period of lake evolution. The setting up of reducing conditions at or near the bottom can prevent the Fe recycling within the sediment column, followed by the neoformation of Fe minerals (Marnette et al. 1993). The occurrence of pyrite as a main Fe mineral phase may be the consequence of the large influx of SO_4^{2-} -bearing waters to the bottom deposits.

3. Gypsum is one of the late diagenetic components of the sediments, and its maximum occurrence corresponds to the sediments originated from 8596 to 6634 cal BP.

4. The short events of P enrichment at 3218 cal BP and at AD 1925 could indicate periods of sediment disturbance preceded by stagnation of the lake system.

8.3. HOLOCENE REGIONAL VEGETATION HISTORY RECORDED IN THE LAKE GOŚCIAŻ SEDIMENTS

Magdalena Ralska-Jasiewiczowa, Bas van Geel & Dieter Demske

The Gostynińskie Lake District, where Lake Gościąg is located, belongs genetically to the areas glaciated during the last cold stage. In the subdivision of Poland into the palaeoecological type regions (Ralska-Jasiewiczowa 1987, Ralska-Jasiewiczowa & Latałowa 1996), it has therefore been included to the Poznań-Gniezno-Kujawy Lake District as its easternmost part. However, as shown by recent pollen-analytical investigations, the vegetational development of the area reveals closer affinities with the central Masovian Lowlands. The best example of it is the pollen diagram from Lake Błędowo, situated in central lowlands ca. 100 km east of Lake Gościąg (Bińka et al. 1991), which, though very poorly dated by ^{14}C , is well correlated with the reference diagram from Lake Gościąg. This may be explained by the similar sandy subsoils, in contrary to the nearby Kujawy subregion, where black-earth (chernozem) soils dominate.

The Holocene vegetation history of the central Polish lowlands and adjacent lake districts, as now, has mostly been based on studies between the late 1950s and early 1980s (e.g. Oszałt 1957, Kępczyński 1960, Borówko-Dłużakowa 1961a, Pyrgała 1972, Wasylikowa 1978, Jankowska 1980, Noryśkiewicz 1982). It also includes sites located very close to Lake Gościąg along the left bank of Vistula River, between Gałun, Gostynin, and Włocławek (Borówko-Dłużakowa 1961b). The main deficiencies of those studies, however, is the poor time resolution in pollen diagrams and/or the lack of radiocarbon dates. The closest recently investigated sites meeting requirements of modern palaeoecology are

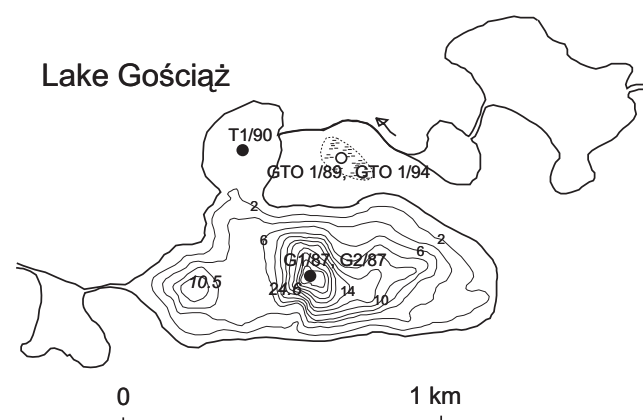


Fig. 8.21. Map of Lake Gościąg showing the location of profiles discussed in this chapter (black dots) and other Holocene profiles investigated by means of pollen and macrofossil analysis (white dot, Demske 1995).

mostly located in the lake districts farther to the west (e.g. Tobolski 1991, Litt & Tobolski 1991, Makohonienko 1991, Filbrandt 1991).

The reconstruction of Holocene development of vegetation in the Lake Gościąg region as presented in this chapter is primarily based on pollen-analytic results coming from the profile G1/87, examined by M. Ralska-Jasiewiczowa and B. van Geel, representing the deepest part of the lake. This profile has been chosen as a reference profile because the laminae are the most regular, best preserved, and most continuous and it has been used for all analyses described in this book. Because of its position within the lake it is assumed to represent the regional changes of vegetation (Fig. 8.21).

The other Holocene pollen diagrams, worked out by Demske (1995), come from the centre of the northern bay Tobyłka (profile T1/90) and from a small kettle hole near the eastern Tobyłka shore (GTO1/94, GTO1/89). Both, and especially the sequences from the kettle hole reflect strongly the local changes of vegetation and water level, which will be discussed in detail by Demske in the second part of this book. This chapter presents a very simplified pollen diagram from T1/90 profile, including only the most important tree, shrub, and herb taxa but omitting nearly all telmato-, limnophytes, and sporophytes. It is meant to present a picture of the most important events, and to give some grounds for the discussion of the regional or local character of pollen records.

The methods used during the core collection, sediment sampling, laboratory treatment, pollen counting, and construction of pollen diagrams are described in Chapter 4, jointly for all chapters on pollen analysis.

Sediment description

The sediments from the central deep (profile G1/87) are composed of calcareous-ferruginous (ferrous sulphide) laminated gyttja throughout the profile (Fig. 8.22); their differentiation concerns mostly the laminae thickness, regularity, disturbance, absence, or changes in the chemical composition and the occurrence of sand bands or massive layers. These sediment characteristics are discussed in more detail by Więckowski et al. (Chapter 5.1), Goslar (Chapter 8.1), and Łacka et al. (Chapter 8.2), and they are only briefly summarized below. The sedimentological data for upper 2.40 m obtained from cores collected by freezing *in situ* are not included here for they are discussed by Goslar in Chapter 9.2.

The sediments from Tobyłka Bay (profile T1/90) have been described in detail by Demske (1995) and will also be presented in the second part of this book. Their lithology is characterized below in a very simplified form. It could not be plotted on the pollen diagram of T1/90 profile (Fig. 8.26), due to the difficulties in the transformation of lithological column on the time scale, but it is

shown in Fig. 8.28, where G1/87 and T1/90 profiles are presented on the depth scale.

Profile G1/87

0–400 cm – olive-grey, calcareous gyttja, semi-liquid in the top (ca. 1 m), liberating abundant gas bubbles, with high proportion of mineral matter. Irregular traces of laminae, their thickness in the top part may exceed 1 cm. Content of carbonates increases downwards from ca. 60% to ca. 90%; from ca. 3 m down Fe content increases from ca. 2 to 7 weight %;

401–734 cm – black, calcareous-ferruginous gyttja, in air changing to brownish-grey. Laminations periodically disturbed or disappearing but rather regular around 4.00 m, 4.20 m, and 4.80–5.27 m. Maximum Mg at 3.80–7.00 m, carbonates generally above 80%;

734–1087 cm – gyttja as above, with regular laminae, their thickness decreasing around 8.60 m and 10.15 m; from ca. 800 cm downwards carbonate content decreases to ca. 60%;

1087–1270 m – gyttja as above, with regular very thin laminae (less than 1 mm) of lower contrast. Fe at maximum (12–14 weight %) from ca. 10.7 m to ca. 11,600 cal BP, Mn rising up to 14 weight % at 12.30–12.70 m, CaCO₃ at around 40%;

1270–1520 cm – gyttja as above, with regular laminae ca. 1 mm thick, sharp contrast between their light/dark parts. Thin massive layers at 14.21 m and 13.96 m, Fe still at maximum down to ca. 14.70 m, Mn still high.

At ca. 1520 cm – the transition between the Holocene and the Late-Glacial.

1520–1628 cm – gyttja as above, with rather regular laminae of lower contrast, their thickness rising to ca. 1.5 mm from 15.65 m; increased content of mineral matter, much lower Fe and Ca, Mn still high;

1628–1688 cm – sand with oscillating contribution of finer mineral fractions;

1688–1704 cm – gyttja with regular rather thin laminae, content of mineral matter decreasing downwards. No lithological bottom boundary was reached.

Profile T1/90

0–78 cm – brown, calcareous fine-detritus gyttja, semi-liquid, with traces of layering;

78–161 cm – dark to black brown coarse-detritus gyttja, with low content of carbonates, high content of iron compounds, traces of layering;

161–435 cm – light to dark brown calcareous fine-detritus gyttja, layering visible;

435–760 cm – calcareous fine-detritus gyttja, irregularly alternating layers of distinct laminae and disturbed or absent laminae;

760–1262 cm – brownish black to blueish black cal-

careous gyttja, mineral matter and iron content increasing downwards. Lamination in layers between 870–960 cm and 1030–1100 cm;

1262–1410 cm – bluish black calcareous-ferruginous gyttja, laminations distinct, and mostly regular, but slightly disturbed in top section 1262–1320 cm.

Late-Glacial/Holocene boundary at 1357 cm distinguished only by decreased thickness of laminae in sediment section below.

1410–1417 cm – calcareous-ferruginous silty gyttja, indistinct microlamination;

1417–1425 cm – sand;

1425–1433 cm – brownmoss peat;

1433–1467 cm – sand (for more details see Chapter 7.4).

Description of local pollen assemblage zones

The description of pollen assemblage zones is presented here in a shortened form of a table (Tab. 8.4) where the most important features characterizing particu-

lar zones of G1/87 and T1/90 profiles are compared in two neighbouring columns.

The information for G1/87 pollen sequence is more complete, because it represents the full data pollen diagram (Fig. 8.22). The information for T1/90 profile is more simplified, as the pollen diagram presented in this chapter (Fig. 8.26) contains selected pollen taxa only. For its complete version see Demske (1995). It should also be noted that the accuracy of the time scale for the G1/87 varved core is much more precise than that for the T1/90 core, which has regular lamination in the Late-Glacial and very early Holocene sediments only. The chronology for the remaining part of Holocene is inferred here from the varve chronology based on profiles from central deep (see Fig. 8.26).

The zonation of diagrams was supported by numerical methods – POLPAL program (Walanus & Nalepka 1996) and principal component analysis (PCA) in case of G1/87 profile (Fig. 8.25), and CONISS in TILIA program (Grimm 1987, 1992) in case of T1/90 profile.

Table 8.4. Description and correlation of local pollen assemblage zones distinguished in G1/87 (Fig. 8.22) and T1/90 (Fig. 8.26) profiles. (L.z.b. – lower zone boundary; L.sz.b. – lower subzone boundary; p.i. – pollen influx (G1/87) (Fig. 8.23); p.c. – pollen concentration (T1/90); p.t.d. – pollen taxa diversity, Fig. 8.24), ss. – samples no.

Profile G1/87	Profile T1/90
<p>G1/87-4 Betula-Populus-Ulmus – 11,530–10,530 cal BP (10,050–9570 ¹⁴C BP), 1519–1428 cm, ss. 84–103</p> <p>L.z.b.: within the diagram section with strong oscillations of <i>Pinus</i> and <i>Betula</i> curves; at rise of <i>Populus</i> cf. <i>tremula</i>, appearance of <i>Ulmus</i>, fall of <i>Juniperus</i>, <i>Artemisia</i>, Chenopodiaceae; rise of <i>Filipendula</i>, <i>Urtica dioica</i> -t., and Filicales monoletae. (= Late-Glacial/Holocene boundary).</p> <p><i>Betula</i> ca. 30% to over 70%, <i>Pinus</i> up to ca. 40%. <i>Populus</i> up to 6%. <i>Ulmus</i> continuous, up to ca. 2.0% at zone top, where <i>Corylus</i> makes ca. 1%. <i>Juniperus</i> and <i>Betula nana</i> -t. become sporadic 250–300 yr above l.z.b. Most heliophytes disappear within 50–100 yr above l.z.b. except for reduced values of <i>Artemisia</i> and Chenopodiaceae. Gramineae initially over 10%, later 3–6%, <i>Filipendula</i>, and <i>Urtica dioica</i> -t. rise coincidentally with appearances and/or rises of diverse telmatophytes and limnophytes. <i>Humulus lupulus</i> cf. appears in upper part of zone.</p> <p>P.t.d. moderate, p.i. initially low, then rises.</p>	<p>TB-6 (a and b) Betula-Populus-Ulmus – ca. 11,400–10,600 cal BP (10,050–9500 ¹⁴C BP), 1357–1323 cm</p> <p>L.z.b.: fall of <i>Artemisia</i>, Chenopodiaceae, <i>Juniperus</i>, rise of <i>Filipendula</i>. (= Late-Glacial/Holocene boundary) The division into subphases at rise of <i>Betula</i> and <i>Ulmus</i>.</p> <p><i>Betula</i> 25–64%, <i>Pinus</i> initially at 59% falls to 27–34%. <i>Populus</i> up to 1.1%, <i>Ulmus</i> continuous up to 1%, <i>Corylus</i> continuous <1% at zone top, <i>Betula nana</i> -t. declines; Gramineae decrease from 12% to 7.2%. <i>Filipendula</i> up to 1.8%.</p> <p>P.c. moderate, oscillating.</p>
<p>G1/87-5 Pinus-Betula-Ulmus-Corylus – 10,530–9850 cal BP (9510–8850 ¹⁴C BP), 1428–1359 cm, ss. 104–114</p> <p>L.z.b.: rise of <i>Pinus</i>, and <i>Corylus</i>, fall of <i>Betula</i>, and start of continuous <i>Quercus</i>.</p> <p><i>Pinus</i> up to 60%, <i>Betula</i> around 35%, <i>Populus</i>, <i>Salix</i> reduced, <i>Corylus</i> rises up to ca. 13%, <i>Ulmus</i> to ca. 5%, <i>Quercus</i> to ca. 1% at zone top. Some heliophytes reappear, <i>Calluna</i> rises, <i>Filipendula</i>, <i>Urtica</i>, and some telmatophytes reduced.</p> <p>P.i. moderate, p.t.d. slightly rising.</p>	<p>TB-7 Pinus-Corylus-Ulmus – ca. 10,600–9900 cal BP (9500–8900 ¹⁴C BP), 1323–1285 cm</p> <p>L.z.b.: rise of <i>Corylus</i>, and <i>Ulmus</i>, fall of <i>Betula</i>.</p> <p><i>Pinus</i> up to 68%, <i>Betula</i> 23–36%. <i>Corylus</i> rising to 9.8%, <i>Ulmus</i> up to 2.9%. <i>Populus</i> up to 1.4%, <i>Quercus</i> <1%. Gramineae, and <i>Filipendula</i> at decline, <i>Artemisia</i> up to 1.1%.</p> <p>P.c. very high.</p>
<p>G1/87-6 Corylus-Alnus-Quercus – 9850–8130 cal BP (8850–7330 ¹⁴C BP), 1359–1230 cm, ss. 115–149</p> <p>L.z.b.: sharp rise of <i>Alnus</i> (from ca. 1 to 25%), start of continuous <i>Tilia</i> and <i>Fraxinus excelsior</i>.</p>	<p>TB-8 Alnus-Ulmus-Corylus (Quercus) – ca. 9900–5900 cal BP (8850–5150 ¹⁴C BP), 1285–1050 cm</p> <p>L.z.b.: rise of <i>Alnus</i> and <i>Quercus</i>.</p>

Table 8.4. Continued.

Profile G1/87	Profile T1/90
<p>Maximum of <i>Corylus</i> (up to 20% or more), coincident decrease of <i>Populus</i> and <i>Betula</i>, <i>Pinus</i> 20–35%, <i>Alnus</i> at ca. 20%, <i>Ulmus</i> and <i>Quercus</i> at ca. 5%, slowly rising <i>Tilia</i> and <i>Fraxinus</i> (<2%). Appearing <i>Acer</i>, <i>Viscum</i> and <i>Hedera</i>. NAP at Holocene minimum. Telmatophytes strongly reduced, limnophytes disappear.</p> <p>P.t.d. the lowest of all zones; p.i. very high, then falling rapidly from 8950 cal BP.</p>	<p>TB-8a <i>Corylus-Quercus(Ulmus)</i> – ca. 9900–7500 cal BP (8850–6650 ¹⁴C BP), 1285–1170 cm</p> <p><i>Corylus</i> up to 20.4%, <i>Alnus</i> rise to 22%, <i>Pinus</i> 30–45%, <i>Ulmus</i> up to 5.9%, <i>Quercus</i> 4–7.5%. <i>Populus</i> decreasing, <i>Tilia cordata</i> and <i>Fraxinus</i> <2%.</p> <p>P.c. forms two Holocene maxima at the beginning and end of subzone.</p>
<p>G1/87-7 <i>Ulmus-Fraxinus-Quercus</i> – 8130–5900 cal BP (7330–5140 ¹⁴C BP), 1230–1015 cm, ss. 150–190</p> <p>L.z.b.: rises of <i>Ulmus</i>, <i>Tilia</i>, <i>Fraxinus</i>, <i>Quercus</i>, and <i>Populus</i>, small rise of <i>Betula</i>.</p> <p><i>Ulmus</i> (up to 10%), <i>Tilia</i> (up to 2.2%) at their highest Holocene values, steadily rising <i>Quercus</i>, reduced and fluctuating <i>Corylus</i>. <i>Pinus</i> slowly decreasing, <i>Populus</i> forming small peaks. <i>Fagus</i>, <i>Taxus</i>, and <i>Carpinus</i> appear; many shrub taxa either appear or start occurring regularly. Many herb taxa, <i>Pteridium</i> and <i>Urtica</i> in particular, rise in frequencies; other herbs reappear, or appear first time.</p> <p>Telmatophytes more frequent, some limnophytes reappear.</p> <p>P.i. falls again and then stabilizes at the lowest Holocene values. P.t.d. rises twice around 7950 cal BP and 7550 cal BP.</p>	<p>TB-8b <i>Ulmus-Quercus-Fraxinus (Tilia)</i> – ca. 7500–5900 cal BP (6650–5150 ¹⁴C BP), 1170–1050 cm</p> <p>L.sz.b.: rise of <i>Ulmus</i>, <i>Quercus</i>, fall of <i>Betula</i>.</p> <p><i>Corylus</i> decreasing (7–13.5%), rises of <i>Fraxinus</i> (to 3%), <i>Quercus</i> (to 8.7%), <i>Tilia cordata</i> (to 1.6%). <i>Ulmus</i> at maximum (ca. 5.9%). First <i>Acer</i>, <i>Fagus</i>, <i>Rhamnus cathartica</i>, <i>Frangula alnus</i>, <i>Viscum</i> and <i>Hedera</i> appear. <i>Urtica</i>, <i>Pteridium</i>, and <i>Calluna vulgaris</i> rise.</p> <p>P.c. oscillating, slowly decreasing.</p>
<p>G1/87-8 <i>Corylus-Quercus-Fraxinus</i> – 5900–3750 cal BP (5140–3470 ¹⁴C BP), 1015–799 cm, ss. 191–228</p>	<p>TB-9 <i>Quercus-Corylus-Ulmus (Tilia)</i> – ca. 5950–4250 cal BP (5150–3850 ¹⁴C BP), 1050–850 cm, and</p> <p>TB-10 <i>Carpinus-Quercus-Corylus</i> TB-10a <i>Quercus-Carpinus-Ulmus</i> – ca. 4250–3700 cal BP (3850–3480 ¹⁴C BP), 850–770 cm</p>
<p>L.z.b.: distinct <i>Ulmus</i> fall, peak of <i>Betula</i>, rises of <i>Corylus</i>, <i>Quercus</i>, Gramineae, <i>Artemisia</i>.</p> <p>Rising <i>Quercus</i> from ca. 5000 to ca. 4200 cal BP at its Holocene maximum (ca. 25%), high <i>Corylus</i> (ca. 7–21%), low <i>Ulmus</i>, reduced <i>Betula</i>, <i>Populus</i> (up to 1%). All those taxa much oscillating. Continuous, then rising <i>Carpinus</i> and <i>Fagus</i>. NAP increased up to ca. 10%, then reduced.</p> <p>P.i. generally higher, but oscillating. P.t.d. at a maximum between samples 192 and 205, then lower.</p> <p>G1/87-8a 5900–4720 cal BP, ss. 192–209</p> <p><i>Ulmus</i> below 2%, then makes a small maximum at 5200–4910 cal BP, <i>Tilia platyphyllos</i> rising above 1%, nearly continuous <i>Juniperus</i>, <i>Taxus</i> maximum (over 1%) around 4800 cal BP; increased Gramineae, fluctuating <i>Artemisia</i>, <i>Urtica dioica</i> -t, and <i>Pteridium</i>, regularly appearing Cereals, and other human indicators, <i>Plantago lanceolata</i> continuous from ca. 5500 cal BP.</p> <p>G1/87-8b 4720–3750 cal BP, ss. 210–228</p> <p>L.sz.b.: rise of <i>Carpinus</i> and <i>Fagus</i>, fall of <i>Ulmus</i>, <i>Tilia platyphyllos</i> and NAP.</p> <p>Consistently rising <i>Carpinus</i>, continuous <i>Fagus</i>; <i>Betula</i> falling to Holocene minimum <10%, <i>Picea</i> oscillating up to 1%, <i>Ulmus</i>, <i>Tilia platyphyllos</i>, and <i>Juniperus</i> decreasing; NAP incl. human indicators reduced.</p>	<p>L.z.b. TB-9a: rise of <i>Corylus</i>, <i>Artemisia</i>, fall of <i>Pinus</i></p> <p>Consistently rising <i>Quercus</i> (9a) to a maximum at ca. 19% (9b – ca. 5100–4100 cal BP), <i>Corylus</i> up to 19% (9a), low <i>Ulmus</i>, both taxa oscillating. Rising <i>Carpinus</i>. <i>Betula</i> slowly decreasing. NAP below 10%.</p> <p>P.c. slowly, consistently decreasing through all the three subphases.</p> <p>TB-9a and b ca. 5950–4250 cal BP</p> <p><i>Ulmus</i> low, makes a small maximum at ca. 5200–5000 cal BP. <i>Tilia platyphyllos</i> nearly continuous, <i>Juniperus</i> below 1%. Small rise of <i>Taxus</i> at ca. 4800 cal BP, slightly increase <i>Calluna</i>, <i>Pteridium</i> (9a and b), and <i>Artemisia</i> (9a). <i>Plantago lanceolata</i> and Cereals starting continuously at ca. 5200 cal BP.</p> <p>TB-10a ca. 4250–3700 cal BP.</p> <p>L.sz.b.: rise of <i>Ulmus</i>, <i>Carpinus</i>, and <i>Pinus</i>, fall of <i>Corylus</i>, and <i>Alnus</i>.</p> <p><i>Carpinus</i> rising from 0.3 to 11%, beginning of continuous <i>Fagus</i>, <i>Quercus</i> and <i>Corylus</i> slightly decreasing, NAP reduced, then rising.</p>
<p>G1/87-9 <i>Carpinus-Betula-NAP</i> – 3750–1075(820)* cal BP (3470–1180 ¹⁴C BP), 799–405 cm, ss. 229–264</p> <p>L.z.b.: falls of <i>Corylus</i>, <i>Fraxinus</i> and <i>Picea</i>, sharp rises of <i>Carpinus</i>, <i>Betula</i>, and Gramineae.</p>	<p>TB-10b – TB-13a jointly ca. 3700–950 cal BP</p> <p>L.z.b. TB-10b: falls of <i>Ulmus</i>, <i>Corylus</i>, <i>Tilia</i>, <i>Fraxinus</i>, maximum of <i>Carpinus</i>, rise of <i>Betula</i>.</p>

Table 8.4. Continued.

Profile G1/87	Profile T1/90
<p><i>Corylus</i> after gradual fall stabilizes below 5%, <i>Ulmus</i> and <i>Fraxinus</i> below 2%, <i>Tilia</i>, <i>Picea</i> below 1%. <i>Quercus</i> over 10%, with some depressions. <i>Carpinus</i> fluctuating strongly (2%–25%). <i>Betula</i> high – with sharp peaks. NAP, incl. human indicators, and also p.i. and p.t.d. oscillate in a pattern with tree-taxa fluctuations, so that 5 subzones recording mostly anthropogenic changes can be distinguished:</p> <p>G1/87-9a <i>Carpinus-Betula</i> – 3700–3360 cal BP (3480–3150 ¹⁴C BP), 791–750 cm, ss. 229–235</p> <p>Rising <i>Betula</i>, peak of <i>Carpinus</i> at 3560 cal BP (< 20%), gradual fall of <i>Corylus</i> and <i>Quercus</i>, <i>Alnus</i> increased, rising Gramineae, <i>Urtica dioica</i> -t., and <i>Plantago lanceolata</i>.</p> <p>G1/87-9b <i>Betula</i>-Gramineae-<i>Artemisia</i> – 3360–2550 cal BP (3150–2500 ¹⁴C BP), 750–644 cm, ss. 236–251</p> <p>L.sz.b.: fall of <i>Carpinus</i>, <i>Corylus</i>, rise of <i>Betula</i>, NAP.</p> <p>Reduced <i>Carpinus</i> (2–7%), and <i>Corylus</i> (2–4%), increasing <i>Betula</i> and <i>Pinus</i>, small rises of <i>Populus</i> and <i>Salix</i>, and of several understory taxa. Rise of NAP, including in particular Gramineae, <i>Artemisia</i>, <i>Plantago lanceolata</i>, <i>Rumex acetosella</i>, and <i>Calluna vulgaris</i>. Cerealia appearing regularly. Pt.d. forming maximum. Pi. peak at subzone onset.</p>	<p>The joint features of above zones are high much oscillating <i>Carpinus</i>, increased <i>Betula</i> (up to 25%), and high <i>Pinus</i> (up to 50%), both falling in TB-13a; reduced <i>Quercus</i>, rising from TB-12a, all other deciduous trees low. NAP increased, with peaks up to 15%, oscillating human indicators.</p> <p>TB-10b <i>Carpinus-Alnus</i> – ca. 3700–3300 cal BP (3480–3070 ¹⁴C BP), 770–670 cm</p> <p><i>Carpinus</i> after initial peak (12%) at ca. 3600–3650 cal BP falls to ca. 4%, <i>Corylus</i>, <i>Quercus</i>, and other deciduous trees decrease, <i>Alnus</i> forms peak to 23%, <i>Betula</i> and NAP incl. human indicators show some rise.</p> <p>TB-11 <i>Pinus-Betula-Carpinus</i> TB-11a – <i>Quercus-Carpinus</i> and TB-11b – <i>Pinus-Quercus-Alnus</i> – jointly ca. 3300–2400 cal BP (3070–2430 ¹⁴C BP), 670–390 cm</p> <p>L.z.b.: fall of <i>Corylus</i> and <i>Alnus</i>, rise of <i>Pinus</i> and <i>Betula</i>.</p> <p><i>Carpinus</i>, <i>Quercus</i>, <i>Corylus</i> makes broad minima, increased <i>Betula</i>; <i>Pinus</i> forms maximum (over 50%). NAP increase, particularly Gramineae (up to 7.2%), <i>Artemisia</i> (to 2.4%), and <i>Rumex acetosella</i>. Cerealia continuous.</p> <p>P.c. slightly increased, oscillating.</p>
<p>G1/87-9c <i>Carpinus-Fraxinus</i> – 2480–2030 cal BP (2470–2070 ¹⁴C BP), 640–564 cm, ss. 252–256</p> <p>L.sz.b.: sharp peak of <i>Betula</i>, rising <i>Carpinus</i>, fall of <i>Artemisia</i> and <i>Rumex acetosella</i>.</p> <p>Peak of <i>Betula</i> (ca.39%) followed by rises of <i>Carpinus</i>, <i>Quercus</i>, <i>Fraxinus</i>, <i>Ulmus</i>, (<i>Alnus</i>). NAP low and still falling. Depressions of all human indicators, rare herb taxa disappear. Pt.d. rising, p.i. decreasing by a half.</p> <p>G1/87-9d Gramineae-<i>Secale-Cannabis</i> – 1950 – 1650 cal BP (AD 1–300), 564–512 cm, ss. 257–259</p> <p>L.sz.b.: decrease of <i>Carpinus</i>, <i>Alnus</i>, rise of NAP and <i>Betula</i>.</p> <p><i>Carpinus</i>, <i>Alnus</i>, <i>Fraxinus</i>, <i>Ulmus</i> forming depressions. <i>Quercus</i> rather high (up 15%), <i>Betula</i> rising. Maxima of human indicators incl. <i>Secale cereale</i> and <i>Cannabis sativa</i> cf. Pt.d. makes maximum. Pi. initially reduced, then rising.</p>	<p>TB-12 <i>Quercus-Carpinus-Pinus</i> TB-12a <i>Carpinus-Juniperus</i> – ca. 2400–2000 cal BP (2430–2040 ¹⁴C BP), 390–290 cm</p> <p>L.sz.b.: rise of <i>Carpinus</i> and <i>Fraxinus</i>, fall of <i>Pinus</i>. Fall of <i>Artemisia</i> and <i>Rumex acetosella</i>.</p> <p><i>Carpinus</i> rising up to 9.5%, <i>Pinus</i> falling, small peaks of <i>Fraxinus</i>, <i>Juniperus</i>, and of <i>Urtica dioica</i> -t., and <i>Melampyrum</i>. P.c. forms depression.</p> <p>TB-12b <i>Betula-Quercus(Fagus)</i> – ca. 2000–1400 cal BP (AD ca. 1–520), 290–170 cm</p> <p>L.sz.b.: fall of <i>Carpinus</i>, rise of <i>Quercus</i> and <i>Corylus</i></p> <p>Small peaks of <i>Fraxinus</i>, <i>Tilia cordata</i> at subzone onset, followed by falls; depression of <i>Carpinus</i> (min. 2.6%), slight rises of <i>Quercus</i>, <i>Corylus</i>. Rises of human indicators including <i>Secale</i> (max.1%). At zone top maximum of <i>Betula</i> (22%) and decrease of NAP, including Gramineae and human indicators. P.c. makes deep depression, then rises.</p>
<p>G1/87-9e <i>Carpinus</i> – 1650–1075(820)* cal BP (AD 300–875(1130)), 512–418(392) cm, ss. 260–264</p> <p>L.sz.b.: sharp rise of <i>Betula</i>, fall of NAP</p> <p>Maximum of <i>Carpinus</i> (up to 25%), preceded by <i>Betula</i> peak (37%), and followed by small rises of <i>Ulmus</i>, <i>Fraxinus</i> and <i>Fagus</i> and later of <i>Salix</i> and <i>Populus</i>. NAP at deep depression, including human indicators. Pt.d. falling. Pi. very high, then decreasing.</p>	<p>TB-13 <i>Carpinus-Quercus-Alnus</i> TB-13a <i>Carpinus-Fraxinus-Ulmus</i> – ca. 1400–950 cal BP (AD ca. 550–975), 170–110 cm</p> <p>L.sz.b.: rise of <i>Carpinus</i>, <i>Fraxinus</i>, <i>Ulmus</i></p> <p>Massive maximum of <i>Carpinus</i> (ca. 16%), distinct rises of <i>Quercus</i>, <i>Fraxinus</i>, <i>Ulmus</i>, <i>Tilia cordata</i>. Reduction of all human indicators (break in <i>Secale</i> and Cerealia). P.c. at distinct maximum.</p>
<p>G1/87-10 <i>Pinus-NAP</i> – 1075(820)* – -35 cal BP (AD 1130(875)*–1985), 392–0 cm, ss. 265–287</p> <p>L.z.b. placed within a ca. 255 yr gap in sample sequence where <i>Carpinus</i> shows gradual fall, and <i>Betula</i>, <i>Salix</i>, and NAP rise.</p>	<p>TB-13b – TB-14b (jointly ca. 975 – -35 cal BP)</p> <p>L.sz.b. TB-13b: decline of <i>Carpinus</i> and <i>Ulmus</i>, rise of <i>Betula</i> and <i>Pinus</i>.</p>

Table 8.4. Continued.

Profile G1/87	Profile T1/90
<p><i>Pinus</i> tends to rise and <i>Betula</i> to fall, both oscillating; <i>Alnus</i> makes a maximum up to 35% below the middle of zone. All other trees decrease gradually below 1 or 0.5%, except for <i>Quercus</i> remaining finally at ca. 2–3%. <i>Salix</i> and <i>Juniperus</i> increase at zone top, NAP increase, oscillating to ca. 35–40% at zone top, with Gramineae, <i>Secale</i>, and <i>Rumex acetosella</i> as main components.</p> <p>G1/87-10a <i>Betula-Alnus</i> – 1075(820)*–450 cal BP (AD 1130(875)*–1490), 392–332 cm, ss. 265–270</p> <p><i>Carpinus</i> slightly below 10%, <i>Quercus</i> over 10%, <i>Fraxinus</i>, <i>Ulmus</i>, <i>Tilia</i>, <i>Fagus</i> continuous around or below 1%, <i>Betula</i> 25–30%, <i>Alnus</i> rises to ca. 25%. NAP, after a small rise, decrease. Human indicators continuous.</p> <p>P.t.d. first high, then decreases. P.i. low.</p> <p>G1/87-10b <i>Juniperus</i>-Gramineae – 450– -35 cal BP (AD 1490 – ca. 1985), 319–0 cm, ss. 271–287</p> <p>L.sz.b.: fall of <i>Carpinus</i>, <i>Betula</i>, rise of <i>Pinus</i>, <i>Juniperus</i>, and NAP.</p> <p><i>Fraxinus</i>, <i>Ulmus</i>, <i>Tilia</i> initially continuous, later sporadic, with small rises at zone top, <i>Carpinus</i> falling to ca 1%, <i>Fagus</i> below 1%, <i>Alnus</i> to ca.10%. <i>Pinus</i> rises up to 50%, <i>Betula</i> at 15%, both with fluctuations. NAP up to 30% and more at zone top, with dominant Gramineae and <i>Secale</i>. Many new human indicator taxa appearing towards the zone top.</p> <p>P.t.d. at Holocene maximum, p.i. moderate, then extremely high at zone top.</p>	<p>Joint feature of subzones above are: falling <i>Carpinus</i>, <i>Ulmus</i>, and <i>Fraxinus</i>, rising <i>Pinus</i>, <i>Juniperus</i>, and <i>Salix</i>. NAP rising, then stable.</p> <p>TB-13b <i>Betula-Carpinus</i> – ca. 975–600 cal BP (AD ca. 1000–1350), 110–70 cm</p> <p><i>Betula</i> rise to 22%, <i>Carpinus</i> reduced to ca. 5%. Distinct falls of all deciduous tree taxa except for <i>Quercus</i>; rising <i>Pinus</i> and all NAP. P.c. sharply falling.</p> <p>TB-14 <i>Pinus-Juniperus-Secale</i></p> <p>L.z.b.: fall of <i>Carpinus</i>, <i>Quercus</i> and <i>Betula</i>, rise of <i>Pinus</i>, <i>Juniperus</i>, and <i>Secale</i></p> <p>TB-14a <i>Quercus-Carpinus-Betulus</i> – ca. 600–100 cal BP (AD ca. 1350–1850)</p> <p>TB-14b <i>Juniperus-Populus</i> – ca. 100– -35 cal BP (AD ca. 1850–1985)</p> <p><i>Pinus</i> rises rapidly to ca. 60%, <i>Betula</i> decreases, <i>Ulmus</i>, <i>Tilia</i>, <i>Fraxinus</i>, <i>Carpinus</i> fall below 1%, <i>Corylus</i> ca. 3%, with small peak at zone top, rises of <i>Juniperus</i> and <i>Salix</i>, <i>Alnus</i> falling at zone top. NAP over 15%, with dominant Gramineae, <i>Rumex acetosella</i> and <i>Secale</i>. P.c. low, stable.</p>

* The double dates mean a small break in the continuity of samples just where the zone boundary should be indicated. The ages of both lower and upper samples delimiting the break are given. From the point of view of historical events such imprecision is significant.

Description of vegetational changes in the Lake Gościąż region during the Holocene

The Vistulian/Holocene transition is well documented in all analytical records (sedimentology, stable isotopes, chemistry, pollen, Cladocera, and diatoms). The most significant change – the shift of ^{18}O measured with a 10 yr time resolution, was completed in ca. 80 yr (Kuc et al., Chapter 7.6). Thus the Younger Dryas/Preboreal boundary is established at ca. 11,510 cal yr BP = 10,050 ^{14}C BP (Goslar, Chapter 6.). In the pollen diagram of G1/87 profile (Fig. 8.22) it falls between samples 83 and 84 dated at 11,558 and 11,508 cal BP.

The vegetational changes following this level, classified in terms of pollen assemblage zones, may be interpreted as follows:

***Betula-Populus-Ulmus* PAZ (G1/87–4; 11,530–10,530 cal BP), (TB-6a – TB-6b; ca. 11,530–10,600 cal BP)**

The climatic change first affected the shrub and herb vegetation around the lake: it is indicated by a strong reduction of *Salix polaris* -t. species, juniper shrubs, xeric grasslands with *Artemisia* and Chenopodiaceae, and disappearance of *Hippophaë*.

At the same time the expansion of tall herbs proceeded with abundant *Filipendula* (*F. ulmaria*?), *Urtica dioica*, *Thalictrum*, different Umbelliferae, Rubiaceae and fern species, suggesting plenty of humid habitats. The good place for their development could have been in the transition belt between the lake shores and the dry land, possibly within the open willow shrub zone. Around 11,160 cal BP *Humulus lupulus* appeared also in those communities. On the drier sandy habitats *Calluna* heaths started to spread. Many new plant taxa that appeared in pollen spectra from that time contributed to enrichment of the herb vegetation, but their ecologic attachment cannot be defined. This concerns for example *Hypericum*, *Veronica* -t., *Geum* -t., *Stachys*, *Anemone* -t., etc.

The changes do not involve yet the dominant tree taxa *Betula* and *Pinus sylvestris* in any essential way. The pollen values of both remain oscillating within the limits similar to those attained during the descending part of Younger Dryas, as is clear from their pollen influx (Fig. 8.23). It took up to 200 yr before the substantial *Betula* expansion began. This delay is also recorded in the pollen diagrams from the northern lake bay (Fig. 8.26, distinguished as TB-6a subzone) and marginal profiles

Lake Gościąg, profile G1/87 pollen influx diagram

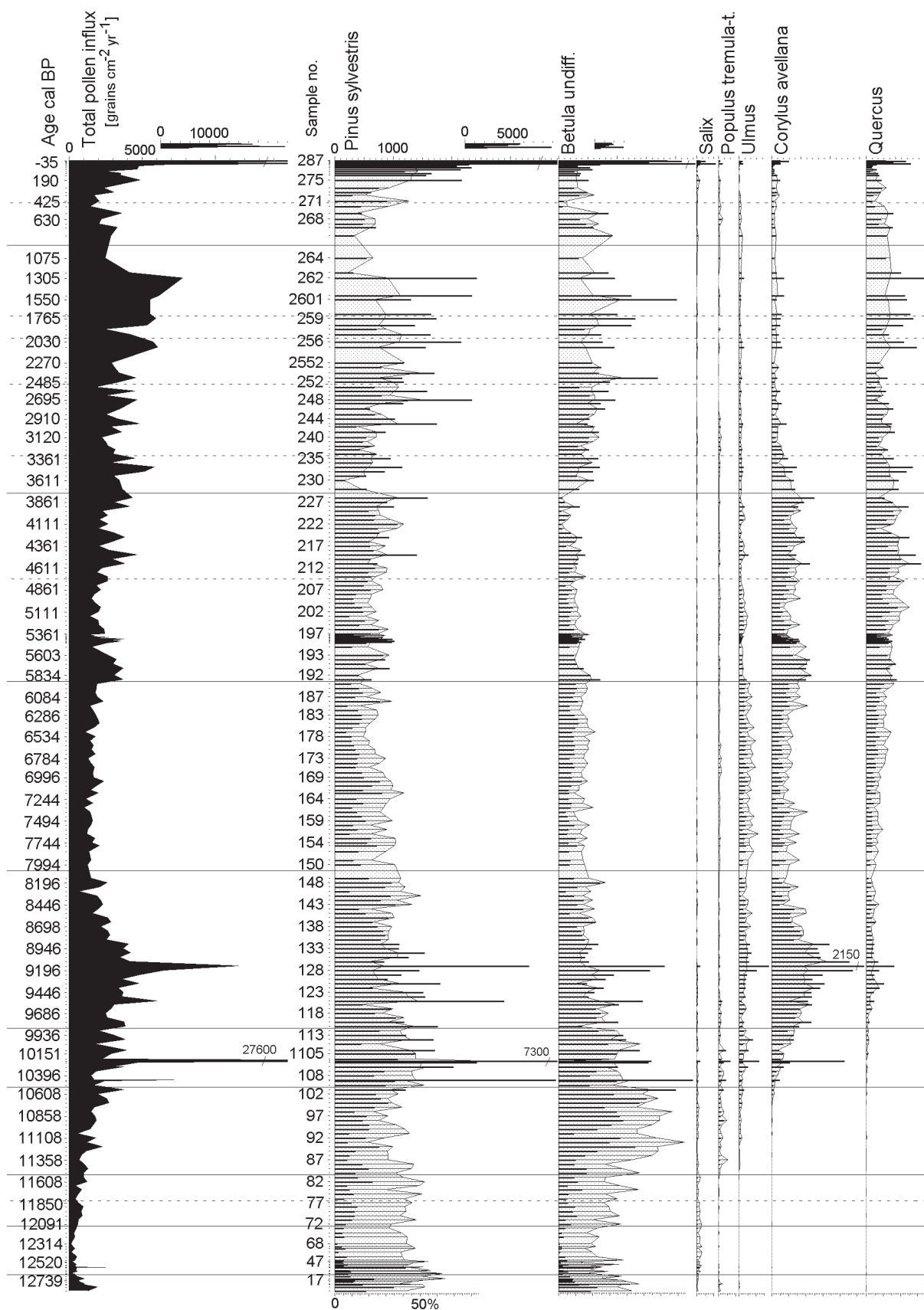
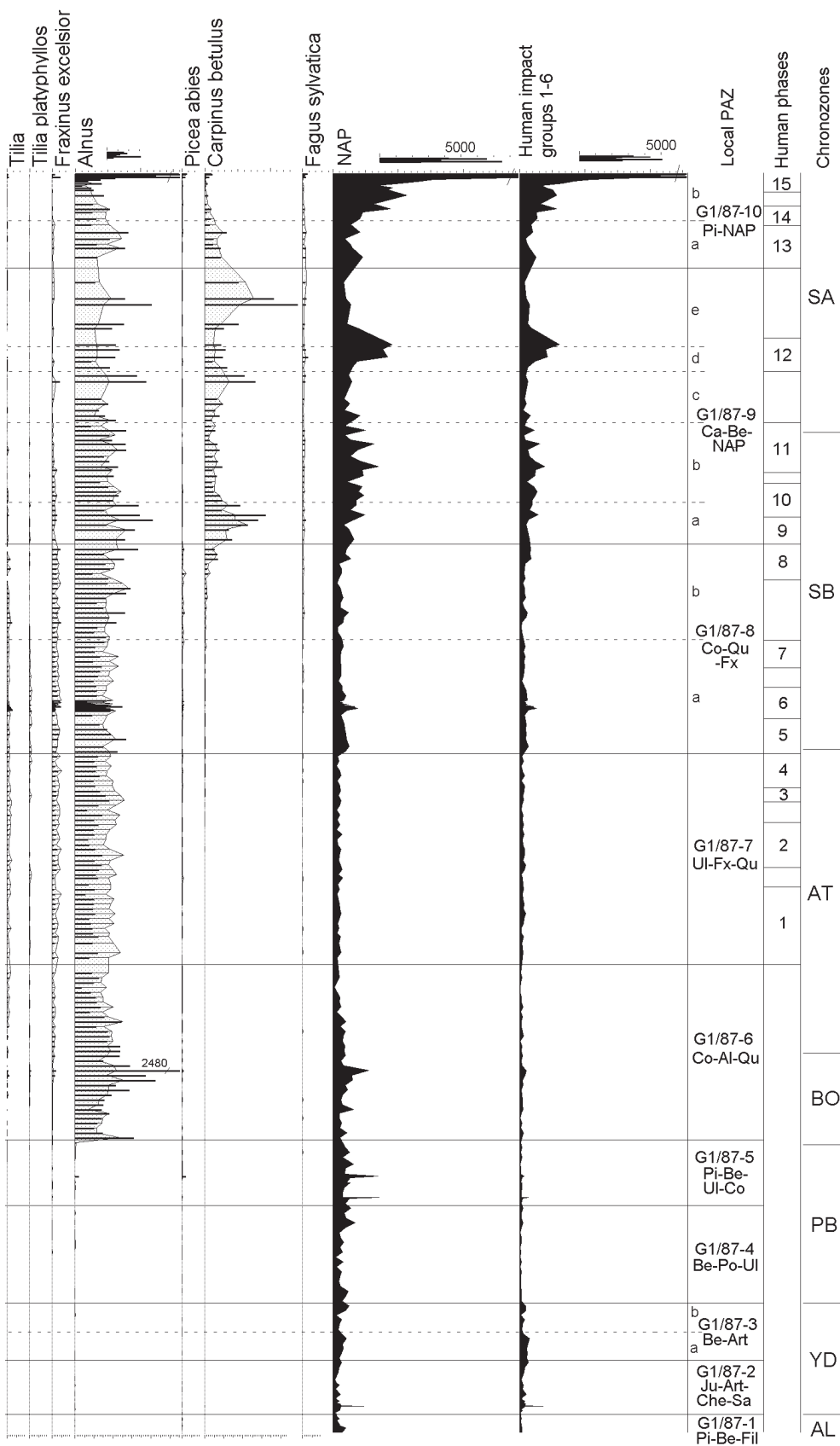


Fig. 8.23. Lake Gościąg, profile G1/87, pollen-influx diagram, selected pollen taxa, and some cumulative influx plots of summarised ecological human impact groups (see Chapter 9.1.3, Fig. 9.17). Influx values of particular pollen taxa (black bars) are superimposed on the percentage pollen



curves (dotted silhouettes). The summarised influx values are presented as black silhouettes. The diagram zonation as in Fig. 8.22. The human phases as in Chapter 9.1.3., Figs 9.8, 9.13, 9.15.

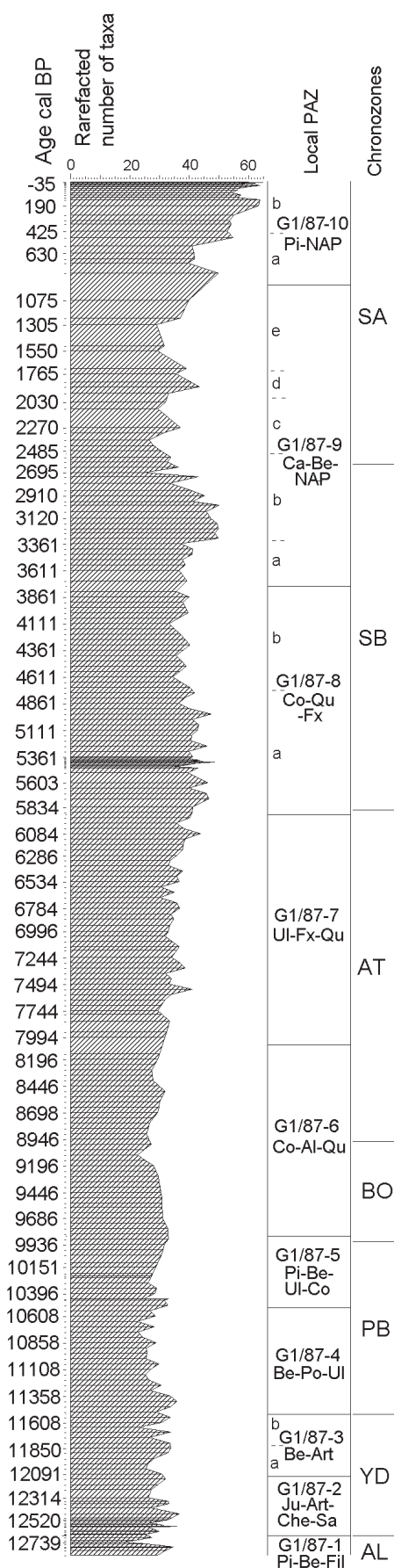


Fig. 8.24. Lake Gościąg, profile G1/87. Rarefaction analysis of the full Late-Glacial and Holocene pollen sequence. Plot of expected number of pollen and spore taxa is based on the pollen count = 1856.

(Demske, 1995). *Betula nana* is still an important shrub component of open forests, and *Populus* (*P. tremula* type) starts expanding quickly.

The spread of birch woods proceeding from around 11,350 cal BP (up to 60–70% of *Betula* pollen) caused further extinction of shrub (*Ephedra distachya*, *E. fragilis* -t., *Juniperus*, *Betula nana* -t.) and herb communities still remaining from the Late-Glacial, as is suggested by disappearance of many ecologically undefined pollen taxa like *Anthemis* -t., Cruciferae, *Ranunculus flammula* -t. (+ *Ranunculus*), and others, and by a decline in the taxa diversity curve indicated from about 11,300 cal BP (Fig. 8.24). The development of birchwoods with pine, with substantial contribution of *Populus* (cf. *P. tremula*) and some *Sorbus aucuparia*, attained its maximum between 11,150 and 10,800 cal BP. It is evidenced by the high *Betula* pollen influx (Fig. 8.23), still rising in the top part of zone, and accompanied here by the increase of *Pinus* pollen influx. The latter means gradual extension of pinewoods.

The continuous occurrence of *Ulmus* pollen (less than 1%) begins in G1/87 (Fig. 8.22), T1/90 (Fig. 8.26), and other diagrams (Demske 1995) right above the Holocene boundary, signalling that this tree is not very far from the lake. From ca. 11,000 cal BP (9800 ^{14}C BP) it exceeds 1% more and more often, and from ca. 10,760 cal BP (9600 ^{14}C BP) the pollen values over 2% suggest its local presence (Huntley & Birks 1983). These facts together with the data from Lake Błędowo (Bińka et al. 1991), situated ca. 100 km east of Lake Gościąg, may well support the *Ulmus* migration maps in central Poland (Ralska-Jasiewiczowa 1983) at its earliest stages.

The most distinctive initial reaction to the climatic change at the beginning of Holocene was the formation of broad telmatophyte zone around the lake expressed first by the rise of grass and sedge pollen values. The reedswamp communities formed during the first ca. 200 yr of the Holocene included *Typha latifolia*, *Cladium mariscus*, *Scirpus lacustris* -t. spp., *Equisetum* spp., *Thelypteris palustris* and also *Schoenus* -t., *Glyceria* -t., *Butomus umbellatus*, *Rumex aquaticus* -t., and *Sparganium erectum* -t. Profiles located closer to the lake margins (Demske 1995) have very high Gramineae pollen values then (*Phragmites* -t.?). The development of Nymphaeaceae populations, mainly *Nuphar luteum* and *Nymphaea alba*, together with *Ceratophyllum*, *Myriophyllum spicatum*, *M. verticillatum*, and *Potamogeton* progressed in the marginal parts of the lake (Demske 1995), as is recorded even in the profile from the lake centre. The accompanying very high frequencies of the green alga *Tetraedron minimum* is evidence for the sudden rise of lake productivity (Ralska-Jasiewiczowa et al. 1992).

The expansion of telmatophyte and wet-shrub zone around the lake was most probably the joint effect of several factors. Some temporary lowering of lake level was one of them, as is also documented by other changes in

lake ecosystems (Demske 1995, Starkel et al. 1996, Sze-roczyńska, Chapter 8.4). However, the climate warming, the favourable lake-water chemistry, and rising lake trophy with still low competition (Birks 1986) certainly contributed in a substantial way to the abundant development of telmatic vegetation.

***Pinus-Betula-Ulmus-Corylus* PAZ (G1/87-5; 10,530–9850 cal BP), (TB-7; ca. 10,600–9900 cal BP)**

During the next ca. 700 yr the shrinking birchwoods were invaded by expanding pine, particularly on drier sandy soils common around the lake, as is documented by a rise of *Pinus* pollen influx (Fig. 8.23) around 10,200 cal BP. This succession changed temporarily the forest structure, making it more open again and enabling the re-appearance of heliophyte herb taxa of different ecological affinities that had persisted from the Late-Glacial (*Gypsophila fastigiata*, *Pleurospermum austriacum*, *Plantago major*, *Sanguisorba officinalis*, *Valeriana*, *Melampyrum*) including the first appearances of *Ophioglossum* and *Succisa pratensis*.

The pine and birch woods were gradually penetrated by the new forest species *Ulmus* and *Corylus*. While *Ulmus* is assumed to have been present in the area from the decline of the previous zone, *Corylus* seems to have spread slightly later. It was probably present near the lake from ca. 10,400 cal BP, when its pollen values exceed 2% (Huntley & Birks 1983). The regular occurrence of *Juniperus* pollen ceases at that time, and herb taxa disappear again, as can certainly be explained by the *Corylus* shading effect eliminating heliophilous species from the open pinewood understory.

Ulmus expanded slowly in the birch-dominated woods on more fertile and more humid habitats, where *Picea* occurred also as a scattered tree. Here also the development of understory shrubs like *Rhamnus catharticus* and *Viburnum opulus* might have affected the abundance of tall herbs, as documented by declines of *Filipendula*, *Urtica dioica*, and *Thalictrum* from around 10,200 cal BP, and of Filicales monoletae at the zone decline.

The well developed telmatic and shallow-water plant communities revealed then new pollen taxa like *Hottonia palustris*, *Oenanthe* -t., *Potamogeton* s. *Coleogeton* and *Nymphaea candida*. The investigations in and around the northern lake bay (Demske 1995) document the activa-

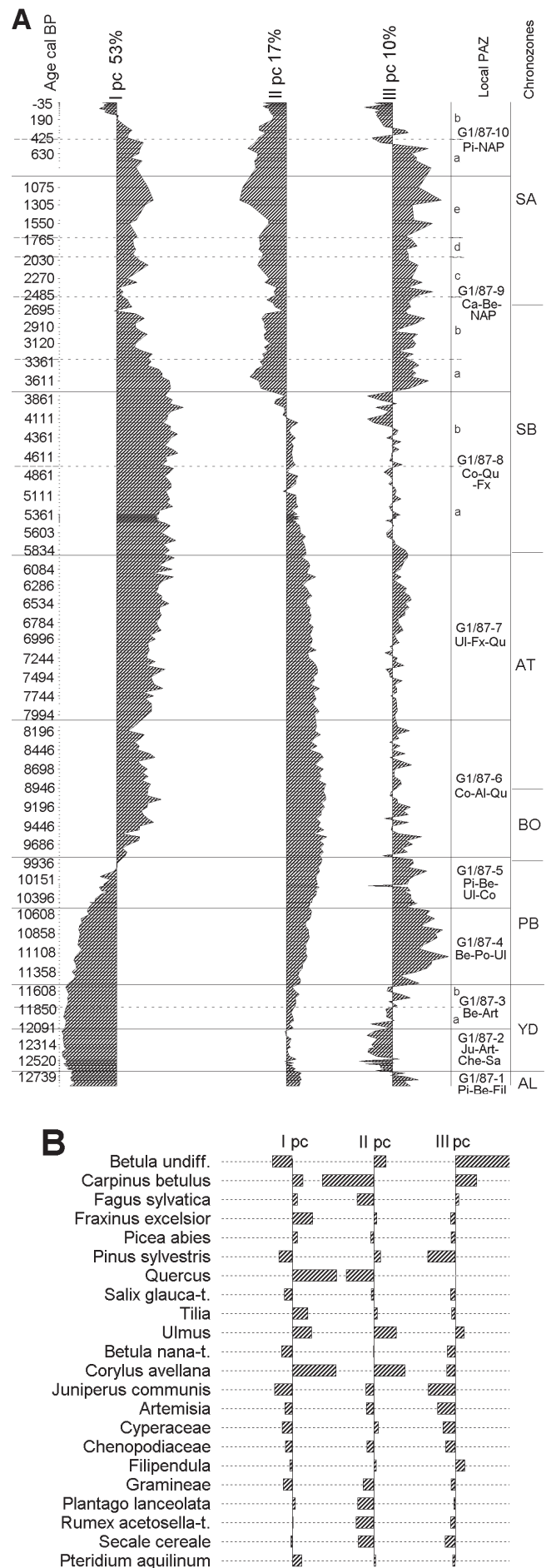
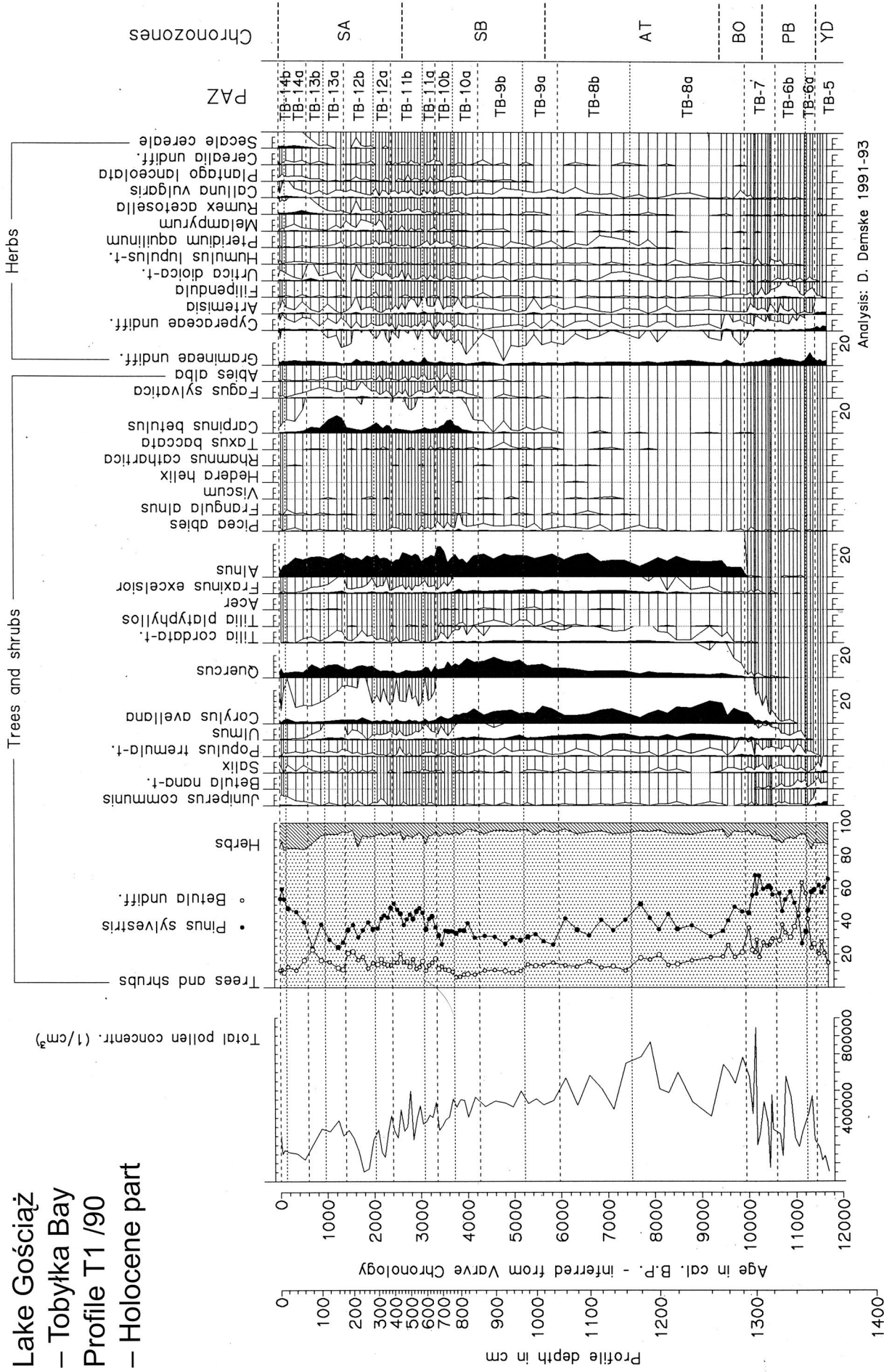


Fig. 8.25. Lake Gościąg, profile G1/87. A – plots of the sample scores on the first three principal components of the full Late-Glacial and Holocene pollen sequence. The ages cal BP of samples and the division of pollen sequence into local pollen assemblage zones are indicated. The percentage of the variance for each component is given on top of the axis. B – the loadings of particular pollen taxa on each of the principal components. The major and most important pollen taxa were used excluding *Alnus*, as a very local overrepresented tree taxon influencing too highly the results of analysis.

Lake Gościąg
 – Tobyłka Bay
 Profile T1 /90
 – Holocene part



Analysis: D. Demske 1991-93

Fig. 8.26. Lake Gościąg, Tobyłka Bay, profile T1/90, Holocene part – simplified pollen diagram, selected pollen taxa without telmatophytes and limnophytes recalculated on a time scale. For lithological data see Fig. 8.27.

tion of Ruda stream inflow following the lowering of the lake level during the preceding zone.

***Corylus-Alnus-Quercus* PAZ (G1/87-6; 9850–8130 cal BP), (TB-8a; ca. 9900–7500 cal BP)**

The time between 9850 and 8130 cal BP was the period of successive profound environmental changes in the study area. The lower boundary of this zone is very sharply indicated in the first component of PCA (Fig. 8.25), even when do not include *Alnus* pollen values in the analysis. The main loading is brought by *Corylus* and *Quercus*, but with substantial contribution of other deciduous trees. The most important events were the rapid expansion of *Alnus* around 9850 cal BP and the gradual extensive spread of *Corylus*. Some distinctly different types of forest communities started to develop at that time: open pinewoods with *Betula* and *Populus tremula* still occupied light sandy soils, but from around 9400 cal BP *Populus cf. tremula* was gradually replaced there by invading *Corylus*. Deciduous woods formed by *Betula* with some *Ulmus* on fresh heavier soils might have become dominated by *Corylus*. From ca. 9400 cal BP *Quercus* started to penetrate both types of habitats. On the wettest soils close to the lake *Alnus* was main component. An extremely rapid expansion of *Alnus* took up the surroundings of the Na Jazach lakes around 9850 cal BP. The explosive character of this expansion is also indicated in the T1/90 diagram from the northern bay, though its percentages are not so high there (Fig. 8.26), and also in the diagram from the adjacent kettle-hole mire (Demske 1995).

A very fast spread of *Alnus* (most probably *Alnus glutinosa*) has been reported from many other sites not only from Polish Lake Districts (Ralska-Jasiewiczowa 1966, Pawlikowski et al. 1982, Noryskiewicz 1982, Miotk-Szpiganowicz 1992), but also from other parts of Europe (Digerfeldt 1972, Gaillard 1984, Berglund et al. 1996; Bennett & Birks 1990, Tallantire 1992, Greig 1996, Chambers 1996).

It was formerly assumed (Birks 1986) that 200–400 yr was necessary for such a rapid *Alnus* invasion. According to our data it might have proceeded still faster, being completed in less than 100 yr. A year-by-year analysis is needed to show it more precisely. *Alnus* could spread around the lakes on the wettest grounds partly covered by birchwoods with some elm, as is suggested by disturbed *Ulmus* and *Betula* pollen concentration curves, but possibly also on water-logged lake shores where the vegetation has not yet reached the successional stage of woodland. Those habitats were previously occupied by sedge-grass communities (of *Magnocaricetalia* type?), as is shown by distinct declines of Gramineae and Cyperaceae (including *Carex* -t.) in pollen spectra recording *Alnus* invasion. The incipient alderwoods included possibly *Salix* ssp., some *Betula*, *Fraxinus*, and scattered

Picea, and they had an abundant understory (*Frangula alnus*, *Viburnum*) with creeping *Humulus* and a herb layer with tall herbs and ferns, including *Thelypteris palustris*. Bennett and Birks (1990) discuss the first increase of *Alnus* pollen at particular sites in the British Isles. They find in the majority of sites a poor fit of its real pollen accumulation rates to the exponential model (Bennett 1983), because of too abrupt increase of *Alnus* pollen values. The “doubling times” for the period of the “step increase” were 20–250 yr (Bennett & Birks 1990).

According to Birks (1986) “main *Alnus* expansion might have been initiated by waterlogging and rising groundwater tables”. However, the data available from European lowlands are not consistent in this respect. According to e.g. Gaillard & Digerfeldt (1991) the records of lake level changes in S Sweden point to the rise of lake levels following the lowering that culminated between 9450 and 9150 ¹⁴C BP (ca. 10,450–10,050 cal BP), and lasted until early part of Atlantic chronozone. In the sites from the Polish lowlands it was assumed that water-level were generally low during 9000–8500 ¹⁴C BP (9950–9470 cal BP) (Ralska-Jasiewiczowa & Starkel 1988), but their datings were rather scarce and in the newer papers this lowering appears rather after 8500 ¹⁴C BP (ca. 9470 cal BP).

In the marginal zone of Lake Gościąg Demske (1995) finds evidences of lower water level after 9000 ¹⁴C BP (9950 cal BP), with a minimum level between 8700 and 8500/8400 ¹⁴C BP (= 9640–9470 cal BP), when the particular water bodies of the lake (main lake, northern bay, kettle-hole) might have been temporarily isolated from each other. In Ruda valley peat was deposited below Lake Mielec at that time (Więckowski et al., Chapter 5.1). Those changes might have produced plenty of habitats accessible for the fast expansion of *Alnus* populations.

Following the minimum water level a very high pollen influx in the sediment is observed between ca. 9550 and 8900 cal BP with a maximum around 9250–9150 cal BP. The most consistent influx rises are shown then by *Corylus*, *Alnus* and *Betula* (Fig. 8.23).

Viscum pollen at that time indicates warm summer seasons. *Hedera* pollen assuming to indicate mild winters with long autumn time is first recorded around 8800 cal BP. The dates of appearance of both climatic indicators speak for a good regional representativity of the central lake core G1/87. In core T1/90 from the Tobyłka Bay the first *Viscum* pollen is noted around 7200 cal BP and *Hedera* around 6600 cal BP only.

From ca. 9000 cal BP *Tilia* (cf. *Tilia cordata*, sporadically *T. platyphyllos*) and *Fraxinus excelsior* start penetrating the forests, for their continuous pollen curves regularly exceed 1%. The increasing shade in the forests and the reduction of open places is evidenced by the NAP curve, which is then the lowest of all Holocene zones, and by the fall of taxa diversity to its Holocene minimum between 9250 and 8850 cal BP (Fig. 8.24). A small rise

of NAP at the zone decline from ca. 8850 cal BP, involving *Artemisia*, *Calluna vulgaris*, *Urtica dioica*, *Humulus lupulus*, *Thalictrum*, and Gramineae, which are taxa of different – dry and humid and rather nitrophilous habitats may be of anthropogenic origin.

The decrease of pollen influx after ca. 9000 cal BP is coincident with the decrease of laminae thickness in the sediment. The pollen concentration curve in T1/90 profile (Fig. 8.26) rises because of the decrease of the accumulation rate. The accompanying changes in lake ecosystems are expressed by changes in the Cladocera assemblages. Those changes are interpreted by Szeroczyńska (Chapter 8.4) as the result of lake eutrophication and of climate-induced development of its littoral zone.

***Ulmus-Fraxinus-Quercus* PAZ (G1/87-7; 8130–5900 cal BP), (TB-8a(cont.), TB-8b; ca. 7500–5900 cal BP)**

The period between 8130 and 5900 cal BP was characterized by a high stabilization of forest communities. The mixed deciduous woods reached their maximum Holocene development as much as it was possible in the area with the prevailing poor sandy soils. The pollen influx decreases to its lowest Holocene level (Fig. 8.23). *Ulmus*, *Fraxinus*, and *Tilia* percentages reach their maximum values, forming the forest of high density and shadiness.

The pattern of woodland types growing in the study region at that time seems to have been the following: pine forests with *Betula* and slowly increasing *Quercus* contribution dominated on more elevated rather dry and poor sandy soils with *Populus tremula* and *Corylus avellana* as main understory taxa. On more humid and more fertile soils sloping towards the lakes *Ulmus*, *Fraxinus excelsior*, both *Tilia* species, *Quercus*, and some *Acer* formed carr-type communities. The wettest soils within the lake complex were occupied by alderwoods, their composition as described in the previous zone.

The oscillations of *Populus* and *Corylus* pollen curves occurring throughout the zone, together with the changing variety and representation of understory shrub taxa like *Frangula alnus*, *Viburnum opulus*, *Rhamnus catharticus*, *Sambucus nigra* -t., and *Hedera helix*, are evidence for the formation of small episodic openings in dense woods. The occurrence of such gaps is also confirmed by temporarily increased and oscillating curves of partly forest-herb taxa like *Humulus lupulus*, *Urtica dioica*, *Thalictrum* (?), *Mercurialis perennis*, and also *Pteridium aquilinum*, *Melampyrum*, *Calluna vulgaris*, and *Rumex acetosella*, the first group connected with rather humid and nitrogen-enriched habitats of carrs and alderwoods, the other with drier and poorer mixed pine forests. The frequencies of herb taxa and the total taxa diversity curve start increasing and oscillating from ca. 8000 cal BP (Fig. 8.24). Those phenomena are supposed to be mostly of anthropogenic origin and are dis-

cussed in Chapter 9, though the natural causes of some gaps, like fires or strong wind activities cannot be excluded.

A regular record of *Taxus baccata* in the Lake Gościaż region is noted from ca. 6685 cal BP. At about the same time the occurrence of its pollen begins also in the bay T1/90 pollen diagram (Fig. 8.26) and in marginal lake profiles (Demske 1995). The recent SE limit of the northern lowland distribution area of *Taxus* runs closely outside the investigated region, on the other side of Vistula River. It occurs again in the southern upland and mountain parts of Poland only (Browicz & Gostyńska-Jakuszewska 1969). So its appearance is certainly climate-indicative here. The Holocene history of *Taxus* though discussed long ago in detail by different palaeoecologists (e.g. Willerding 1968, Averdieck 1971, Środoń 1975), still has no isopollen maps, mostly because of poor recognition of its pollen.

The late phase of zone G1/87-7 from ca. 6900 cal BP is distinguished by the changing proportions between temporarily retreating *Pinus* and very slowly invading *Quercus*, with some spread of *Betula* (Fig. 8.23), what may suggest some disturbances of forest density. A substantial spread of *Corylus* is indicated at the end of the zone from ca. 6200 cal BP by its doubled percentages (from ca. 10% to ca. 20%). It is accompanied by a series of minor phenomena like increased records of *Tilia platyphyllos*, *Taxus*, *Picea*, *Frangula alnus*, and some herb taxa, including first appearances of *Plantago lanceolata* and *Knautia arvensis*. All that speaks for the beginning of changes in the regional forest structure, being in all probability of anthropogenic nature (see Chapter 9.1.1). However, in the bay profile (T1/90), which records more local pollen, no changes of this type can be traced (Fig. 8.26). The *Ulmus* pollen curve starts declining very slowly around 6400 cal BP and declines consistently through the upper subzone limit, without showing any distinct fall at 5900 cal BP while such a fall is then distinctly indicated in G1/87 profile.

The record of lake vegetation shows the reappearance of the whole group of limnophytes, including *Potamogeton*, *Nuphar*, *Nymphaea alba*, *Myriophyllum spicatum*, *M. verticillatum*, and *Rumex aquaticus* -t., starting from ca. 8000 cal BP, as may signal some eutrophication in the shallower parts of lake. At the same time a drastic change of Cladocera assemblages occur (Szeroczyńska, Chapter 8.4), including altogether nearly total extinction of Bosminidae and planktonic species. The possible reasons for the change in the lake ecosystems observed around 8000 cal BP are discussed in Chapter 8.8.

***Corylus-Quercus-Fraxinus* PAZ (G1/87-8; 5900–3750 cal BP), (TB-9; ca. 5900–4250 cal BP, TB-10a; ca. 4250–3700 cal BP)**

As mentioned above, the first symptoms of decreasing stability of forest communities could already be seen

Lake Gościąż
Profile G1/87

Lake Gościąż-Tobyłka Bay
Profile T1/90

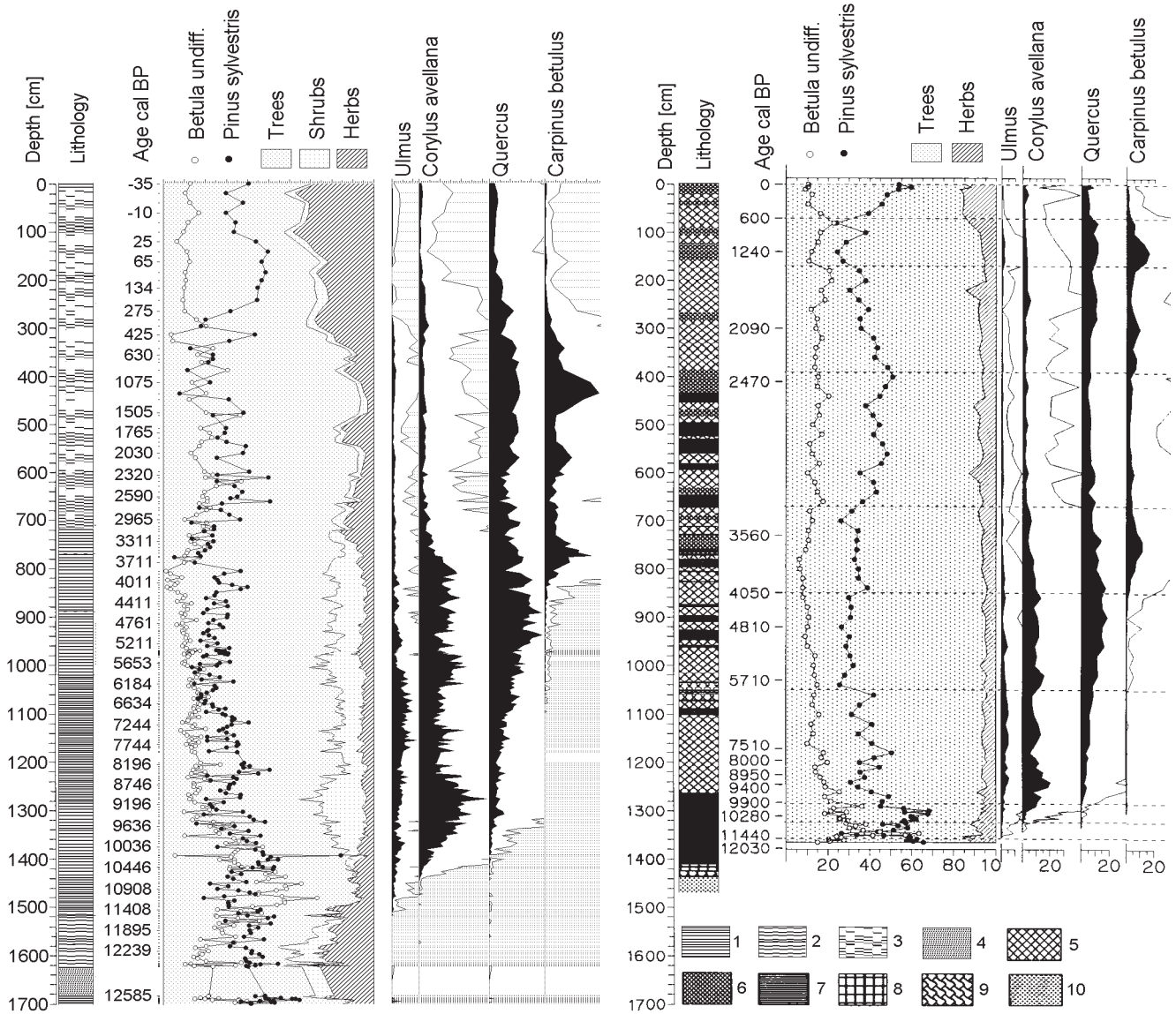


Fig. 8.27. The comparison of summary pollen diagrams completed with few selected major pollen taxa from profiles G1/87 from the lake centre and T1/90 from Tobyłka Bay, both plotted on the depth scale. 1 – calcareous gyttja, regular laminae, 2 – calcareous gyttja, wavy laminae, 3 – calcareous gyttja irregular laminae, 4 – sand, 5 – calcareous gyttja, laminae lacking or strongly disturbed, 6 – dark detritus gyttja, 7 – calcareous gyttja, laminae distinct or slightly disturbed, 8 – calcareous gyttja with silt and sand, 9 – brown moss peat, 10 – sand.

around 6200 cal BP. The rapid decrease of *Ulmus* in the deciduous woods that happened around 5900 cal BP (subzone G1/87-8a) accelerated the process of environmental changes towards the opening of dense shady forest structure and gradual change in its composition.

The extermination of *Ulmus* took place within several decades. However, as shown by small oscillations in its percentage and influx values, there might have been some disturbances in its populations starting ca. 500 years earlier. After long discussions of hypotheses concerning the *Ulmus* fall in Europe about 5000 ¹⁴C BP, in-

cluding climatic, edaphic, anthropogenic, and pathogenic reasons (see references in Chapter 9.1.3), the *Ulmus* decrease bred by an ascomycete fungus *Ceratocystis ulmi* spread by bark-beetles of genus *Scolytus* (Rackham 1980) have been accepted as the main cause of elm decline in the Lake Gościąż area, although in combination with the human activities. This problem discussed already by Ralska-Jasiewiczowa and van Geel (1992) is presented more thoroughly in Chapter 9.1.3.

The opening of the forest structure around the lake is expressed by a transitory rise of *Betula* and substantial

increases of both percentage and influx pollen values of *Quercus* and *Corylus*. For a short time the total pollen influx is doubled, clearly indicating the improvement of tree-flowering conditions by better light penetration (Fig. 8.23). Some forest herb taxa such as *Melampyrum*, *Solanum dulcamara*, *Mercurialis perennis*, *Vaccinium* -t., and ferns like *Dryopteris filix-mas*, and *Polypodium vulgare*, start to manifest their presence then. The part of the subzone that follows reflects vegetation changes connected with the progressive development of human settlements (Chapter 9.1.3). The short-lasting spread of *Taxus* is also discussed in this context.

Interesting is a small but distinct increase of *Tilia platyphyllos* pollen values observed in both diagrams (G1/87 ca. 5900–4720 cal BP, T1/90 ca. 5950–4250 cal BP). This tree, rarely present in the woods around Lake Gościąg since ca. 9500 cal BP, is today absent from forests surrounding the lake (Kępczyński & Noryśkiewicz, Chapter 3.7), though Gościąg lies within the area of its scattered occurrence (Faliński & Pawlaczyk 1991). The rise of its pollen in the diagram corresponds broadly with the main depression in the *Ulmus* curve, and its gradual decline occurs when some regeneration of *Ulmus* is indicated around 5300–5100 cal BP. It is difficult to suggest the type of forest community for the broad-leaved lime. This tree needs well aerated fertile soils of mull type, and nowadays it grows often on humid valley slopes with active erosional processes in mixed deciduous forests with a rich tall-herb layer and substantial presence of nitrophilous species (Matuszkiewicz 1981). It is less tolerant to high groundwater table than *Tilia cordata*. It might have been scarce in the mixed deciduous wood on fresh habitats around the lake, where *Ulmus* played a substantial part, and took advantage of reduction of elm trees getting more light for better flowering. A slight rise in *Acer* pollen accompanies increase of *Tilia platyphyllos*, as is also reflected synchronously in the bay profile T1/90 (Fig. 8.26). Today *Acer pseudoplatanus* together with *Tilia platyphyllos* and *Ulmus scabra* form an association *Aceri-Tilietum* Faber 1936, which occurs on the types of habitat described above, characterized by a rich tall-herb layer distinguished in particular by constant and abundant presence of several *Campanula* species (Matuszkiewicz 1981). It might be incidental, but the only regular appearance of *Campanula* pollen is restricted to this section of the diagram. At any rate the above-described changes indicate the presence of rather fertile, still not degraded soil fragments in the lake vicinity.

During the later stages of the zone *Ulmus* pollen curve shows still three small regeneration episodes, each next one smaller and shorter, 5300–4950 cal BP, around 4400–4300 cal BP, and around 4000 cal BP. Their direct connection with the changing intensity of human activities near the lake is not quite clear. Possibly the subsequent attacks of elm disease might have been involved (Peglar 1993).

During the older part of zone the role of *Quercus* is greater, and in G1/87 sequence (Fig. 8.22) around ca. 5100 cal BP its pollen percentages (20–25%) became a subdominant component of pollen sum, sustaining a similar level till ca. 4300 cal BP. However, its pollen influx as well as the influx of the dominant *Pinus* remains at a moderate level (Fig. 8.23) until the time of Neolithic settlements in the study region ended around 4700 cal BP. From ca. 4750 cal BP (subzone 8b) the decreased pollen frequencies of the main anthropogenic indicators and Gramineae suggest the reduction (cessation??) of economic activities around the lake for at least ca. 600 yr, enabling some regeneration of natural forest communities. This process began at first with gradual replacement of birch populations by expanding pine on drier habitats. Around 4500–4250 cal BP *Pinus* and *Quercus* reach very high influx values, indicating open structure and good flowering conditions of mixed pinewoods (Fig. 8.23). *Corylus* and *Fraxinus* were still abundant in deciduous wood patches with *Quercus* and fewer other trees like *Tilia cordata*, *Ulmus*, and *Acer* on more fertile land. *Tilia platyphyllos* pollen was reduced to single occurrences, its habitats probably being overgrown by other tree species. Those successions altogether speak for the progressing degradation of soils in the region. Some spread of spruce and later of alder proceeded on humid soils.

By the end of the zone *Carpinus*, perhaps sporadic in the area or nearby from ca. 4750 cal BP (continuous pollen appearance up to 0.8%), entered the woods around the lake (1.5% at 4250 cal BP), and from ca. 3860 cal BP it started to expand substantially (6%, see Huntley & Birks 1983). The accompanying *Fagus* curve, continuous (1%) but still not tending to rise, may at best reflect scattered sites of beech not far away. The *Carpinus* expansion by the end of zone coincides with the first signs of new human activities and it progressed thereafter according to a pattern very typical for this tree in terrain disturbed by man (Chapter 9.1.3). Small peaks of *Picea* pollen (over 1%) coinciding with the oscillations in *Alnus* curve seem to express some disturbances affecting also the alderwoods.

Around 5400 a single *Vitis* pollen was found, coincidentally with the maximum of land occupation indicators. The cultivation of grape-wine by Neolithic settlers, cannot be totally excluded, but seems highly improbable. More possibly, the wild *Vitis vinifera* ssp. *sylvestris* was growing in the adjacent alderwoods throughout the times of climatic optimum. A find of *Vitis* pollen of similar age is known from Lake Błędowo (Bińka et al. 1991, see Chapter 9.1.3 p. 292), and earlier Atlantic-age finds were noted in the same site as well as in Wolbrom (SW Polish Uplands, Latałowa 1976), and in the Bieszczady Mts. (SE Poland, Ralska-Jasiewiczowa 1980). In the latter paper its significance as climate indicator is broadly discussed.

The increased frequencies and variety of limno- and telmatophytes (*Nymphaea alba*, *Myriophyllum verticillatum*, *M. spicatum*, *M. alternifolium*, *Hottonia palustris*, *Rumex aquaticus* -t., *Hippuris vulgaris*, *Potamogeton*, *Scirpus lacustris* -t., and *Sparganium erectum*) observed in the older subzone in the diagram from the central deep, and much more distinctly in the cores from marginal lake parts (Demske 1995), speak for lake eutrophication progressing between 5900 and ca. 4900 cal BP, possibly in connection with the settlement activities, elm extinction, and soil erosion to the lake, however it is still not indicated by the changes of sediment accumulation rates in the bay (Fig. 8.28). This process seems to have been set back during the younger part of zone, most distinctly from ca. 4600 cal. BP, when the human populations disappeared from the area. The very distinct reduction of limno- and telmatophytes representation lasts then at least till the end of zone: frequent are only vegetative remains of Nymphaeaceae in marginal lake profiles (Demske 1995). A transitory rise of water level is assumed to occur at that time (more pelagial taxa of Cladocera, Szeroczyńska, Chapter 8.4).

***Carpinus-Betula*-NAP PAZ (G1/87-9; 3710–1075(820) cal BP), (TB-10b – TB-13a; ca. 3700–950 cal BP)**

The lower boundary of this zone is strongly indicated by all the three components of PCA. The main loading in second PC is brought by *Carpinus* (Fig. 8.25).

The profound changes in the structure of the deciduous woods after 3700 cal BP are very difficult to describe without involving the whole history of settlement affecting the natural vegetation of the region at that time (Ralska-Jasiewiczowa & van Geel, Chapter 9.1.3). That is why the detailed analysis of subsequent vegetational changes, designated as subzones a-e of PAZ 9 in G1/87 (Fig. 8.22) and subzones TB-10b to TB-13a in T1/90 (Fig. 8.26) is presented in Chapter 9.1.3. In this chapter we tried mostly to trace the response of natural environment to the anthropogenic stress.

The very fast development of *Carpinus* populations during the initial part of the zone (subzone 9a), completed within ca. 250 yr (pollen rise from 4% to over 20%), was clearly accompanied by expansion of *Betula*, *Populus*, Gramineae, and some human indicators. However, the beginning of the whole process is recorded still at the decline of phase G1/87-8b (TB-10a), and at that time the rise of *Carpinus* coincides with the fall of *Betula* to its minimum Holocene values in both diagrams. This suggests that the expansion of *Carpinus* started at the expense of *Betula* woods in the situation of rather reduced or absent human impact. The further development of hornbeam populations (G1/87-9a, TB-10b) proceeded clearly under different circumstances. It coincides with the strong reduction of the still remaining stands of deciduous woods with *Tilia cordata*, *Fraxinus*, *Ulmus* and

in particular of *Corylus* thickets, their pollen record shrinking consistently from ca. 3850 until ca. 2400 cal BP along with increasing amount of grassland openings (Gramineae, *Plantago lanceolata*, etc.). The pollen influx supports the supposition that *Carpinus* at that time expanded on culturally disturbed habitats as well as did *Betula*. Another evidence for a substantial change of environmental situation from 4000–3700 cal BP can be found when we compare both profiles G1/87 from the lake centre and T1/90 from the lake bay in terms of changing accumulation rates. Their simplified pollen diagrams plotted on the depth scale (Fig. 8.27) illustrate well those events. From ca. 5000 cal BP until the time of *Carpinus* and *Betula* spread between 4000–3700 the sediment accumulation rates in both diagrams are very similar (Fig. 8.28), but from that time in the profile T1/90 strongly influenced by local environmental changes the accumulation rates accelerate drastically suggesting the rise of eutrophication and lake shallowing. In the profile G1/87 from the lake centre, though the vegetational changes progressing in the region are recorded much more distinctly, no local influence on sedimentation rates is observed as yet.

The successional process that brought about such a substantial spread of *Carpinus* is still not fully understood. Some ecological properties of this tree might help to understand it: *Carpinus* certainly has strong features of a pioneer tree, such as high reproductivity, high light demands, and quick colonization of all suitable places. However, in secondary succession on abandoned fields and pastures it appears late, following the colonization of the area by light-seed pioneer trees like *Betula* or *Populus tremula*. The reason for this is that hornbeam seedlings cannot develop in the grasslands or herb communities in fallow, and the development of pioneer trees changes the structure of sod, which may take 20–30 yrs (Faliński & Pawlaczyk 1993).

Both G1/87 and T1/90 pollen diagrams suggest that the initial *Carpinus* spread began in the woods that might have been still the remnants of post-farming Neolithic activities, with a high contribution of *Betula* and *Populus tremula*. This period (around 3800 cal BP), appears also in the Lake Gościąg records as the time of a low water-level (Więckowski et al., Chapter 5.1), and *Carpinus* is recently known as a tree abundantly entering riverside forests (e.g. of *Ficario-Ulmetum* type) if their water table becomes low (Faliński & Pawlaczyk 1993). Such was also the possibility for *Carpinus* to expand on large terraces of the Vistula valley. When the Early Bronze Age tribes settled in the Gościąg region and started to graze their cattle in the woods, *Carpinus* could also be the winning tree due to its high resistance against grazing and very fast offshoot reproduction (Faliński & Pawlaczyk 1993).

In the Lake Gościąg region *Carpinus* reached its first maximum around 3560 cal BP (ca. 3300 in ¹⁴C BP).

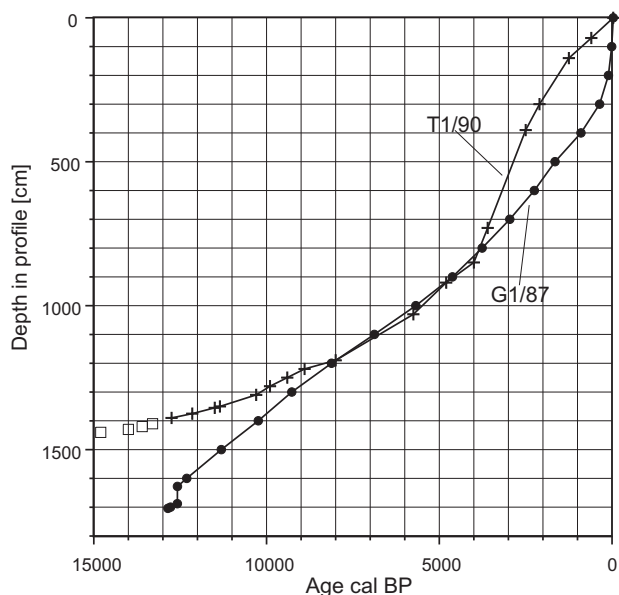


Fig. 8.28. A comparison of age-depth curves for G1/87 and T1/90 profiles showing the differences in the sediment accumulation rates in both parts of the lake. The plots show a very stable accumulation rate in G1/87 profile, its significant acceleration indicated in the last centuries and very low accumulation rate in T1/90 profile till ca. 8000 cal BP, accelerating distinctly from ca. 4000 cal BP. Between ca. 8000 and 3800 cal BP the sediment accumulation rates in both profiles are very similar.

Around that time, or only slightly earlier (3500 ¹⁴C BP), it also became the dominant component of deciduous woodlands in the areas of eastern Great Poland (Tobolski 1990, 1991) and of eastern Baltic coastal zone (Latałowa 1982). The anthropogenic factor as the main stimulus to this first *Carpinus* expansion (Ralska-Jasiewiczowa 1981) should be considered with some caution; as we remember the late-temperate stage of the interglacial cycle was a favourable time for *Carpinus* expansion also in the earlier interglacials (e.g. Eemian, see Mamakowa 1989) without any influence of man. But certainly the disturbance of phytocoenotic equilibrium of Atlantic forests by activities of Neolithic settlers, in combination with the elm disease spreading in several waves made the wood stands easier to be entered by a new-coming expansive tree species characterized by the high adaptability to different soil conditions and fast, easy reproduction.

The relative abundance of hornbeam-dominated woods in the Lake Gościąg region lasted no more than 100 yr. They must have occupied mostly the more fertile habitats, which were not very extensive in this area, and the new colonization wave caused their gradual strong recession during the next 1000 yr.

Between 3300 and 2550 cal BP (G1/87-subzone 9b; T1/90-TB-11a,b) the deciduous hornbeam-dominated woods were probably reduced to scattered fragments (*Carpinus* 4–6%). The oak trees might have been partly saved for a time as single well-flowering trees, useful for different purposes. Later (from ca. 2700 cal BP), when a

minimum of *Carpinus* pollen (1.5%) is indicated, the amount of oak trees seems to have been distinctly reduced too (*Quercus* <10%). *Ulmus* and *Fraxinus* were initially the only other deciduous trees giving the continuous pollen curves higher than 1%. Those trees were probably connected mostly with the alderwoods on wet habitats (carr-type woods). However, from ca. 2980–2700 cal BP their pollen representations fell below 1% too. The development of shrubs and understory trees (*Sorbus aucuparia*, *Populus* cf. *tremula*, *Salix*, *Frangula alnus*, *Rhamnus catharticus*, *Viburnum opulus*) in response to forest felling was followed by progressing expansion of birch woods and pine woods, depending on habitat situation. In pine stands some contribution of *Quercus* might have persisted. The alderwoods remained then as the only forest communities that were not heavily devastated.

Around 2450 cal BP a sharp peak of *Betula* pollen close to 40% (nearly doubled pollen influx – Fig. 8.23) expresses a fast expansion of pioneer woods on abandoned lands due to the economic breakdown (G1/87-subzone 9c; T1/90-TB-12a). This process lasted no more than ca. 100 yr and was followed by a forest succession involving first of all *Carpinus*, then *Quercus*, to a lesser degree *Alnus* and *Fraxinus*, and only very slightly *Ulmus*, *Corylus*, and *Fagus*. This regeneration cycle was completed within ca. 350 yr. It exemplifies extremely well Faliński's hypothesis (1986, 1993) about the secondary succession on abandoned fields and pastures on the former habitats of *Carpinus*-dominated mixed deciduous woods. This assumes that the full cycle of such succession going through the stage of pioneer light-seed trees like *Betula* and *Populus tremula* would bring about the regeneration of stabilized *Carpinus*-dominated wood within ca. 350 yr. However, the deciduous woods could not anymore regain their area from the initial part of the zone (3700–3300 cal BP), as especially concerns *Carpinus* (max. 13%). The pinewoods became then the absolutely dominant forest community.

A very similar successional pattern was later repeated once again (G1/87-subzone 9d; T1/90-part of TB-subzone 12b). The intensive settlement activities during the time span 1950–ca. 1650 cal BP (AD 1–300) resulted in the consecutive devastation of deciduous woodstands, this time on both fresh and humid to wet habitats (*Carpinus* decline to ca. 4%, *Alnus* to ca. 10%, *Fraxinus* and *Ulmus* below 1%). The economic breakdown, happening around 1650 cal BP (between AD 235–350; G1/87-subzone 9e; T1/90-end of TB-12b, TB-13a), released a new tree succession, starting with a short-lasting colonization of abandoned fields and pastures by birch and leading to a massive reproduction of *Carpinus*-dominated woods, which reached their maximum Holocene development in the region (ca. 25% in G1/87 profile) around 1240 cal BP (AD 710). Those woodstands were probably located in some distance from the lake, possibly e.g. to the east of

Lake Wierzchoń, where a belt of *Tilio-Carpinetum* woods is preserved today (Kępczyński & Noryskiewicz, Chapter 3.7). Around the lake *Carpinus* populations were probably not so well developed: the maximum pollen percentages of *Carpinus* are then 16 % in the centre of Tobyłka Bay (T1/90, Fig. 8.26) and only ca. 5% in the adjacent kettle-hole mire (Demske 1995).

The structure of *Carpinus* forests at that time might have been of the type proposed by Tobolski (1990, 1991) as the historical primeval form of hornbeam woods growing in Greater Poland between ca. 3400 to 1650 ¹⁴C BP, but not occurring in Poland anymore: in such woods *Carpinus* would form the highest tree layer and canopy, the contribution of other deciduous trees would be insignificant, and, particularly, very few *Corylus* would be in the wood understory.

During this whole transformation time the *Quercus* pollen percentages remain very stable at slightly over 10%, suggesting the occurrence of scattered old oak trees, exposed and well flowering. They produced pollen in rather even amounts over a large area and were rather independent from local vegetation changes. A fairly high and stable influx of *Quercus* pollen (Fig. 8.23) speaks for such an explanation too. It seems clear that the pollen record obtained from the central lake core reflects the regional changes in forest composition.

The disappearance of any limnophyte taxa except for *Potamogeton* S. *Eupotamogeton* from ca. 3500 cal BP until the end of zone and then the reduced frequencies of telmatophytes from ca. 3000 cal BP observed in the profile from the lake centre, may suggest some rise of water level. The increase in the pelagial taxa of Cladocera between 3000 and 2000 cal BP (Szeroczyńska, Chapter 8.4) speaks also for a rather high lake level. The following gradual lowering of water level, rising eutrophication and changes in sediment chemical composition (Więckowski et al., Chapter 5.1, Łacka et al., Chapter 8.2, Szeroczyńska, Chapter 8.4) did not find any expression in the record of limnophyte/telmatophyte vegetation at the lake centre. Also the sedimentation rates, rising distinctly in the Tobyłka Bay (T1/90 core) already from the decline of subzone 10a (ca. 4000 cal BP, Fig. 8.28), in the core from the lake centre remain stable till the end of zone.

***Pinus*-NAP (G1/87-10; 1075(820) – -35 cal BP), (TB-13b – TB-14a,b; 975 – -35 cal BP)**

The top pollen zone, covering approximately the last 1000 yr, records the drastic environmental changes progressing in the study region governed main by human activity. The sediment accumulation rates rise then also significantly in the G1/87 profile from the central lake deep (Figs 8.27, 8.28). The economic development of the area generally increased after the foundation of Polish State in AD 966, but later it oscillated in connection with the pro-

gress of historical events and changing settlement. Unfortunately this uppermost part of profile G1/87 suffers from deficient sampling resolution. Still two main stages of environmental history in the Lake Gościąg area can be roughly seen in the record of the last ca. 1000 yr.

The lower spectra of subzone G1/87–10a (ca. AD (875) 1130–1490), register the end of a rather short (a couple of hundred yr) episode of animated economic activities in the region including *Carpinus* felling and increase of acreage of open land used by man and then left abandoned and exposed to the secondary succession (increase of *Pteridium*, *Calluna*, *Betula*), (see Chapter 9.1.3). This episode was probably followed by a time (ca. 150 yr) of a more reduced settlement, when the still remaining hornbeam woods stabilized or even slightly regenerated (*Carpinus* ca. 7%), and *Populus tremula* and *Alnus* regained their habitats on wetter abandoned grounds around the lake. The lands used economically shrank then (NAP around 10%). Percentages of *Quercus* pollen remained stable for more than 1600 yr at a level slightly exceeding 10%, expressing the presence and good flowering of oak trees probably protected in the lake region. The other deciduous trees (*Fraxinus*, *Tilia*, *Ulmus*) were scattered as minor contribution to the existing deciduous wood fragments and include also single *Fagus* specimens. *Taxus* and *Hedera* reappear in their understory.

The top zone of the diagram subzone G1/87–10b (AD 1490–1985), from the Late Medieval Period to recent time records the final devastation of natural pattern of forest communities in the region. The pine woods were left as the only meaningful forest community, deciduous woods with hornbeam were reduced to small fragments, and alderwoods were heavily destroyed. Oak remained as the only deciduous tree of any importance. The anthropogenic changes of vegetation during this time are described in details in Chapter 9.2.4.

8.4. THE HOLOCENE CLADOCERAN SUCCESSION IN THE LAMINATED SEDIMENTS OF LAKE GOŚCIAŻ

Krystyna Szeroczyńska

In Poland an analysis of Cladocera from sediments accumulated during the Holocene was made for lowland lakes, such as Wigry and Wiżajny (Czeczuga et al. 1970, Czeczuga & Kosacka 1977), Jeziorak and Gopło (Bilska & Mikulski 1979, Mikulski 1977), Strażym (Błędzi 1987), Woryty, Błędowo, Skrzetuszewskie, Suszek (Bińska et al. 1991, Szeroczyńska 1985, 1991), Biskupin (Szeroczyńska 1995), and for mountain lakes, such as Przedni and Zadni Staw in the Tatra Mts. and Mały and Wielki Staw in the Karkonosze Mts. (Szeroczyńska 1984, 1993a). Studies are now being carried out on lakes Kortowo (Z. Niewiadomski), Giecz, Tłokowo (I. Polcyn), to