

Fig. 7.15. A – SEM photograph of core slice of varved sediment. Thick laminae produced by diatoms blooms are periodically interlayered with thin laminae of carbonates. Bar scale = 100 μm . B – SEM photograph of white lamina consist of subsequential, seasonal diatom layers of various genera. Bar scale = 10 μm . C – SEM photograph of beige lamina showing fine crystals and aggregates of carbonates. The barite twins visible at the arrow mark. Bar scale = 10 μm . D – EDS spectrum of the carbonate layer. Carbonate aggregates are enriched in Mn and contain small admixture of Fe and traces of Ba.

ters as well as the Mn enrichment suggest an oligotrophic stage of the lake evolution during the Younger Dryas.

7.4. LATE-GLACIAL VEGETATION HISTORY RECORDED IN THE LAKE GOŚCIAŻ SEDIMENTS

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This chapter presents the development of Late-Glacial vegetation in the NW part of the Gostynińskie Lake District in central Poland. The lakeland is located on the

western side of Vistula valley in its middle course, in the depression called Płock Basin, which was filled by the southernmost ice lobe during the maximum extent of the Vistulian Glaciation (Churski, Chapter 2.1).

The reconstruction of vegetation history is based on palynological and partly also on plant-macrofossil investigations of the Lake Gościąg sediments. The annual lamination of these sediments covers altogether nearly 13,000 yr (Ralska-Jasiewiczowa et al. 1987, Goslar, Chapters 6, 7.2). The best developed laminae occur in the deepest parts of the lake, but they reach only as far back as the latter part of the Late-Glacial. The records of ear-

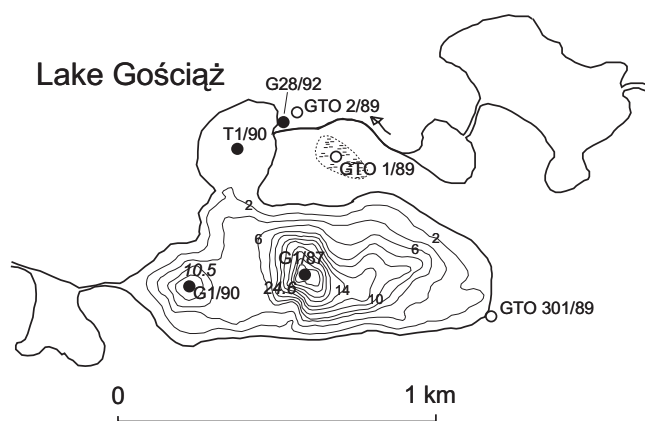


Fig. 7.16. Map of Lake Gościąż showing the location of profiles discussed in this paper (black dots), and other Late-Glacial profiles investigated by means of pollen and plant macrofossil analyses (white dots) (Demske 1995).

lier stages of the Late-Glacial have been found in the deposits from shallower and marginal parts of the lake, which are not varved or are varved in their younger parts only.

All the explanations concerning the core collection, sediment sampling, laboratory treatment, pollen counting, and construction of pollen diagrams are described in Chapter 4.6.1 jointly for all chapters discussing the results of palynological studies.

The development of vegetation during the Late-Glacial is traced in 7 sediment profiles. Two represent lake deeps: central deep (G1/87) investigated by Ralska-Jasiewiczowa and van Geel and western deep (G1/90) – by Ralska-Jasiewiczowa alone; and five come from its marginal zones: the centre of northern Tobyłka Bay (T1/90), eastern shore of bay (G28/92, GTO2/89), neighbouring kettle-hole mire (GTO 1/89), and eastern shore of main lake basin (GTO 301/89), all investigated by Demske (1995) (Fig. 7.16). The full results of Demske's studies aiming to reconstruct the history of local vegetation and water-level changes are discussed more thoroughly in a separate paper (Demske 1995). In this chapter two of his profiles (G28/92 and T1/90) are used, to give material for the presentation of the full sequence of Late-Glacial events found at Lake Gościąż site*.

Sediment description

The differentiated lithology of profiles investigated by Demske was described in detail by the Troels-Smith (1955) system (Demske 1995). In this paper a shortened

description of the Late-Glacial sediments is presented together with a simplified description of their Holocene part (in square brackets).

Profile G28/92

[0–3.40 m – subsequently: swamp peat, calcareous detritus gyttja, sand, drift peat];

3.40–4.17 m – calcareous detritus gyttja to marl gyttja with traces of microlaminae;

Transition to Late-Glacial at 4.17 m:

4.17–4.45 m – lake marl, traces of laminae;

4.45–4.67 m – calcareous fine-detritus gyttja, slightly silty, weak laminae;

4.67–4.74 m – medium-coarse sand with fine gravel;

4.74–4.85 m – fine-medium sand with humus and root fragments with some coarser sand and gravel at 4.82–4.85 m;

4.85–5.20 m – fine-medium sand with some fine plant detritus.

Profile T1/90

[0–8.36 m – calcareous detritus gyttja, in lower part periodical traces of laminae, for more details see Chapter 8.3];

8.36–14.10 m – calcareous ferruginous gyttja, with differentiated lamination periodically disturbed or disappearing, and some massive layers;

Transition to the Late-Glacial around 13.57 m indicated by thinning of laminae:

14.10–14.17 m – calcareous gyttja with detritus and sand, indistinct microlamination, iron content disappearing and silt content increasing downwards;

14.17–14.25 m – silty to coarse sand with humus and some gyttja; plant detritus and macrofossils;

14.25–14.33 m – brownmoss peat (mostly *Drepanocladus* and *Calliergon*) slightly decomposed, with some sand and fine gravel;

14.33–14.67 m – fine sand with some humus and plant detritus.

Profile G1/87

[0–12.70 m – calcareous ferruginous laminated gyttja; in upper part lamination periodically disturbed or disappearing; for more details see Chapter 8.1 and 8.3];

12.70–15.20 m – calcareous ferruginous gyttja regularly laminated with a high content of Fe₂O₃ (up to 18%), increased content of mineral residuum and a few massive mineral layers;

Transition to the Late-Glacial at 15.20 m:

15.20–16.28 m – calcareous ferruginous gyttja regularly laminated with increased content of non-carbonate mineral matter;

16.28–16.88 m – layer of sand;

16.88–17.04 m – calcareous ferruginous gyttja, regu-

* We have to apologize for a somewhat heterogenous graphic form of pollen diagrams counted by M. Ralska-Jasiewiczowa & B. van Geel and D. Demske, presented in the chapters on the Late-Glacial and Holocene. The diagrams were produced in different places (Gliwice and Berlin) by means of different programs (POLPAL for Windows and TILIA), and bringing them to the complete uniformity appeared too complicated and time-consuming.

larly laminated, content of mineral matter decreasing downwards.

Profile G1/90

[0–11.04 m – calcareous ferruginous gyttja with peridical lamination];

11.04–14.725 m – calcareous ferruginous gyttja with increased content of mineral matter in the lower part; thin regular lamination, periodically slightly thicker;

Transition to the Late-Glacial around 13.54 m:

14.725–14.78 m – silty gyttja with humus streaks, and plant detritus; increasing iron content at top;

14.78–14.87 m – calcareous silty gyttja;

14.87–14.92 m – strongly humified peat;

14.92–14.93 m – very fine silt.

Description of local pollen assemblage zones

All the pollen diagrams were subdivided by numerical methods. For profiles G28/92 and T1/90 the CONISS dendrograms were used (Demske 1995) according to the TILIA program (Grimm 1987, 1992); for profiles G1/87 and G1/90 the POLPAL ZONATION program (Walanus & Nalepka 1996) as well as Principal Component Analysis (PCA) (Fig. 7.23) were applied. However, because of strong fluctuations in *Pinus* and *Betula* pollen, not all boundaries shown by numerical analyses could be accepted, and the assistance of traditional division of pollen diagrams was necessary.

The shortened descriptions of local pollen assemblage zones are presented in tables. The descriptions of full Late-Glacial profiles (G28/92 and T1/90) are compared in Tab. 7.1, and those of laminated Late-Glacial profiles G1/87 and G1/90 in Tab. 7.2.

Table 7.1. Profiles from the northern lake bay (p.c. = pollen concentration).

Profile G28/92 E shore of northern lake bay (Fig. 7.17)	Profile T1/90 Central part of northern lake bay (Fig. 7.18)
TG-1 Cyperaceae-Gramineae (5.00–4.87 m) Dominant Gramineae (max. 23%) and Cyperaceae (max. 28%); <i>Pinus</i> up to 37% and <i>Betula</i> up to 9%. Significant <i>Betula nana</i> -t., <i>Hippophaë rhamnoides</i> , <i>Artemisia</i> , Chenopodiaceae, <i>Helianthemum nummularium</i> -t., and <i>Saxifraga oppositifolia</i> -t. pollen. P. c. extremely low	TB-1 (below 14.38 m) – no countable pollen record from bottom sand was available
TG-2 <i>Hippophaë-Betula nana</i> -t. – <i>Salix</i> (4.87–4.71 m) Max. of <i>Hippophaë</i> , <i>Betula nana</i> -t., and <i>Salix</i> (<i>S. glauca</i> -t., <i>S. polaris</i> -t., <i>S. herbacea</i> -t.) pollen, abundant <i>Schoenus</i> -t., <i>Equisetum</i> , <i>Hippophaë</i> hairs (max. 41%) and <i>Glomus</i> cf. <i>G. fasciculatus</i> chlamydo spores (max. 96%). P. c. very low. Subzones: TG-2a (4.87–4.79 m) – high <i>Pinus</i> (max. 54%), low <i>Betula</i> (max. 16%), rising <i>Betula nana</i> -t. (max. 5.6%), decreasing Gramineae and Cyperaceae, high <i>Salix glauca</i> -t. (2.6%) and <i>S. polaris</i> -t. (2.8%) pollen. <i>Juniperus</i> , <i>Larix</i> and <i>Populus tremula</i> -t. present. TG-2b (4.79–4.74 m) – max. of <i>Hippophaë</i> (29.3%), <i>Tofieldia</i> (3.8%) and <i>Taraxacum</i> -t. (1.3%). TG-2c (4.74–4.71 m). – a layer of sand with gravel with extremely low, uncountable pollen frequency.	TB-2 <i>Hippophaë-Betula nana</i> -t. – <i>Salix</i> (14.38–14.24 m) High <i>Hippophaë</i> , Cyperaceae, and Gramineae, significant <i>Betula nana</i> -t., <i>Salix glauca</i> -t. and <i>S. polaris</i> -t. pollen. Frequent <i>Equisetum</i> , <i>Glomus</i> (max. 22%). P. c. very low. Subzones: TB-2a (14.38–14.33 m) – high <i>Pinus</i> (53%) and low <i>Betula</i> (8–22%), <i>Betula nana</i> -t. around 2% and <i>Salix polaris</i> -t. up to 2%, significant <i>Populus tremula</i> ; <i>Tofieldia</i> and <i>Dryas</i> pollen present, <i>Taraxacum</i> -t. 2.7%. TB-2b (14.33–14.31 m) – <i>Hippophaë</i> peak (one spectrum) up to 17.8% (<i>Hippophaë</i> hairs 6.8%), <i>Schoenus</i> -t. up to 3%. TB-2c (14.31–14.24 m) – <i>Pinus</i> 23–37%, <i>Betula</i> up to 32%, <i>Hippophaë</i> (3.8–1.5%), <i>Salix glauca</i> -t. (4.8%), <i>Filipendula</i> present. Max. of Gramineae (17%), Cyperaceae (18%), <i>Schoenus</i> -t. (33%) and <i>Scirpus lacustris</i> -t. (6.4%). <i>Cladium mariscus</i> and <i>Typha latifolia</i> appear. At 14.33–14.25 m – 12,720±500 ¹⁴ C BP.
TG-3 <i>Artemisia-Chenopodiaceae-Gramineae</i> (4.71–4.67 m) One spectrum: High <i>Pinus</i> (53%), low <i>Betula</i> (13%), max. of <i>Artemisia</i> (9.2%) and Gramineae (13%); presence of <i>Myriophyllum spicatum</i> and <i>M. alterniflorum</i> .	TB-3 <i>Pinus-Artemisia</i> (14.24–14.19 m) High <i>Pinus</i> (around 50%), <i>Betula</i> down to 26%, rise of <i>Artemisia</i> (ca. 2%), decrease of all <i>Salix</i> and all Cyperaceae pollen types.
TG-4 <i>Pinus-Betula</i> (4.67–4.52 m) Very high <i>Pinus</i> (58–77%), low <i>Betula</i> (20–29%), reduced <i>Salix</i> types. <i>Artemisia</i> low (1%), <i>Cladium mariscus</i> present.	TB-4 <i>Pinus-Betula</i> (14.19–13.94 m) High increasing <i>Pinus</i> (41–68%), lower <i>Betula</i> (20–35%), substantial then decreasing <i>Juniperus</i> (3.6–0.3%), <i>Artemisia</i> up to 2%. <i>Filipendula</i> and <i>Cladium</i> present.

Table 7.1. Continued.

Profile G28/92 E shore of northern lake bay (Fig. 7.17)	Profile T1/90 Central part of northern lake bay (Fig. 7.18)
Subzones: TG-4a (4.67–4.61 m) – <i>Pinus</i> max. 77%, declining <i>Juniperus</i> , <i>Betula nana</i> -t., Gramineae (4.2%), Cyperaceae (2.0%). Rapid rise of p. c.	Subzones: TB-4a (14.19–14.11 m) – <i>Pinus</i> below 50%, rising <i>Juniperus</i> (to 3.6%); <i>Hippophaë</i> , <i>Betula nana</i> -t. significant, Gramineae up to 10%, Cyperaceae up to 8.6%. <i>Filipendula</i> sporadic. Small rise of p. c.
TG-4b (4.61–4.52 m) – rising <i>Betula</i> to 29%, decreasing <i>Pinus</i> to 58%, increased <i>Betula nana</i> -t. and Gramineae, <i>Filipendula</i> continuous. Reduced <i>Juniperus</i> , Cyperaceae. P. c. lower.	TB-4b (14.11–13.94 m) – dominating <i>Pinus</i> (52–68%), rising <i>Betula</i> (20–35%); decreasing <i>Betula nana</i> -t., <i>Juniperus</i> , Gramineae, Cyperaceae; disappearing <i>Hippophaë</i> , <i>Salix polaris</i> -t. Continuous <i>Filipendula</i> (around 0.6%). Rising p. c.
TG-5 <i>Pinus-Juniperus</i> (4.52–4.16 m) High <i>Pinus</i> (to 70%) and low <i>Betula</i> (<20%). Rising <i>Juniperus</i> (to 3%), <i>Artemisia</i> (to 5.5%) and Chenopodiaceae (below 1%). <i>Filipendula</i> sporadic. <i>Scirpus lacustris</i> -t. and <i>Schoenus</i> -t. continuously present. P. c. slowly decreasing throughout both subzones.	TB-5 <i>Pinus-Juniperus</i> (13.94–13.57 m) High <i>Pinus</i> (around 65%), and low <i>Betula</i> (10–20%). Rising <i>Juniperus</i> (to 12%), <i>Artemisia</i> (to 5.8%). and Chenopodiaceae. <i>Filipendula</i> reduced. <i>Schoenus</i> -t. and <i>Scirpus lacustris</i> -t. frequent. P. c. strongly decreasing.
Subzones: TG-5a (4.52–4.37 m) – <i>Juniperus</i> , <i>Betula nana</i> -t. and Chenopodiaceae at max., <i>Artemisia</i> rising, <i>Saxifraga oppositifolia</i> -t. present.	Subzones: TB-5a (13.94–13.77 m) – rising <i>Betula nana</i> -t. (up to 1.5%), max. values of <i>Juniperus</i> , <i>Artemisia</i> , and Chenopodiaceae. P. c. rapidly decreasing.
TG-5b (4.37–4.16 m) – decreasing <i>Juniperus</i> and Chenopodiaceae; <i>Artemisia</i> at max. then declining, increasing Cyperaceae. Gramineae maximum (26%) at the zone top.	TB-5b (13.77–13.57 m) – <i>Juniperus</i> , <i>Betula nana</i> -t., <i>Artemisia</i> , Chenopodiaceae declining, <i>Saxifraga oppositifolia</i> -t. present. <i>Betula</i> increasing at top. Low p. c., rises upwards.
TG-6 (initial part) <i>Betula-Gramineae-Filipendula</i> (4.16–... m) Decrease of <i>Betula nana</i> -t., <i>Juniperus</i> and <i>Artemisia</i> , gradual rise of <i>Betula</i> (up to 35%), and first <i>Ulmus</i> pollen; rise of <i>Filipendula</i> , <i>Urtica</i> , Gramineae. <i>Typha latifolia</i> and <i>Nymphaea alba</i> appear. Rapid rise of p. c.	TB-6 (initial part) <i>Betula-Populus-Ulmus(-Filipendula)</i> (13.57–... m) Decrease of <i>Juniperus</i> , <i>Salix glauca</i> -t., <i>Artemisia</i> , rise of <i>Populus</i> , <i>Filipendula</i> , <i>Urtica</i> and Gramineae followed by rise of <i>Betula</i> and appearance of <i>Ulmus</i> , <i>Typha latifolia</i> and <i>Nuphar</i> . Rapid rise of p. c.

Table 7.2. Profiles from the lake deeps (p. i. = pollen influx, ss. = pollen samples).

Profile G1/87 – central lake deep (Fig. 7.20)	Profile G1/90 – western lake deep (Fig. 7.21)
G1/87–1 ¹ <i>Pinus-Betula-Filipendula</i> (17.04–16.92 m, ss. 1–26) Dominant <i>Pinus</i> (to 50–60%), <i>Betula</i> (to 35–47%); substantial <i>Populus</i> (max. 1.8%) and <i>Betula nana</i> -t. (max. 1.3%). <i>Juniperus</i> and <i>Salix</i> types continuous. Gramineae ca. 3%, Cyperaceae ca. 2%, <i>Filipendula</i> ca. 1% to 0.1% at zone top. <i>Typha latifolia</i> , <i>Cladium mariscus</i> , <i>Nuphar</i> present. P. i. moderate, decreasing.	G1/90–1 ² <i>Pinus-Betula-Filipendula</i> (-Cyperaceae-Gramineae) (14.92–14.69 m, ss. 2–19) Dominant <i>Pinus</i> (60–70%), low <i>Betula</i> (10–20%) to ca. 30% at zone top. <i>Salix</i> ssp. and <i>Betula nana</i> -t. significant. <i>Populus</i> appear. Cyperaceae (18%) and Gramineae (10%) form peaks, <i>Filipendula</i> continuous, <i>Nuphar</i> present. P. i. fluctuating.
G1/87–2 ³ <i>Juniperus-Artemisia-Chenopodiaceae-Salix</i> (16.92–15.82 m, ss. 28–71) <i>Juniperus</i> max. in the middle (15%) and top (18%) parts of zone. <i>Betula</i> around 20%. <i>Betula nana</i> -t., <i>Salix</i> diff. types incl. <i>Salix polaris</i> -t. substantial; <i>Artemisia</i> , Gramineae, Cyperaceae all up to 8–10%, Chenopodiaceae up to 2%. Many Late-Glacial heliophytes present. <i>Scirpus lacustris</i> -t. and <i>Typha latifolia</i> sporadic. P. i. low, decreasing.	G1/90–2 <i>Juniperus-Artemisia-Chenopodiaceae-Salix</i> (14.69–14.41 m, ss. 23–45) <i>Betula</i> up to 20%. Increasing <i>Juniperus</i> (1.5-over 10%), and <i>Betula nana</i> -t. (1–3.5%), <i>Salix glauca</i> -t. and <i>S. polaris</i> -t. substantial. Gramineae rise to ca. 10%, <i>Artemisia</i> to 8%, Chenopodiaceae at ca. 2%. <i>Filipendula</i> and numerous Late-Glacial heliophytes present. <i>Typha latifolia</i> sporadic. P. i. fluctuates, decreasing.
G1/87–3 <i>Betula-Artemisia</i> (15.82–15.19 m, ss. 72–83) Increased <i>Betula</i> and decreasing <i>Juniperus</i> , reduced Gramineae and Cyperaceae. P. i. slowly increasing.	G1/90–3 <i>Betula-Artemisia</i> (14.41–14.05? m, ss. 47–88) Slowly rising <i>Betula</i> , decreasing <i>Betula nana</i> -t., <i>Juniperus</i> , and Gramineae. P. i. increases, then fluctuates.

Table 7.2. Continued.

Profile G1/87 – central lake deep (Fig. 7.20)	Profile G1/90 – western lake deep (Fig. 7.21)
Subzones: G1/87–3a (ss. 72–77) – <i>Juniperus</i> falling from 17 to 3%, reduced <i>Betula nana</i> -t. (<1%); significant <i>Salix polaris</i> -t. Many Late-Glacial heliophytes. <i>Nymphaea candida</i> and three <i>Myriophyllum</i> spp. present. G1/87–3b (ss. 78–83) – <i>Betula</i> and <i>Betula nana</i> -t. at max. (47%; 3%) in the middle of subzone, then falling. <i>Juniperus</i> reduced to ca. 1.5%, <i>Salix polaris</i> -t. <0.3%, and Chenopodiaceae <0.5% with small max. at subzone top, where Gramineae and Cyperaceae rise and <i>Hippophaë</i> reappears. <i>Artemisia</i> decreases gradually.	Subzones: G1/90–3a (ss. 47–“125” ⁴) – decreasing <i>Juniperus</i> (from 8 to ca. 2%), <i>Betula nana</i> -t. (<1%), significant <i>Salix polaris</i> -t. and <i>S. glauca</i> -t., reduced <i>Artemisia</i> . Single <i>Dryas octopetala</i> and <i>Selaginella selaginoides</i> spores and numerous Late-Glacial heliophytes, <i>Myriophyllum</i> spp. present. G1/90–3b (ss. “125” ⁴ –88) – <i>Betula</i> at max. (32%), in the middle of subzone. Falling <i>Salix glauca</i> -t., <i>Juniperus</i> (below 1%), Chenopodiaceae (below 0.5%), <i>Artemisia</i> (to 1%). <i>Salix polaris</i> -t. and some heliophytes disappear at zone top. Cyperaceae higher than in 3a.
G1/87–4 (initial part) <i>Betula-Populus-Ulmus</i> (15.19–... m, ss. 84–...) Rapid falls of <i>Betula nana</i> -t., <i>Juniperus</i> , <i>Artemisia</i> , Chenopodiaceae. <i>Betula</i> at 26–46%, <i>Populus</i> increases (2–3%), then <i>Ulmus</i> appears. Gramineae over 10%, rising <i>Filipendula</i> , <i>Urtica</i> , <i>Equisetum</i> , reappearing <i>Typha latifolia</i> . Rise of p. i.	G1/90–4 (initial part) <i>Pinus-Betula-Filipendula</i> (14.05–... m, ss. “157”–... ⁴) Falls of <i>Betula nana</i> -t., <i>Juniperus</i> , <i>Artemisia</i> , Chenopodiaceae. <i>Betula</i> 12–32%, <i>Ulmus</i> appears, reappearance of <i>Populus</i> , rise of Gramineae, <i>Filipendula</i> , <i>Urtica</i> , <i>Scirpus lacustris</i> -t., <i>Typha latifolia</i> , <i>Cladium mariscus</i> , <i>Equisetum</i> . Rapid rise of p. i.

¹ In the profile G1/87 from central lake deep (Fig. 7.20) the zone G1/87–1 has a lithological lower boundary at the beginning of laminated gyttja sediment, which does not correspond with the successional beginning of zone.

² In the profile G1/90 from the western lake deep (Fig. 7.21) the G1/90–1 zone is mostly contained in non-laminated sediment (transition from humified peat to gyttja), plus 40 bottom laminae.

³ In the zone G1/87–2 between ss. 35 and 36 a layer of sand ca. 60 cm thick contains mixed pollen spectra with rebedded pollen (Ralska-Jasiewiczowa et al. 1992). These spectra are not described in the table, but they are plotted in Fig. 7.25.

⁴ The inconsistency in sample numbering results from the overlapping of core segments found by Goslar (Chapter 7.2) after the sampling and pollen counting had been performed (see Fig. 7.21).

Vegetation and lake history

Corings evidence the existence of at least four dead-ice hollows that together formed Lake Gościąg basin *s. str.*, and the fifth adjoining smallest kettle-hole which is filled today by a mire (Starkel et al., Chapter 7.1, Demske 1995). The location of oldest sediments found illustrates the rule that melt-out processes advanced earlier in the smaller hollows, where the dead-ice blocks were not so voluminous and possibly not buried so very deep. This is the case for the northern basins.

The vegetational succession during the earlier stages of the Late-Glacial up to the middle Allerød is based on data from two profiles representing the northern small bay-part of recent Lake Gościąg (Figs 7.17, 7.18). Such a location certainly brings a record of much more local changes than found in profiles from central parts of the lake representing predominantly the regional pollen inflow. This reservation is most meaningful for the times when the lake was completely formed and surrounded by a rather closed forest cover. However, also during the periods of rather open vegetation it has some consequences expressed, e.g., by better representation of macrofossils, and terrestrial microfossils (e.g. *Glomus* cf. *G. fasciculatus*) in the sediment.

The profiles from lake deeps include the later part of

Late-Glacial only. However, due to the higher sediment accumulation rates and increased sediment thickness, the records of vegetational changes are here more developed (see Fig. 7.24). The correlation of pollen assemblage zones and subzones distinguished in all four profiles is presented in Tab. 7.3.

The interpretation of older pollen assemblage zones (from Cyperaceae-Gramineae till *Pinus-Betula* subzone a, Figs 7.17 and 7.18) is based exclusively on Demske investigations (1995) and his original paz's numbering has been preserved.

Cyperaceae-Gramineae paz (TG-1); supposed early part of Oldest *Dryas* chronozone

This oldest zone documents the time when the dead-ice melting just began in the small depressions on the northern side of present lake in the area occupied today by the inlet of the Ruda stream into the northern lake bay. The material accumulating was sand with fine gravel and little organic matter, partly rebedded. The AP/NAP ratio <50% suggests treeless vegetation *in situ* (Ruffaldi 1994). Gramineae and Cyperaceae communities with *Betula nana* shrubs dominated on humid places, and pioneer open-ground flora with prominent *Artemisia* and Chenopodiaceae and with *Botrychium*, *Helianthemum* spp. and

Lake Gościąg – Tobyłka Bay Profile G 28/92 – bay margin

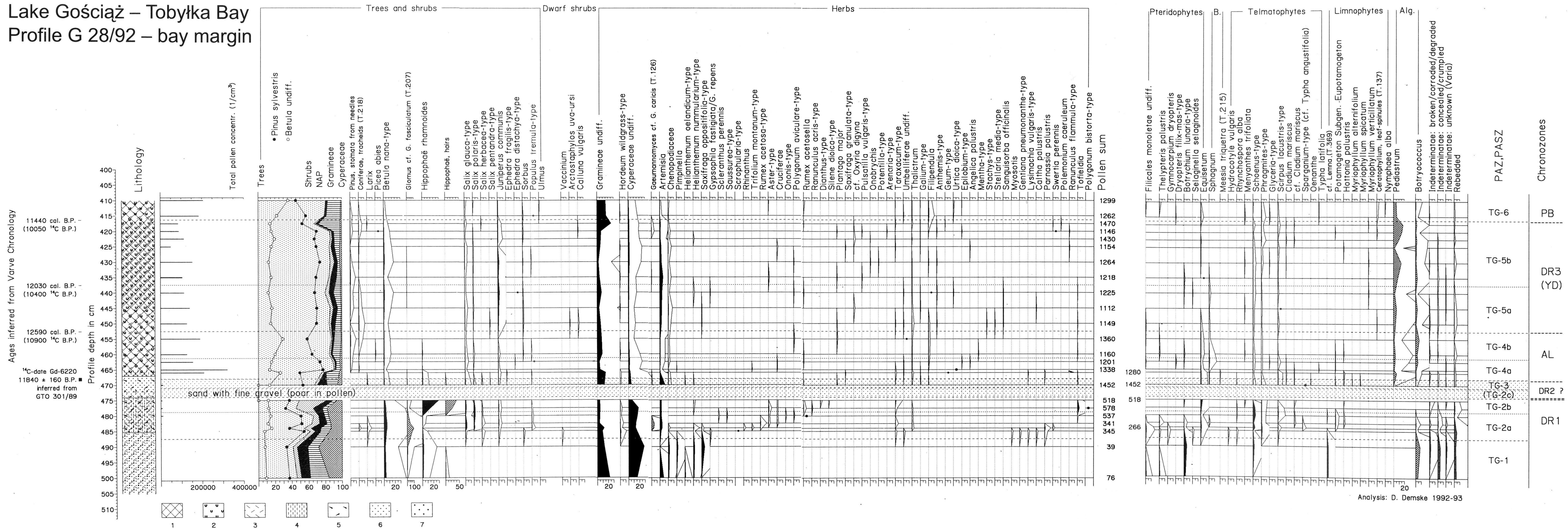


Fig. 7.17. Lake Gościąg, Tobyłka Bay, profile G28/92, Late-Glacial part – complete percentage pollen diagram. ● – sporadic taxa found beyond the counted pollen sum; 1 – detritus gytija; 2 – marl; 3 – fine detritus; 4 – humus; 5 – coarse detritus; 6 – sand; 7 – fine gravel; B – Bryophytes; Alg. – Algae.

Saxifraga ssp., colonized drier unstable soils. Shrubs of *Hippophaë*, *Salix* and *Juniperus* were scattered in the landscape. The poor pollen frequency restricts any more detailed interpretation.

***Hippophaë-Betula nana-Salix* paz (TG-2, TB-2); supposed late Oldest Dryas and Bølling chronozones**

The next stage of vegetational development, described as one zone with three subzones (2a, b, c), reflects the sequence of profound environmental changes though recorded in a very shortened form.

In its initial part, sand with a substantial content of humus was deposited at the bay margins (G28/92). The humus was probably inwashed from soils formed under the shrub vegetation on humid habitats around the incipient basin. The silty sand accumulating in the centre of the bay basin contained, besides organic matter eroded from the basin margins, also some autochthonous limnic sediment, as evidenced first by algal flora (*Botryococcus*, *Zygnema*-type, *Gloeotrichia* type, *Spirogyra* type) (Demske 1995, see van Geel 1978, van Geel et al. 1981, 1983, 1989). Later the subaquatic brownmoss peat consisting mostly of *Drepanocladus* and *Calliergon* species (Fig. 7.19) was formed in the still shallow bay depression (profile T1/90). It was slightly decomposed and it split into layers inclined in the profile ca. 30°, which may indicate still active melting processes (thermokarst?) following its formation. In the marginal G28/92 profile a layer of sandy humus correlative with this peat by the *Hippophaë* pollen maximum was cut by the inwash of sand with gravel. The brown moss peat at the bay centre was also covered by sand with gravel, penetrating its top section, but as the palynological records show, it happened later than at the bay margin.

***Betula nana-Salix* pasz (TG-2a, TB-2a); supposed late Oldest Dryas chronozone**

The vegetation surrounding the lake was initially open, but later the participation of shrubs, and finally also of trees gradually increased. The herb communities with dominant *Artemisia* contained Chenopodiaceae, *Helianthemum* ssp., *Saxifraga oppositifolia* -t. ssp., *Salix herbacea* -t. ssp., *Gypsophila fastigiata*, and on sandy places *Rumex acetosella*, *Scleranthus perennis* and *Polygonum aviculare*. The presence of large grass pollen of *Hordeum*-wild-grass type and *Hordeum* type (Beug 1961) coming probably from psammophilous grass species, may indicate abundant dune habitats. The fresh grassland and herb meadow communities on humid places were represented by *Ranunculus acris* -t., *Rumex acetosa* -t., *Gentiana pneumonanthe* -t., *Caltha*, *Lysimachia*, *Saussurea* -t., and other ecologically undefined pollen taxa. The local occurrence of sedge-dominated mires is confirmed by the presence of *Gaeumannomyces* cf. *G. caricis* hy-

phopodia (Demske 1995 and Fig. 7.18 this Chapter, Type 126 van Geel et al. 1989, Pals et al. 1980).

The shrub vegetation included *Salix glauca* -t., *Salix polaris* -t., *Juniperus*, *Hippophaë* and *Betula nana*. *Hippophaë*, *Dryas octopetala* and some Papilionaceae taxa represent a group of plants with the nitrogen-fixing nodules (Birks 1986). The presence of *Betula nana* is indicated by pollen and macrofossils and possibly also by numerous chlamydospores of fungus *Glomus* cf. *G. fasciculatus* (Type 207 van Geel et al. 1989, Walter & Breckle 1983) which is an indicator of local occurrence of birch in general. However, less probable is its origin from tree birches that possibly appeared already in the region (*Betula* undiff. pollen in TG-2a up to 15%, TB-2a up to 22%), but still sporadically on scattered sites. The other trees present in the area were *Populus* (*P. tremula* -t.), *Sorbus aucuparia*, and maybe *Larix*.

***Hippophaë* pasz (TG-2b, TB-2b); supposed Oldest Dryas/Bølling transition**

Further progress in the vegetational succession was characterized by the spread of *Hippophaë* and *Salix* shrubs and the appearance of birch trees *in situ* (*Betula* pollen up to 30%, nutlets of *Betula* sect. *albae*, Fig. 7.19).

The development of willow thickets is documented by increased percentages of all *Salix* pollen types and the presence of *Salix* twig fragments in the sediment.

The *Hippophaë* maxima in both profiles (G28/92 – 29.3%, T1/90 – 19.8%) accompanied by abundant hairs (41%, 6.8%) indicate its expansion in the close surroundings of the lake, suggesting the amelioration of climate and approach of forests.

The formation of plant assemblages of eutrophic mire type is documented by pollen of species belonging to *Caricetalia fuscae* (*Tofieldietalia*) order (like *Tofieldia calyculata*, *Parnassia palustris*, *Sweetia perennis*, and *Selaginella selaginoides*), typical today in Poland of mountain mires supplied by eutrophic neutral to alkaline waters. The similar or higher (up to 14%) frequencies of *Tofieldia* pollen as compared to those in G28/92 and T1/90 profiles were found in Late-Glacial profile from Niechorze (western Baltic coast, Ralska-Jasiewiczowa & Rzętkowska 1987) in *Hippophaë-Salix* paz preceding Allerød, where it is also accompanied by *Parnassia palustris* and *Selaginella selaginoides*.

***Salix-Hippophaë* pasz (TB-2c); supposed Bølling chronozone**

The following stage of vegetation development is recorded in T1/90 profile only. It covers here the brown moss-peat layer including its sandy top. In profile G28/92 the inwash of sand with gravel cutting through the *Hippophaë* maximum in the preceding pasz stopped the se-

Lake Gościaz
 – Tobyłka Bay
 Profile T1 /90

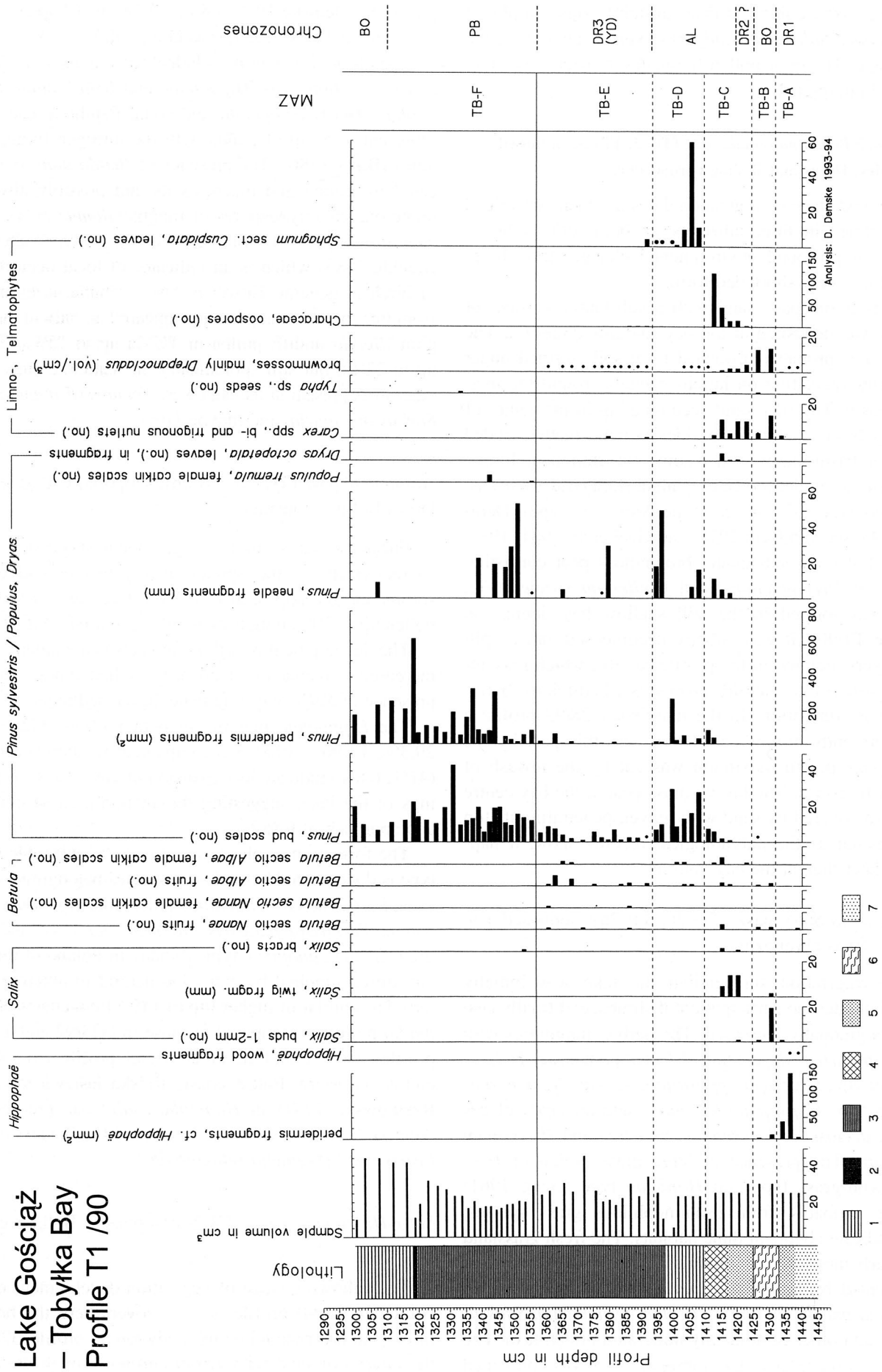


Fig. 7.19. Lake Gościaz, Tobyłka Bay, profile T1/90, Late-Glacial part – plant macrofossil diagram (data are recalculated for a 25 cm³ standard volume) – selected macrofossil taxa. ● – sporadic taxa; 1–7 –see explanations at Fig. 7.18.

Table 7.3. The correlation of pollen assemblage zones and subzones in particular cores.

Age cal BP	Chrono-zones	Profiles								Age 14C BP
		G 28/92		T 1/90		G 1/87		G 1/90		
		PAZ	PASZ	PAZ	PASZ	PAZ	PASZ	PAZ	PASZ	
11,000	PB	TG-6 <i>Bet-Gram-Fil</i>		TB-6 <i>Be-Pop-Ul</i>		G1/87-4 <i>Be-Pop-Ul</i>		G1/90-4 <i>Pin-Be-Fil</i>		9800
	YD	TG-5 <i>Pin-Jun</i>	TG-5b <i>Be-Art</i>	TB-5 <i>Pin-Jun</i>	TB-5b <i>Be-Art</i>	G1/87-3 <i>Be-Art</i>	G1/87-3b <i>B. nana</i>	G1/90-3 <i>Be-Art</i>	G1/90-3b <i>B. nana</i>	10,050
	TG-5a <i>Chen</i>		TB-5a <i>Chen</i>		G1/87-3a <i>Ju-Chen</i>		G1/90-3a <i>Jun</i>		10,320	
12,870 beg.lam.*	Al	TG-4 <i>Pin-Be</i>	TG-4b <i>Pin-Be-Fil</i>	TB-4 <i>Pin-Be</i>	TB-4b <i>Pin-Be-Fil</i>	G1/87-1 <i>Pin-Be-Fil</i>	G1/90-1 <i>Pin-Be-Fil</i> (Cyp-Gram)		10,930	
supposed cal BP 13,000			TG-4a Gram-Cyp		TB-4a <i>Be-Jun-B. nana</i>					
14,000	OD	TG-3 <i>Art-Chen-Gram</i>		TB-3 <i>Pin-Art</i>						11,800
	Bo	TG-2 <i>Hipp-B. nana-Sal</i>	no pollen	TB-2 <i>Hipp-B. nana-Sal</i>	TB-2c <i>Sal-Hipp</i>					12,000
	Ost D		TG-2b <i>Hipp</i>		TB-2b <i>Hipp</i>					
			TG-2a <i>B. nana-Sal</i>	TB-2a <i>B. nana-Sal</i>					13,000	
		TG-1 Cyp-Gram		non-countable						

* beg.lam. = beginning of lamination

dimentation of autochthonous limnic material (or eroded it away?) and left the deposit very poor in pollen, giving uncountable spectra.

The expansion of tree and shrub vegetation recorded during this phase included *Betula pubescens* (up to 32% pollen and abundant macrofossils of cf. *B. pubescens*), *Salix* species (*S. glauca* -t.), *Populus tremula*, and probably also *Pinus* (up to 37%, 1 budscale). The populations of *Hippophaë* became gradually reduced but were still substantial. The shrub communities on drier sites consisted also of *Juniperus* and *Ephedra* (*E. distachya* and *E. fragilis* -t.). The widespread open herb vegetation of rather xeric type contained *Artemisia*, *Chenopodiaceae*, *Helianthemum* ssp., *Plantago maritima* -t., *Sedum*, *Gypsophila fastigiata*, *Rumex acetosella*, psammophilous grass species of *Hordeum* -t., and *Hordeum* wild-grass t. The calciphilous *Selaginella selaginoides*, *Saxifraga oppositifolia* -t. and *S. granulata* -t. species, and dwarf willows of *Salix herbacea* -t. and *Salix polaris* -t. were still present. The acidiphilous *Ericaceae* dwarf shrubs (*Empetrum*, *Arctostaphylos*, and *Vaccinium* type) appeared, following the stabilization of humus soil. They formed together "assemblages of opportunistic plants with contrasting geographic and ecological affinities today grow-

ing..."on open immature base-rich or neutral mineral soils ... gradually stabilizing and accumulating humus in conditions of low competition and abundant light, space and time" (Birks 1986, p. 19), broadly known from early stages of Late-Glacial development of plant communities.

This vegetation type was clearly the remnant of more severe, rather dry and continental conditions. The coincident appearance of *Filipendula*, *Urtica* and increased frequencies of *Thalictrum*, *Umbelliferae*, and *Galium* -t. indicated the changes in herb communities (tall herbs) accompanying the expansion of forests because of improvement of climatic conditions. This change is also evidenced by the formation of hydrosereal pattern at the margins of incipient lakes. The algal populations of *Pediastrum* and *Botryococcus* colonized the open lake water where macrophytes like *Potamogeton* and *Ceratophyllum* appeared. The rich reedswamp zone formed around lake shores was composed of *Typha latifolia*, *Scirpus lacustris* -t., *Schoenus* -t., *Equisetum*, *Sparganium* -t., *Phragmites*, *Cladium mariscus*, and *Alisma*. The fen vegetation developing at places with lower water table was dominated by sedges (esp. *Carex rostrata*), with accompanying *Meyanthes*, *Hottonia*, and *Rynchospora alba*.

The stage described corresponds most probably to the Bølling chronozone, as is very roughly confirmed by the ^{14}C date of $12,720 \pm 500$ BP, coming from the brownmoss peat. The date, might still be too old because of the reservoir effect. The deposition of brownmoss peat in the incipient lake bay was interrupted by the inwash of sand with gravel, so a full sequence of vegetational changes belonging to that period is probably not recorded.

***Artemisia-Chenopodiaceae-Gramineae* paz (TG-3) and *Pinus-Artemisia* paz (TB-3); supposed Older Dryas**

During this zone the sand, initially with fine gravel and later with silt and organic matter, was deposited in the bay (T1/90) and at its margins (G28/92). Information about environmental changes in this period also comes from the sandy bases of other profiles studied by Demske (1995) where the sediment accumulation started at that time.

The rise of *Pinus* pollen up to more than 50% is supported by finds of budscales, wood, and needle fragments (Fig. 7.19), which document the existence of local pine stands, where also *Populus tremula* and *Sorbus aucuparia* occurred. The role of *Betula* decreased, as suggested by decrease in its percentage, but the macrofossils confirm its continuous local presence. The macrofossils evidence also the willow and *Betula nana* shrubs growing near the lake. *Hippophaë* and *Juniperus* thickets were scarcer, and herb communities with very abundant *Artemisia* (up to more than 9%) expanded, with Chenopodiaceae, *Helianthemum*, *Papaver* (*P. radicum* -t.), Papilionaceae species of *Ononis* -t., and *Dryas octopetala*, the latter documented by both pollen and leaf fragments. The general decline of shrubs and development of heliophyte herb vegetation reflects possibly drier climatic (more continental?) conditions (van Geel & Kolstrup 1978).

At the same time the representation of Cyperaceae, *Glyceria* -t., *Sparganium* -t., *Equisetum*, and particularly the high Gramineae values (presence of *Phragmites* rhizomes in G28/92) suggests the continuing development of lake-shore vegetation, connected possibly with the progress of melting-out processes. Worth mentioning is the persisting presence of *Typha latifolia*. The aquatic macrophytes included *Potamogeton*, *Hottonia*, *Littorella uniflora*, *Myriophyllum spicatum*, *M. verticillatum* and *M. alterniflorum*, indicating altogether arising shallow-water conditions. Characeae first appeared as well.

The zone has generally been ascribed to the Older Dryas chronozone, roughly supported by the ^{14}C date of $11,840 \pm 160$ BP coming from one of profiles not discussed here (Demske 1995). However its precise distinction and correlation between profiles, as well as the location of upper boundary are difficult and obscured due to the differences in both the processes of sediment formation and the succession of local shore vegetation between particular parts of the lake.

***Betula-Pinus* paz (TG-4, TB-4), and *Pinus-Betula-Filipendula* paz (G1/87-1, G1/90-1); Allerød, upper boundary 12,660 cal BP**

The pollen record of this zone occurs in its full sequence in G28/92 and T1/90 profiles (Figs 7.17 and 7.18); its decline appears also at the base of profiles G1/87 and G1/90 from the central and western deeps of the lake (Figs 7.20, 7.21 and 7.22). In all profiles the sediment is calcareous gyttja, with a substantial content of silt and sand in the bay profiles, a thin humus layer, and some contribution of silt at the base of G1/90 and some silt also in G1/87.

In the upper part of the zone the annual laminations appear in all four profiles. In G1/87 laminae start directly from the base, in G1/90 they begin ca. 20 cm above the base, and in T1/90 they appear already 9 cm above the lower end of the zone discussed (at 14.10 m). They are correlative with other profiles only from 13.97 m upwards; in G28/92 the traces of lamination appear in the almost entire zone, but they are weak and uncountable. The beginning of lamination has been dated by Goslar (Chapter 7.2) at 12,857 cal BP in G1/87, 12,719 cal BP in G1/90 and 12,770 cal BP in T1/90. These calendar dates correspond, according to Goslar's chronology, with the decline of the Allerød, and the whole zone represents the full Allerød chronozone. The sequences of sediment changes described record the processes of lake formation progressing in different ways, in the particular basins. In spite of those differences the final melting-out of dead-ice and the end of deepening processes evidenced by the beginning of laminae formation terminated in all basins roughly synchronously during the middle to late phase of the zone.

The basic characteristic of the vegetational succession during this zone is the expansion of forests composed mostly of pine and birch. The contribution of *Betula* shows only slight oscillations throughout the zone, but the domination of *Pinus* increases gradually at expense of shrubs and herbs, as is clearly recorded in the T1/90 profile counted with good sample resolution.

Gramineae-Cyperaceae paz (TG-4a) and *Betula-Juniperus-Betula nana* paz (TB-4a); older part of Allerød

During the older phase of zone the coverage of the lake surroundings by pine-birch tree stands with *Populus tremula* and *Sorbus aucuparia* was rather loose. The shrubs formed by *Juniperus*, *Hippophaë*, and *Ephedra* on drier habitats and by *Betula nana* and *Salix* species on humid places were still frequent though gradually shrinking. The substantial role of *Betula*, not pronounced in the pollen diagrams, is evidenced by abundant macrofossils (Fig. 7.19). The record of *Pinus* budscales, poor at the beginning of the zone, is later well correlated with the rising pollen curve, both reflecting gradually increasing im-

Lake Gościąg
Profile G1/87 (Late-Glacial part)

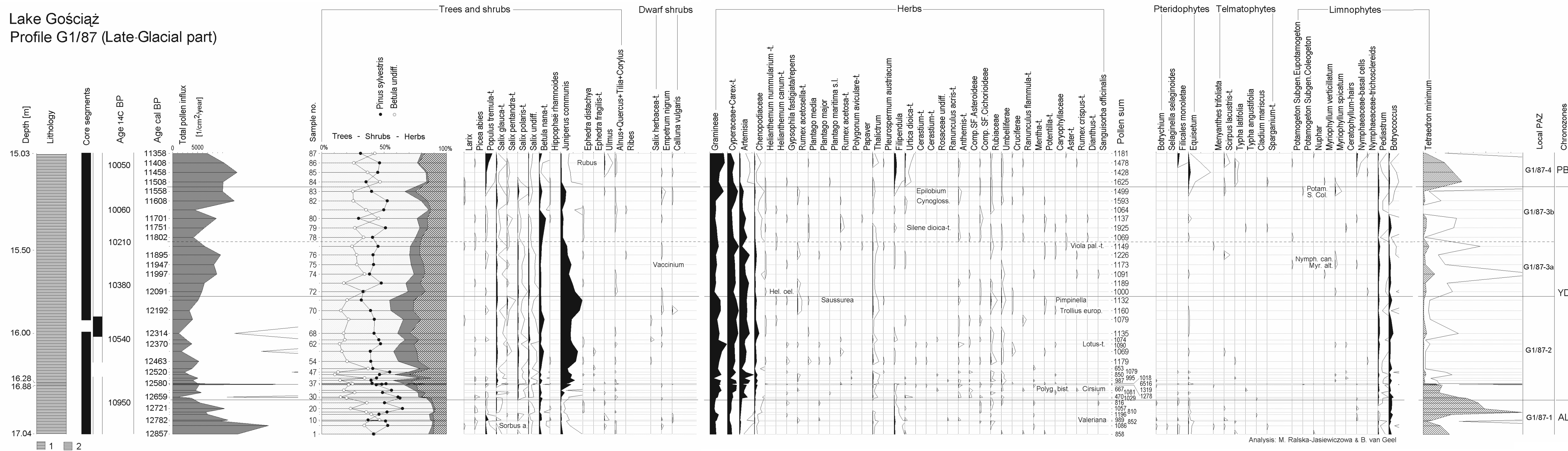


Fig. 7.20. Lake Gościąg, profile G1/87 from the central lake deep, Late-Glacial part – complete percentage pollen diagram. 1 – calcareous-ferruginous gyttja, regularly laminated, 2 – sand. Parts of core segments indicated in black were sampled for pollen analysis.

portance of pine in forest communities (Demske 1995). The peak of *Pinus* pollen in the G28/92 profile may be a local over-representation phenomenon.

The heliophyte herb vegetation, represented by *Artemisia*, *Chenopodiaceae*, *Helianthemum*, and *Saxifraga*, with psammophilous *Gramineae*, *Sedum*, and *Rumex acetosella* on sandy habitats, and many ecologically undefined herb taxa, was still widespread. *Filipendula*, *Humulus*, and *Urtica dioica* grew on moist richer soils.

Pinus-Betula-Filipendula pasz (TG-4b, TB-4b) and paz (G1/87-1, G1/90-1); younger part of Allerød, upper boundary 12,660 cal BP

The younger phase is characterized by the reduction of shrub vegetation expressed by the gradual disappearance of *Hippophaë*, and a decrease of *Juniperus*, *Salix* spp., and *Betula nana* t. pollen frequencies. The dominance of pine woods seems to increase, however in the G1/87 profile the *Pinus* pollen influx generally decreases (Fig. 7.21), with some fluctuations, towards the zone upper boundary. The same concerns the *Betula* pollen influx, quite high at the subzone base, and then quickly

falling down. The dry (*Artemisia*, *Chenopodiaceae*, *Botrychium*, *Gypsophila*, *Sedum*, *Rumex acetosella*, *Plantago major*, *Polygonum aviculare*, *Onobrychis* -t.) and moist (*Filipendula*, *Sanguisorba officinalis*, *Valeriana*, *Caltha palustris*, *Ranunculus flammula* -t.) open-ground vegetation is still rich in plant taxa but more limited in area, particularly the vegetation of dry habitats. By the end of zone a maximum of *Betula* pollen occurring in all profiles may signal the approaching change of climate. Demske (1995) reports at that time the reappearance of *Helianthemum nummularium* -t., *Saxifraga oppositifolia* -t., and *Salix herbacea* -t., and Ralska-Jasiewiczowa & van Geel (Fig. 7.20) note the appearance of *Pleurospermum austriacum*, *Gypsophila fastigiata* and *Selaginella selaginoides*.

The high amounts of *Carex* type and *Gramineae* pollen in G1/90 profile (Fig. 7.22) are certainly connected with the formation of the western lake basin, expressed by the sediment change from humus to gyttja.

Due to the changing status of the transforming lake the local telmatophyte and limnic vegetation was subject to substantial changes. During the early stage of zone (TB-4a) the Characeae meadows expanded at the un-

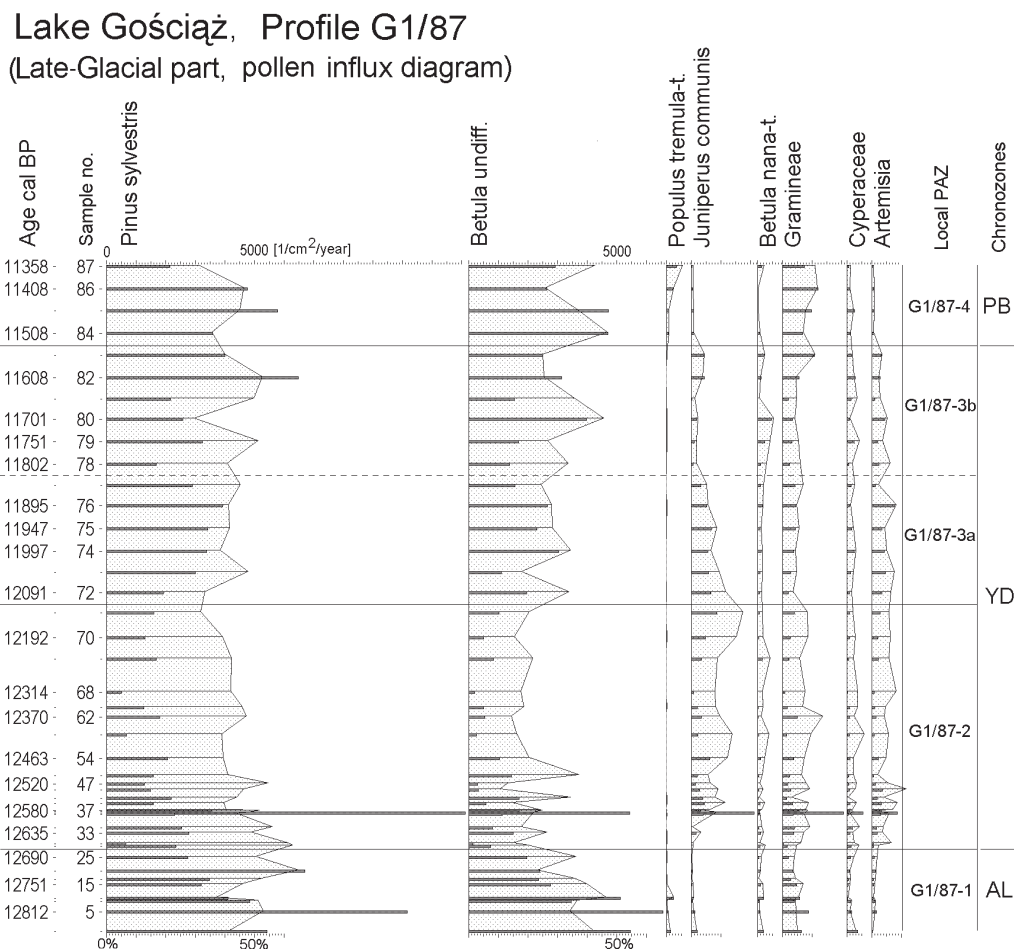


Fig. 7.21. Lake Gościąż, profile G1/87 – pollen influx diagram, selected major pollen taxa. Pollen influx values (black bars) are superimposed on the percentage pollen curves (dotted silhouettes).

stable sandy bottom of the lake bay (Demske 1995). *Potamogeton* (pollen and seeds of *P. perfoliatus*), Nymphaeaceae (basal hair-cells), all *Myriophyllum* species (*M. spicatum*, *M. verticillatum*, and *M. alterniflorum*), *Ceratophyllum* (hairs) and *Hippuris vulgaris* formed limnic submerged and floating-leaved macrophyte vegetation, and *Tetraedron minimum*, *Pediastrum*, *Botryococcus* and *Scenedesmus* comprised the microphyte assemblages. The reed-swamp and fen communities maintained roughly similar composition as in the preceding subzone. After the final lake deepening at the later phase of the zone (TB-4b), the shallow-water macrophyte vegetation became strongly reduced; the record of aquatics was restricted to single *Potamogeton* and *Myriophyllum* pollen. The algae were represented by increased *Botryococcus* frequencies. According to Demske (1995), moss assemblages composed of *Sphagnum* sect. *Cuspidatum* species and brownmosses including *Meesia triquetra* spread in the swamp zone at the lake shores (abundant single moss leaves and *Sphagnum* spores), forming possibly also floating mats.

***Pinus-Juniperus* paz (TG-5, TB-5),
Juniperus-Artemisia-Chenopodiaceae-Salix paz (G1/87-2,
G1/90-2) and *Betula-Artemisia* paz (G1/87-3, G1/90-3);
Younger Dryas, 12,660–11,520 cal BP**

The next stage of vegetational development corresponding to the Younger Dryas cool period is recorded in all four profiles (Tabs 7.1 and 7.2), but it is represented by very different sediment thicknesses (Fig. 7.24). The thickest comes from the central deep of the lake (G1/87 – 115 cm). Its lower boundary is extremely sharply indicated by the first component of PCA (Fig. 7.23). The record of changes is best developed in this profile and it is divided into two pollen zones (*Juniperus-Artemisia-Chenopodiaceae-Salix* and *Betula-Artemisia*) well distinguished by PCA (Fig. 7.23). The medium thick section from the western deep (G1/90 – 68 cm) has been described accordingly. In the short sections from the bay (T1/90 – 37 cm, G28/92 – 46 cm) only one pollen zone (*Pinus-Juniperus* paz) with two subzones (*Chenopodiaceae* and *Betula-Artemisia* pasz's) could be correlative with zones of G1/87 and G1/90 profiles distinguished.

In the deeps of the central and western basins and in the centre of the northern bay was deposited calcareous gyttja sediment with distinct and well correlative annual lamination (Goslar, Chapter 7.2). It indicates the formation of the strong thermocline and persistence of calm conditions for sediment accumulation following the termination of melting-out processes in the lake at the decline of preceding period. The gyttja was characterized by an increased contribution of mineral matter in individual layers coming possibly from the increased shore ero-

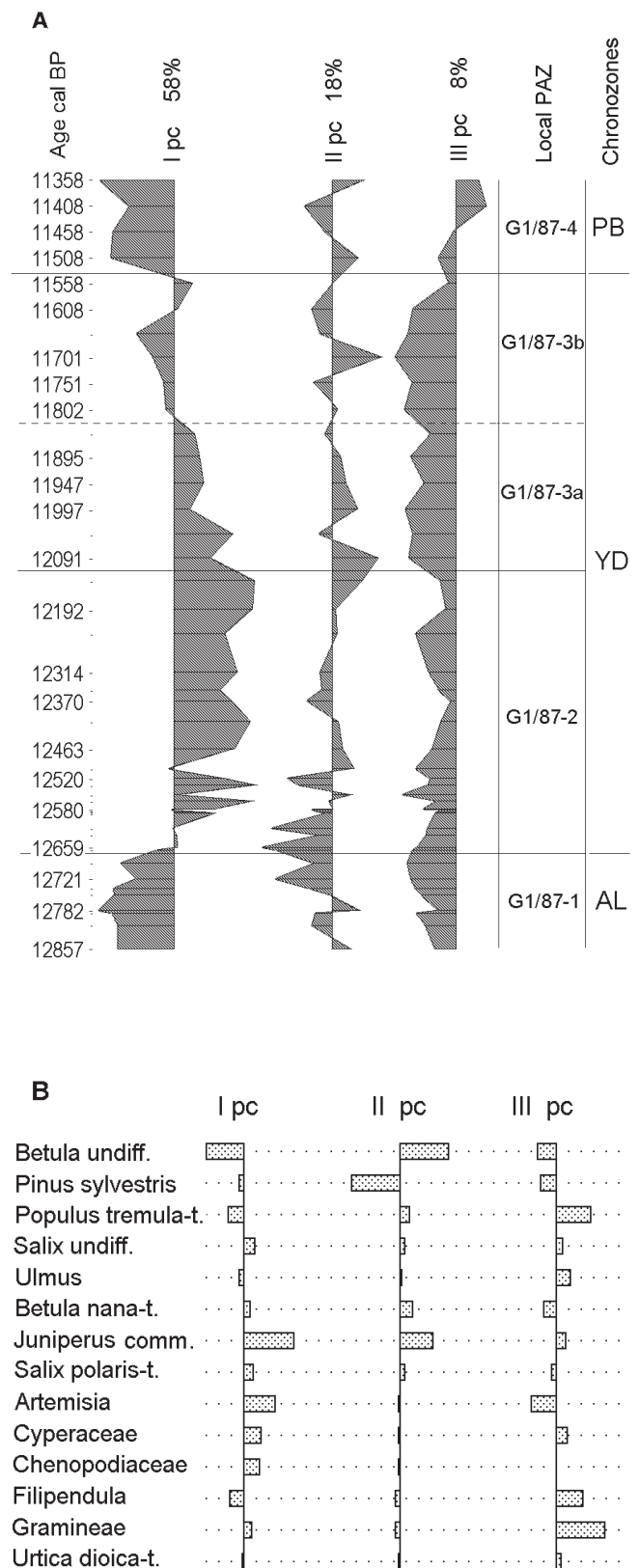


Fig. 7.23. Lake Gościąg, profile G1/87. A – Plots of sample scores on the first three principal components of the Late-Glacial pollen sequence. The ages cal BP of samples and the division of pollen sequence into local pollen assemblage zones are indicated. The percentage of the variance for each component is given on top of the axis. B – The loadings of particular pollen taxa on each of the principal components.

Lake Gościąg Profile G1/90 (Late-Glacial part)

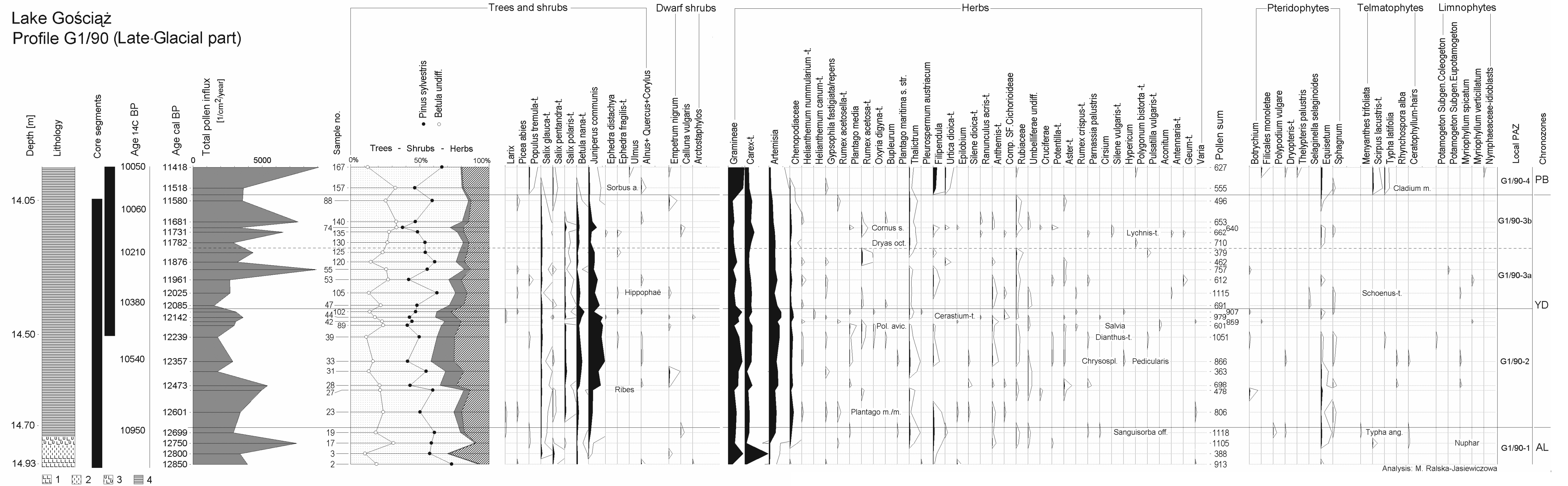


Fig. 7.22. Lake Gościąg, profile G1/90 from the western lake deep, Late-Glacial part – complete percentage pollen diagram. 1 – fine silt, 2 – humified peat, 3 – calcareous gyttja, 4 – calcareous-ferruginous gyttja, regularly laminated. Samples from both core segments (indicated in black) were used for pollen analysis, their numbers are ordered accordingly in two neighbouring columns.

Analysis: M. Ralska-Jasiewiczowa

sion during spring floods (Goslar, Chapter 7.2). In the shallow marginal parts of the lake (G28/92 profile) marl gyttja with traces of microlaminae was deposited, evidencing the abundance of calcium with accompanying deficit of nitrates and phosphates (Birks & Birks 1980).

Juniperus-Artemisia-Chenopodiaceae paz (G1/87–2, G1/90–2); *Chenopodiaceae* pasz of *Pinus-Juniperus* paz (TG-5a, TB-5a); older part of Younger Dryas, 12,660–12,100 cal BP

The initial part of zone reflects the fast reaction of plant communities to the rapid and deep climatic change evidenced by the decline of $\delta^{18}\text{O}$ in the authigenic carbonates for ca. 2‰ within 80–150 yr (Kuc et al., Chapter 7.6). It is expressed by the spread of grasslands with dominant *Artemisia* and *Chenopodiaceae*, and of *Juniperus* shrubs coincident with the reduction of woods, particularly of *Betula*, and also of *Populus* participation. These changes, occurring within less than 100 yr, suggest not only the temperature decline, but also a decrease in moisture.

During the following ca. 500 yr the landscape of the lake surroundings was transformed again into a sort of parkland with fragmented tree stands composed mostly of *Pinus* and *Betula*, where possibly also *Larix* (and *Picea*?) were sporadically present. The reduction of *Pinus* population is not very distinctly reflected by pollen, which was probably produced more abundantly and freely dispersed in an open landscape; it is, however, shown by the strongly decreased record of pine macrofossils (Fig. 7.19). The shrub vegetation, composed mostly of *Juniperus* with *Ephedra* and sporadic *Hippophaë*, expanded on drier, more exposed habitats, while *Betula nana* accompanied by different *Salix* species occupied lower more humid places around the lake.

The composition of heliophytic herb communities, presenting a mixture of different elements well-known from Late-Glacial records, suggests some prevalence of dry habitats (*Gypsophila fastigiata*, *Helianthemum nummularium* -t., *H. canum*, *Plantago media*, *Bupleurum*, *Rumex acetosella*, *Calluna*, *Botrychium*, etc.) with dominating *Artemisia* and *Chenopodiaceae*. The tall herbs (*Filipendula*, *Urtica*, *Pleurospermum austriacum*, *Thalictrum*, *Epilobium angustifolium*), though present during the whole zone, show however a distinct reduction of their more thermophilous components like *Filipendula* and *Urtica* during the coldest top part of zone, when *Juniperus* reaches its maximum abundance.

The telmatophyte and limnophyte communities abundant in the early stage of the zone (as documented by the bay profiles) and containing some thermophilous plant taxa, such as *Typha latifolia*, *Scirpus lacustris* -t. species, *Cladium mariscus*, *Nymphaeaceae* (vegetative remains), seem to have partly retreated during the later phase of the

zone, corresponding to the coldest stage of the Younger Dryas. Characeae expanded again. Submersed aquatics were hardly evidenced (*Potamogeton*). *Tetraedron minimum* populations, very abundant at the onset of the zone, rapidly decreased later, perhaps in consequence of decreased lake productivity.

During the initial phase of the zone, around 12,580 cal BP, a strong inwash of shore material interrupted the deposition of laminated sediment, reaching as far as the lake centre. This event is documented by a layer of sand ca. 60 cm thick inserted into varved gyttja, ca. 80 varves above the base of the zone in G1/87, and in all other central profiles. This disturbance of varve continuity has been overcome by the precise correlation of the central cores with the cores from western deep, which was not reached by the sand inflow (Goslar, Chapter 7.2). The gap in the laminae sequence caused by the sand layer is defined as spanning 4_{-2}^{+6} yr. This statement corrected the earlier erroneous assumption that the gap covered a much longer period (Ralska-Jasiewiczowa et al. 1992, see Goslar, Chapter 7.2). It is difficult to say whether the deposition of sand represents one or several events: the granulometric analysis of the sand (Pawlikowski, oral inf.) speaks rather for several sand supplies, happening possibly within a short time. Astonishingly this deposit has a very high pollen influx (Fig. 7.21). If we take that the whole layer was deposited in no more than several years, each of 6 analysed samples contains pollen influx representing less than one year, and the pollen concentration is similar, or only slightly lower than in the 6-, or 10-years gyttja samples. The lumps of peaty soil in-

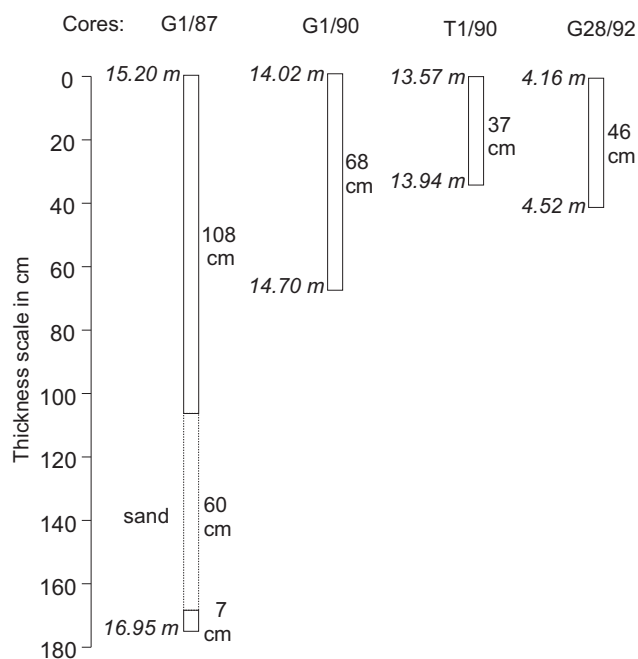


Fig. 7.24. The thickness of Younger Dryas sediments in particular cores.

washed from the lake shores, or some high-influx Allerød sediment eroded from shallower parts of lake bottom, might have been the source of this pollen. The six pollen samples covering the sand layer gave mixed spectra containing reduced contributions of taxa typical of Younger Dryas (like *Juniperus*, *Salix polaris* -t., *Artemisia*, Chenopodiaceae, *Carex* type), increased frequencies of Allerød taxa (*Populus*, *Filipendula*), and a substantial content of clearly rebedded pollen (*Alnus*, *Quercus*, *Corylus*, *Ulmus*, *Ilex* and also pre-Quaternary spore-morphs) (Fig. 7.25).

Betula-Artemisia pasz of *Pinus-Juniperus* paz (TG-5b, TB-5b) and *Betula-Artemisia* paz (G1/87-3, G1/90-3); younger part of Younger Dryas, 12,100–11,540 cal BP

The lower boundary of this zone dividing the Younger Dryas chronozone into two parts is clearly indicated in the first component of PCA (Fig. 7.23). During the older part of zone (G1/87-3a, G1/90-3a; 12,100–11,820 cal BP) a substantial development of *Betula* tree stands with some *Pinus* began (Fig. 7.21). The *Juniperus* percentage pollen curve suggests its decreasing populations but the influx values remain unchanged (Fig. 7.21). The open herb vegetation with dominant *Artemisia* and Chenopodiaceae, and with *Helianthemum* and *Gypsophila* was still widespread; the contribution of Gramineae and of Cyperaceae might have decreased slightly. By the end of this phase some representatives of tall herbs (*Filipendula*, *Urtica*) reappeared. The climatic change towards more humid conditions is suggested for that time, but with the temperatures remaining still low (Kuc et al., Chapter 7.6).

In the younger part of the zone (G1/87-3b, G1/90-3b; 11,820–11,540 cal BP) the development of tree clusters progressed, resulting in a strong reduction of *Juniperus* and *Salix* thickets and of heliophyte herb communities. This successional trend strongly suggests a change of climate, not only in terms of moisture but also of a temperature rise. Such an explanation is supported by the course of the $\delta^{18}\text{O}$ curve (Kuc et al., Chapter 7.6). The small rises of *Juniperus*, *Salix* and some herbs (Chenopodiaceae, *Empetrum*, Gramineae) at the very end of zone (11,600–11,550 cal BP) in G1/87 profile, may express a short cool oscillation, as they are coincident with the last distinct depression in the $\delta^{18}\text{O}$ curve. The trace of a similar change can be found in the G1/90 profile, but at the level dated at ca. 11,700 cal BP, so the meaning of those records is dubious.

During this zone the revived development of species-rich reed-swamps and reappearance of limnic macrophytes (*Myriophyllum spicatum* and *M. verticillatum*, *M. alterniflorum*, *Nymphaea candida*) is observed. Small microflora blooms (*Pediastrum*, *Botryococcus*, *Tetradron minimum*) may evidence somewhat increased lake productivity.

Betula-Gramineae-Filipendula paz (TG-6),
Betula-Populus-Ulmus paz (TB-6, G1/87-4),
Pinus-Betula-Filipendula paz (G1/90-4); initial parts of zones recording transition from the Late Glacial into the Holocene, 11,540-...* cal BP

The rapid change of dominating plant communities clearly recorded in all diagrams around 11,500 cal BP documents the reaction of vegetation to the definite change of climate opening the Holocene climatic cycle. The fast rise of temperature is reflected by the increase of $\delta^{18}\text{O}$ by ca. 2‰ concluded in 20–80 yr found in all four investigated profiles (Kuc et al., Chapter 7.6). The change of plant cover was initiated by a strong reduction of open herb and shrub vegetation, expressed by declining or disappearing pollen record of *Artemisia*, Chenopodiaceae, *Helianthemum nummularium* -t., *Plantago media*, *Rumex acetosella*, and of *Juniperus*, *Betula nana* -t., *Salix polaris* -t. including last sporadic evidence of *Hippophaë*. The development of tall herbs on humid habitats (*Filipendula*, *Urtica* and Umbelliferae) progressed coincidentally. All those changes occurred within several decades. These changes seem to have been slightly preceded by the expansion of swamp/fen communities (rises in Gramineae, Cyperaceae, and *Equisetum* frequencies followed by *Typha latifolia*, *Scirpus lacustris* -t., *Schoenus* -t., *Cladium mariscus*, and *Thelypteris palustris*), which began already at the very end of Younger Dryas. At this initial stage of vegetational change the expansion of trees (*Pinus* and *Betula*) is not as yet reflected in more substantial way; their pollen percentages are similar to those in the younger part of Younger Dryas, though the *Betula* pollen influx (Fig. 7.21) and concentration (Fig. 7.18) trends distinctly towards rising. The only tree starting to spread that early was *Populus tremula*.

In the central profile (G1/87) the YD/PB boundary level falls between samples dated at 11,558 and 11,508 cal BP. In the PCA plot (Fig. 7.23) the first component indicated this boundary very accurately by a change of loadings being a reversal to that at AL/YD boundary. In the western core (G1/90) the whole record of vegetational succession is very consistent with that from the G1/87 profile, and the boundary is dated between 11,580 and 11,518 cal BP. In the bay profile (T1/90) *Artemisia* and *Juniperus* fall coincidentally with *Populus*, *Filipendula*, and *Urtica* rises, to define the YD/PB boundary between samples dated around 11,556 and 11,517 cal BP. The *Betula* and *Pinus* percentage curves do not show any substantial rises yet, but their pollen concentration is nearly doubled.

The development of reedswamps recorded in T1/90 profile right above the boundary is distinguished by the appearance of *Thelypteris palustris* together with the ris-

* for the discussion of the full zone see Chapter 8.3.

Lake Gościąg Profile G1/87 (sand layer)

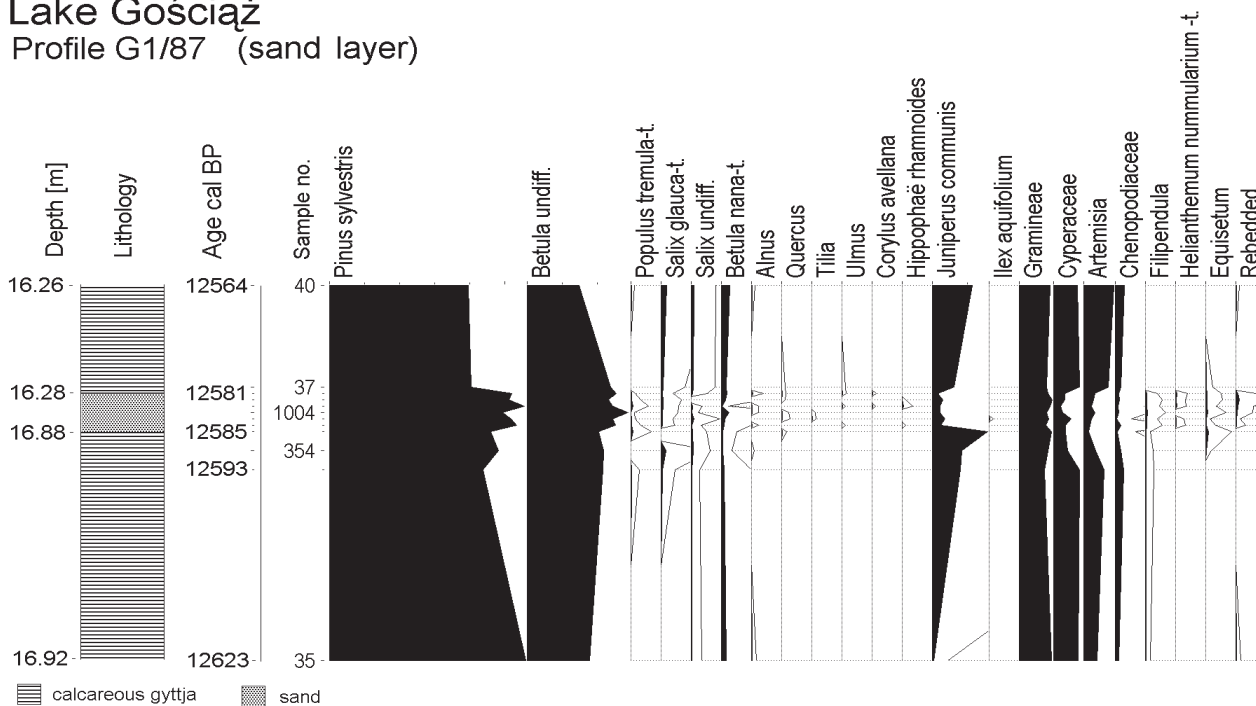


Fig. 7.25. Lake Gościąg, profile G1/87. The fragment of percentage pollen diagram showing the composition of pollen spectra (selected pollen taxa) of samples from the sand layer occurring in the initial part of the Younger Dryas sediment (see Fig. 7.20). The pollen composition of the neighbouring samples from the calcareous laminated gyttja is also shown for comparison.

ing frequencies of undefined Filicales monoletae. The increased richness of aquatic pollen taxa in G1/87 profile (*Potamogeton*, *Nuphar*, *Nymphaea alba*, *Myriophyllum verticillatum* and *M. spicatum*) (Fig. 7.20) is supported by numerous Nymphaeaceae vegetative microfossils, very abundant also in G28/92 profile (Fig. 7.17). *Tetraedron*, *Pediastrum*, and *Scenedesmus* blooms around or right above the boundary are registered in all profiles. The succession of telmatic and limnic shallow-water communities, though proceeding in a somewhat differentiated way around different parts of the lake, reflected generally the water-level lowering progressing from the close of the Younger Dryas, and the following increase of lake productivity in response to climatic amelioration at the onset of the Holocene.

The further stages of vegetational succession, including tree expansion, that needed more time to develop are described in Chapter 8.3.

Some particular problems concerning processes of lake formation, vegetation development, and climatic change during the Late-Glacial

1. The processes and rates of lake basins formation

The information obtained by studying profiles from different parts of recent Lake Gościąg and from its margins shows the complicated patterns of lake and landscape formation.

Evidently, depressions of glacial origin different in shape and size existed initially as several separated basins. The depressions were filled with dead-ice blocks covered by layers of mineral material varying in thickness. The attempt to reconstruct this pre-lacustrine stage in lake history is presented in Chapter 7.1 (Starkel et al.).

The beginning and rates of melting-out seem to have depended largely on the thickness and size of the ice blocks, possibly also on the thickness of the mineral cap. We have no way to date the actual beginning of melting, but we can define the onset of its more advanced stage when the conditions allowed the accumulation of organic sediment. In the Lake Gościąg system alone we registered the beginning of sediment accumulation (though with countable pollen) from the early Oldest Dryas (G28/92 – Tobyłka Bay margins), the late Oldest Dryas (T1/90-Tobyłka Bay centre), the Bølling, probably late Bølling (GTO 1/89 - neighbouring kettle-hole mire, Demske 1995), the Older Dryas or transition to Allerød (GTO 301/89 - eastern margins of main Gościąg basin, GTO 2/89 - between Tobyłka Bay and kettle-hole mire, Demske 1995), and late Allerød (G1/87, G1/90 – central and western lake deeps) (see Fig. 7.16).

Nearly all depressions where the sediment accumulation started the earliest were shallow; the sediment depths are there in the range of several meters only (G28/92 – 5.5 m, GTO 2/89 – 5 m, GTO 301/89 – 6.5 m). These depressions were filled around the onset of Holocene, and then overgrown by a thin peat layer with the top today at

the level of recent Gościąg water-table. The small lake in the neighbouring kettle-hole (GTO 1/89 – sediment depth 8 m) was overgrown by a mire around 7900 cal BP (Demske 1995). The deeper depression of Tobyłka Bay (Demske depth of sediment + water 16.4 m) functioning until today as a part of the lake due to the constant water flow from Ruda stream, was evidently isolated from the main lake in the early Late-Glacial. Its primary icebody was then much smaller and thinner and could melt-out much earlier than dead-ice in western (max. total depth 25.1 m) and central (max. total depth 44.6 m) lake depressions. Similar observations are reported e.g. by Bohncke & Wijmstra (1988) from the pingo lakes in The Netherlands, where older Late-Glacial sediments occur in the border zones rather than in the centres of the basins.

2. Autochthonous peat or drifted detritus layers underlying lacustrine sediments?

Sediment accumulation in some profiles from the Lake Gościąg system began with the layer of peat-like matter. Similar organic layers are often found at the base of Late-Glacial lacustrine sediments accumulated in out-melted lake basins of formerly glaciated areas. They are normally considered to be formed of allochthonous humus/detritus derived from the surrounding topsoils. However, according to our observations it may also be a sort of autochthonous, often brownmoss peat formed sub-aquatically in still shallow out-melting small basins, or as mats, and at margins of bigger not yet completely out-melted basins. As lake formation progresses peat could be inundated and subsided to the lake bottom.

We cannot find another explanation for occurrence of moss peat layers of substantial thickness at the base of sediments in continuously developed lacustrine profiles e.g. in lakes Mały Suszek (11,810±140 ¹⁴C BP – Miotk-Szpiganowicz 1992), Maliszewskie (11,460±210 ¹⁴C BP – Balwierz & Żurek 1987), or of swamp peat at Miłkołajki (11,040±380 ¹⁴C BP – Ralska-Jasiewiczowa 1966, and 11,380±70–10,240±110 ¹⁴C BP – Ralska-Jasiewiczowa & Pazdur, unpubl.). In the lakes of Lublin Polesie situated to the south of the glaciated areas similar sediment sequences originating from the Late-Glacial were found, but their origin is ascribed to karst processes (Lake Krowie Bagno – Bałaga et al. 1980/81, Lake Łukcze – Bałaga 1990).

In the Lake Gościąg system the sandy humus layer of Oldest Dryas age found at the base of the G28/92 profile may be of drift origin, but the Bølling brownmoss peat from the centre of Tobyłka Bay seems to be formed *in situ*. The origin of humus layers up to several cm thin with plant detritus appearing at the base of profiles from the western deep (G1/90) and in some cases also from the central deep (G1/85, Ralska-Jasiewiczowa et al. 1987) is not quite clear, though the composition of pollen spectra,

as well as not much increased content of the mineral component as compared with overlying gyttja, speak rather for its formation *in situ*.

3. The progress of Late-Glacial *Hippophaë* expansion

The expansion of *Hippophaë rhamnoides* around the lake is abundantly evidenced (high contribution of pollen and hairs) in the profile sections from the Oldest Dryas/Bølling transition. The rapid spread of *Hippophaë* has been observed in many Late-Glacial pollen sequences from Poland at the beginning of both Bølling and Allerød. The metachroneity of this phenomenon may have had a geographic pattern: it appears at the Oldest Dryas/Bølling transition in SEE Poland (Bałaga 1990) and central Poland (Wasylikowa 1964, Krajewski & Balwierz 1984), its stratigraphic position in the SW lake districts is not well recognized because of sediment compaction and/or poor dating, and seems to be connected with the onset of Bølling in the Kujawy area (Jankowska 1980), but is rather obscure farther west (Legnica region – Litt 1988, Makohonienko 1991, Tobolski & Litt 1994). However, in the Baltic coastal zone (Krupiński 1991, Latałowa 1989, Ralska-Jasiewiczowa & Rzętkowska 1987) and also in the NE Lake Districts (Ralska-Jasiewiczowa 1966) it clearly indicates the subsequent warming at the Older Dryas/Allerød transition. Such a pattern may depend on different distance to the deglaciation zone. At any rate the preliminary isopollen maps for *Hippophaë* published by Huntley & Birks (1983) need now some complement.

4. The contribution to the knowledge on pre-Allerød plant indicators of climate

The records of pre-Allerød chronozones in the profiles from Tobyłka Bay and its marginal zone (T1/90, G28/92) are shortened and fragmentary. However, the sites recording the early Late-Glacial stages in continuous sequences are so scarce in Poland, that even deficient information they give is useful for palaeovegetation and climate reconstructions:

- The subarctic and continuously improving climate of Oldest Dryas, with July temperature of at least ca. 12°C or more is confirmed by the presence of *Hippophaë*, *Populus tremula*, *Sorbus aucuparia*, and during its closing phase of *Hippophaë* expansion by the appearance of tree birches documented by macrofossils.

- The possible presence of *Pinus in situ* during the Bølling, was questioned at the closest Late-Glacial site, ca. 60 km south at Witów (Wasylikowa 1964), but later was more probable in central Poland in view of some new finds of macrofossils (e.g. Krajewski & Balwierz 1984). Now it is suggested in the Lake Gościąg area by a find of a *Pinus* budscale in Bølling brownmoss layer of the T1/90 profile and indirectly supported also by the

finds of pinewood fragments in sediment of the subsequent Older Dryas chronozone (GTO 301/89, Demske 1995). The appearance of *Typha latifolia* and *Cladium mariscus* in species-rich telmatophyte communities in Bølling suggests mean July temperatures of no less than 16°C, and mean January temperatures no colder than -4°C.

– The occurrence of pine and birch tree stands during the Older Dryas is confirmed by macrofossils. Presence of Characeae, of all three *Myriophyllum* species, and *Typha latifolia* seem to indicate thermic conditions close to or only slightly more severe than those during the Bølling, defined by mean July temperatures of at least 14–15°C.

5. The climate of the descending part of the Younger Dryas

The two-step change of vegetation during the younger part of Younger Dryas starting from ca. 12,100 cal BP is most distinctly recorded in the diagram from G1/87 profile, but it is also evident in all other profiles discussed. Its first step between 12,100 and ca. 11,820 cal BP involving a change of proportions between *Juniperus* and *Betula* contributions to the plant cover is explained mostly in terms of changing humidity, with the temperatures being still low; the second step (ca. 11,820–11,540 cal BP) showing all evidence of the progressing reduction of heliophyte herb communities is assumed to indicate also the amelioration of thermic conditions. The explanation of such pattern of changes by a change of climate gets some support from the stable-isotope studies (Kuc et al., Chapter 7.6). The $\delta^{18}\text{O}$ curve, measured with a very fine time resolution in the central cores (G1/87, G2/87) reveals minimum values documenting the coldest phase between ca. 11,950 and 11,880 cal BP, preceded around 12,000 cal BP by a short oscillation towards warmer conditions. In the G1/90 core from the western deep the whole profile between ca. 12,040 and 11,880 cal BP evidences the Younger Dryas thermic minimum. The increase of $\delta^{18}\text{O}$ indicating some warming begins around 11,850–11,870 cal BP in the central and in western cores. In Tobyłka Bay its beginning is recorded some decades later, around 11,790 cal BP. Generally, both stable-isotope and vegetational change speak for the more humid though rather cold climate at the time between ca. 12,100–11,880(11,850) cal BP, followed by a distinct warming during at least the last ca. 300 yr of the Younger Dryas.

Similar trends in vegetational succession recorded in some Polish sites with the sufficiently developed YD sediments (e.g. Lake Łukcze – Bałaga 1990, Lake Mały Suszek – Miotk-Szpiganowicz 1992) seem to confirm generally the proposed scheme. The rise of temperature in the younger part of YD has been widely recognized in the different part of Europe (Pennington 1977, Lowe &

Walker 1980, De Groot et al. 1989). The onset of climatic warming around 10,250 ^{14}C BP (= ca. 11,870–11,880 cal BP), suggested long ago by Scandinavian scientists for SE Sweden (see Berglund 1966), has been more recently recognized by change in beetle fauna as a warming around 10,500 ^{14}C BP (ca. 12,300 cal BP) with a response of terrestrial vegetation delayed by ca. 300 yr (Berglund et al. 1984). A similar time of ca. 10,500 ^{14}C BP (ca. 12,300 cal BP) for the Younger Dryas rise of temperature was concluded for The Netherlands from pollen-analytical data (Bohncke 1992), where it seems to have been also connected with the precipitation decline. Both dates are rather close to the first step of vegetational change at Lake Gościąg, with still low temperatures indicated by ^{18}O . A more detailed discussion would be possible with the support of isotope data from Sweden and Holland.

6. The rates of climatic and vegetational change at the Late-Glacial/Holocene transition

The rapidity of climatic change terminating the last glacial stage as measured by the change of $\delta^{18}\text{O}$ content in the Lake Gościąg sediments (Kuc et al., Chapter 7.6) shows a good consistency with the very fast rates of a few decades stated for the Greenland ice-cores (Dansgaard et al. 1989). The response of vegetation was clearly differentiated into several steps: the earliest reaction of aquatics and telmatophytes seems coincident with the very first beginning of the temperature rise or starting even a little earlier, suggesting a water-level lowering preceding slightly the thermic change. The open rather xeric herb/shrub vegetation retreated very quickly, and tall herbs and *Populus* spread correspondingly within less than 50 yr after the isotope boundary. However, the actual expansion of trees (mostly *Betula*) proceeded with the distinct time lag of 200–300 yr. The repetition of pollen analysis at this critical transitional profile section with a very fine time resolution is now in progress.

7.5. DEVELOPMENT OF THE LAKE GOŚCIAŻ BIOTA DURING THE LATE-GLACIAL

7.5.1. YOUNGER DRYAS DIATOM ASSEMBLAGES OF LAKE GOŚCIAŻ

Barbara Marciniak

Forty four samples coming from the lower part of the profile G1/87 from the central deep of Lake Gościąg (Fig. 7.26) have been analysed for diatom content (age 11,558–12,644 cal BP). As a result of qualitative analysis 183 diatom taxa belonging to 33 genera have been distinguished.

Four local diatom-development phases have been dis-