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AN INTERSTADIAL FLORA FROM THE ZALESIAKI LOCALITY NEAR DZIAŁOSZYN (SILESIAN-CRACOVIAN UPLAND)

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ABSTRACT. Vegetation changes near the Zalesiaki site based on the results of pollen and plant macrofossil analyses indicate a nearly closed cycle of vegetation development, interstadial in nature, with a clear climatic optimum. The flora list contains 178 taxa varying in rank, 78 of them identified to species level. An interesting situation arises in relation to the interstadial history of the vegetation through the presence of macrofossils of *Brasenia schreberi*, *Dulichium spathaceum*, *Aldrovanda vesiculosa* and *Nymphoides peltata* in the flora of this site. The geological position of the organogenic sediments is not univocal, but it does not exclude the Pilica Interstadial/Interglacial (= Lublin Interglacial). That they are coeval is neither excluded nor confirmed by comparison of the pollen succession from Zalesiaki with others of an interstadial nature from Poland which are referred to the Pilica Interstadial/Interglacial stratigraphic unit.

KEY WORDS: pollen analysis, plant macrofossil analysis, pollen succession, interstadial

INTRODUCTION

The Zalesiaki site is situated 12 km southwest of Działoszyn, in the central part of the Wieluń Upland (Fig. 1). Organogenic deposits were first bored there by Assist. Prof. R. Więckowski, who was carrying out an exploratory investigation in this area.

In 1992 samples were taken for palaeobotanical study aiming at the determination of the stratigraphic position of the organogenic deposits and a presentation of the vegetational history in the region of the site. The research study was financed from the fund of the Department of Earth Sciences, Silesian University, in Katowice and the fund for Research Project KBN No 6P04D 037 08.

GEOLOGICAL BACKGROUND TO THE ORGANOGENIC DEPOSITS

Sandy formations occurring very commonly on the surface in the region of the Zalesiaki site, are referred by Skompski (1971) to the lower valley outwash fan built up during the Warta Glaciation.

The organogenic sediments present in a small depression, 170 × 60 m in area, were examined palaeobotanically. They lie just under the ground surface, at a depth of 1.60–3.24 m (Fig. 2).

The lithological profile of the deposits is as follows:

depth [m]description of deposits:

0.00–0.10 slightly muddy, grey, sandy soil

0.10–0.19 strongly sandy peat with numerous pebbles (mainly flints) up to 5 cm in dia.

0.19–0.40 varigrained sand

0.40–0.90 varigrained sand and gravels, white-cream, in parts slightly clayey, with pavement layer (granitoids, porphyries, flints, limestones) up to 20 cm in dia. at the top

0.90–1.44 grey clay, slightly greenish, in places yellowish, very sandy with sporadic fragments of flints and limestones and, in places, with small inserts of varigrained yellow sand

1.44–1.60 grey plastic sandy silt

1.60–1.94 light brown organic silt, with very slight admixture of sand, lightly plastic, HCl^-

1.94–2.38 dark brown organic silt, very weakly plastic, HCl^-

2.38–2.73 strongly decomposed peat, black, brittle, with numerous sandy laminae, HCl^-

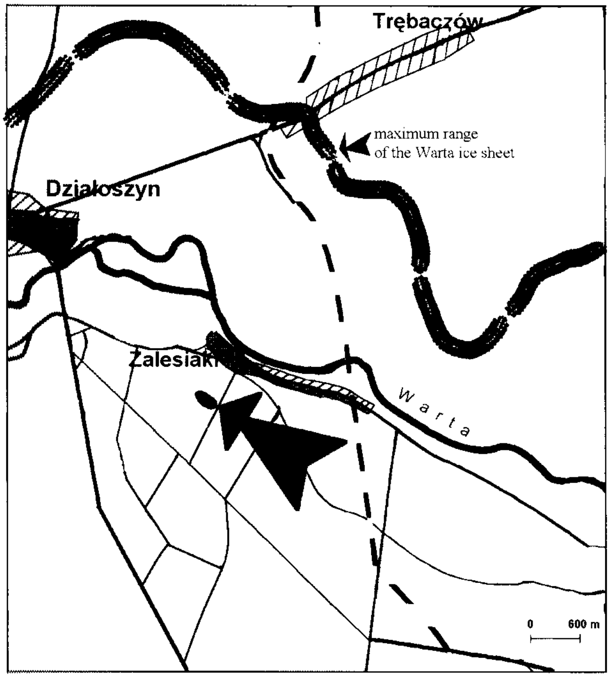

Fig. 1. Location of the Zalesiaki site

2.73–3.23 strongly decomposed peat, compact, at top slightly sandy, HCl⁻

3.23–3.24 brown organic silt, HCl⁻

3.24–3.35 medium-grained light yellow sand

The genesis of the grey-yellow clay which overlies the silts covering the organogenic deposits, at a depth of 0.90–1.44 m, is controversial. The Zalesiaki site lies in the direct forefield of the Warta Glaciation (Fig. 1). The maximum range of the ice sheet extended several kilometres to the north and north-east of this site (Baraniecka & Sarnacka 1971, Skompski 1971, Haisig 1974). According to present-day opinion, the origin of the clay cannot therefore be attributed directly to the Warta ice sheet. On the basis of macroscopic field observations neither can it be regarded as typical boulder clay. Probably, it occurs only locally in the depression, since it has not been found in the profiles of several probes made on neighbouring slopes. In this situation it seems most probable that this clay arose during the Odra Glaciation, and was later shifted and redeposited. The present configuration of the ground allows us to speculate that some slopes may have existed around the depression which were sufficiently steep for solifluction to have occurred. It may be supposed that processes of this kind took place under the periglacial conditions of the Warta Glaciation. It may well be therefore that the organogenic deposits underlying the clay represent the Pilica Interstadial/Interglacial.

The TL dating of the sample of silt occurring under the clay determined its age at 155 000 ± 40 000 BP (laboratory of the Silesian Polytechnic at Gliwice), which allows us to refer the deposits under study to the Pilica Interstadial/Interglacial but does not exclude other stratigraphical positions. The sands which underlie the organogenic deposits were not dated, since owing to hydrogeological con-

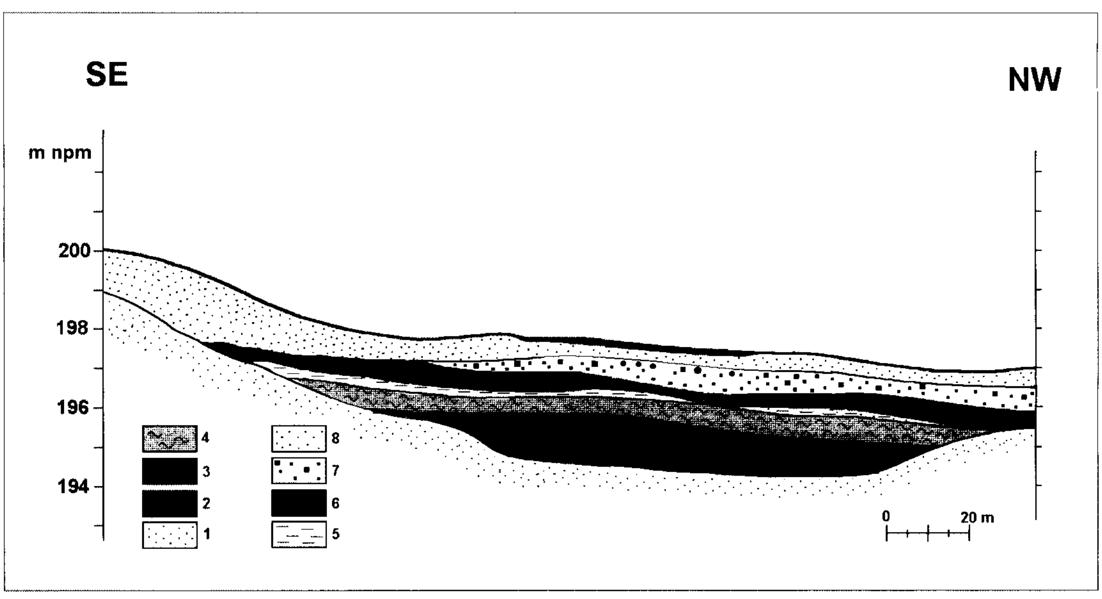

Fig. 2. Geological section through the Quaternary deposits of the Zalesiaki site. **1** – medium-grained sand, **2** – peat, **3** – organic silt, **4** – sandy silt, **5** – grey sandy silt, **6** – clay, **7** – varigrained sand and gravels, **8** – varigrained sand

Fig. 3. Percentage pollen diagram from Zalesiaki. Grain size distribution: 1. <0.002, 2. 0.002–0.005, 3. 0.005–0.01, 4. 0.01–0.05, 5. 0.05–0.1 6. 0.1–0.25, 7. 0.25–0.5, 8. 0.5–1.0 [mm]
Lithology: 1 – peat, 2 – organic silt, 3 – sandy silt

not dated, since owing to hydrogeological conditions (perched water-table) no samples could be taken. The results of TL dating should be treated with great caution as the geological status of the deposits is not quite clear (Baraniecka 1990b, Stankowski 1990). There are no boulder clays of the Odra Glaciation on the surface in the neighbourhood of the site. The Upper Oxfordian limestones come very close to the surface here so it may be supposed that in many places the overlying formations have not survived. Generally, however, boulder clay of the Odra Glaciation occurs in this region in the form of a tight mantle covered with fluvioglacial sediments. It cannot be completely ruled out therefore, that the grey-yellow clay overlying the organogenic deposits in the Zalesiaki profile originated during the Odra Glaciation and now occurs in situ, even though this seems a little improbable. In this situation the results of dating would be false and the organogenic deposits would represent one of the earlier periods of the Pleistocene.

STUDY METHODS

This work is based on palaeobotanical studies carried out by the method of pollen analysis and an analysis of plant macrofossils. Samples were derived from a pit, 3.35 m deep. A grain-size analysis of the deposit was additionally conducted by the pipetting method as well as an analysis of the organic matter content. The results of both these analyses are presented in a pollen diagram.

Samples for study by pollen analysis were subjected to maceration, applying 10% KOH, 10% HCl, 40% HF and Erdtman's acetolysis. Preparations were stored in glycerine.

Sporomorphs were counted chiefly with the use of a PZO Biolar microscope at magnifications of ×500 and ×1250. More difficult determinations were made with the help of an Amplival Zeiss microscope at the W. Szafer Institute of Botany, PAScs in Kraków.

Deposit samples, 50 cm^3 in volume, were boiled with an addition of 10% KOH and next rinsed on sieves of 0.5 and 0.2 mm meshes. Remains were segregated and identified under a Karl Zeiss Jena binocular microscope, using a comparative collection at the W. Szafer Institute of Botany, PAScs in Kraków.

The results obtained are illustrated by pollen and plant macrofossil diagrams. Both types of diagram were prepared and drawn using the POLPAL programme produced by Dr. Adam Walanus of the Institute of Physics, Silesian Polytechnic, at Gliwice.

The total pollen of trees, shrubs and terrestrial herbaceous plants (P) constituted the basis for percentage calculations in the pollen diagram. The percentage occurrence of pollen of aquatic and reedswamp plants, spores of Pteridophyta and Bryophyta was computed in relation to this basic total (P) plus the contribution of the given taxon.

The diagram of plant macrofossils was constructed in the form of a histogram, showing the absolute numbers of specimens in a given sample.

FLORA LIST

The flora list (Tab. 1) based on the results of analyses of pollen and plant macrofossils contains 178 taxa varying in rank, 78 of which were identified to species level. The names of taxa have been taken from Mirek et al. (1995) and Ehrendorfer (1973). For extinct plants, the names used are those given by the authors of identifications.

DESCRIPTION OF THE LOCAL POLLEN ASSEMBLAGE ZONES

The pollen diagram from the Zalesiaki site has been divided into six local pollen assemblage zones (L PAZ), according to the principles given by West (1970), Birks (1973), Janczyk-Kopikowa (1987) and Goździk et al. (1988). Each zone is marked with the letter Z (=Zalesiaki), numbered from the bottom upwards and bears a name (Fig. 3).

Z-1 *Betula-Salix*-NAP L PAZ

Depth: 3.24–3.16 m; frequency: AP 57–121 grains/cm^2, NAP 26–33 grains/cm^2

The pollen proportion of trees and shrubs is 69.0–78.6%. Pollen of *Betula* undiff. (max. 52.8%). and *Pinus sylvestris* type (15.7–23.9%) is dominant. The pollen value of *Salix glauca* type reaches 2.9% and *Betula nana* 1.4%. The variety of herbaceous taxa is considerable. Poaceae undiff. (to 13.3%), Cyperaceae (to 6.8%) and *Artemisia* (to 6.3%) pollen predominates; pollen of *Parnassia palustris*, *Comarum palustre*, *Sanguisorba officinalis* (2n=56), *Gypsophila fastigiata* type, *Bupleurum, Veronica, Saxifraga hirculus* type, *Geum*, *Aster* type and others occurs sporadically.

The zone has no lower boundary, while the upper one is indicated by the rise in the pollen values of trees and shrubs (AP), brought about by a rapid increase in the *Pinus sylvestris* type, and by a fall in *Betula* undiff. and *Salix glauca* type.

Table 1. Flora list

Key:
P – pollen
S – spores
M – macrospores
+ – *Pediastrum* occurrence
F – fruits, seeds, fruit scales etc.
N – hairs, needles, sclerotia etc.
W – wood
→ – spills over to a neighbouring zone
♣ – maximum values or most frequent occurrence
♦ – occurs only in one sample within the given zone (1–3 specimens)

ZALESIAKI	Local pollen assemblage zones L PAZ					
	Z-1 Betula-Salix-NAP	Z-2 Pinus-Betula	Z-3 Pinus-Quercus-Alnus-(Ulmus)	Z-4 Pinus-Carpinus-Alnus	Z-5 Betula-Pinus	Z-6 Pinus-NAP-Betula nana
	1	2	3	4	5	6
CHLOROPHYTA						
Hydrodictyaceae						
Pediastrum Meyen	+	+	+	+	+	+♣
MYCOTA						
Hyphomycetes						
Cenococcum graniformae (Sow.) Ferd. & Winge	–	–	N♦	N	–	–
BRYOPHYTA						
Musci (excl. *Sphagnum* Ehrh.)	S♣	S	S	S	S	S♣
Sphagnaceae						
Sphagnum Ehrh.	S	S	S♣	S♣	S	S
PTERYDOPHYTA						
Equisetaceae						
Equisetum L.	S♦	–	S	S	S	S♦
Huperziaceae						
Huperzia selago (L.) Bernh. ex Schrank & Mart.	–	–	–	S♦	S♦	S♦
Hypolepidaceae						
Pteridium aquilinum (L.) Kuhn	S	S♦	S♣	S	S	–
Isoëtaceae						
Isoëtes L.	M♦	–	–	–	M	M
Lycopodiaceae						
Lycopodium annotinum L.	S♦	–	S♦	S	S♦	S♦
Lycopodium clavatum L.	S♦	–	S	S	–	S♦
Ophioglossaceae						
Botrychium Sw.	S♦	–	S♦	–	S	S
Osmundaceae						
Osmunda cinnamomea L.	–	–	–	–	S♦	–
Thelypteridaceae						
Thelypteris palustris Schott	–	–	S	–	–	–
Filicales monolete	S	S	S♣	S	S	S
GYMNOSPERMAE						
Cupressaceae						
Juniperus L.	P	P♦	–	P♦	P	P
Ephedraceae						
Ephedra distachya L. type	–	–	–	–	–	P♦
Pinaceae						
Abies Mill.	–	–	P	P	–	–
Larix Mill.	P	P	P	P	P	P
Picea abies (L.) H. Karst.	P	P	P	P	P	P
Pinus sylvestris L.	–	–	N♦W♦	–	–	–

Table 1. Continued

	1	2	3	4	5	6
Pinus sylvestris L. type	P	P	P♣	P	P	P
Pinus L.	–	–	–	W	W	–
ANGIOSPERMAE						
Aceraceae						
Acer L.	–	–	P♦	P♦	–	–
Alismataceae						
Alisma plantago-aquatica L.	–	–	–	F♦	F	–
Apiaceae (Umbelliferae)						
Bupleurum L.	P	–	–	P♦	–	P
Apiaceae undiff.	P	P	P♣	P	P	P
Asteraceae						
Anthemis L. type	P	P	P	P	P	P♣
Artemisia L.	P♣	P	P	P	P	P♣
Aster L. type	P♦	P	P	P	P	P♦
Centaurea cf. *montana* L.	–	–	–	–	P♦	–
Cirsium Mill.	–	–	P♦	–	–	–
Eupatorium cannabinum L.	–	–	–	F♦	–	–
Senecio L. type	–	–	–	P♦	P♦	–
Solidago L. type	P	P	P	P	P	P
Asteraceae undiff.	–	–	–	–	P	P
Betulaceae						
Alnus Mill.	–	–	–	–	W♦	–
Alnus glutinosa (L.) Gaertn. type	P	P	P	P♣	P	P
Alnus Mill. / *Betula* L.	–	–	–	–	W♦	
Betula sect. Albae	–	–	–	–	F♦	–
Betula nana L.	P	P	PF	P F→	P	P♣
Betula cf. *nana* L.	–	–	F♦	F♦	–	–
Betula sect. Nanae	–	–	–	F♦	F♦	–
Betula pubescens Ehrh.	–	–	–	F	–	–
Betula cf. *pubescens* Ehrh.	–	–	F♦	F	F	–
Betula cf. *pendula* Roth	–	–	F♦	F♦	–	–
Betula L.	–	–	W♦	W♦	–	–
Betula L. undiff.	P♣	P	PF♦	PF	PF	P
Brassicaceae (Cruciferae)	P	–	P	P	P	P
Callitrichaceae						
Callitriche autumnalis L. em. Wahlenb.	–	–	–	F♦	F	–
Campanulaceae						
Campanula L.	–	–	–	P	P	P
Cannabaceae						
Humulus lupulus L.	–	P♦	P	P♣	P♦	–
Caprifoliaceae						
Sambucus nigra L.	–	–	–	–	P♦	P♦
Viburnum L.	–	–	P♦	–	–	–
Caryophyllaceae						
Cerastium L./ *Stellaria* L.	P	P♦	–	P	P	P♣
Gypsophila fastigiata L. type	P♦	–	–	–	–	P♦
Silene L. type	P♦	P♦	–	–	P♦	P♦
Spergula arvensis L. type	–	–	P♦	–	–	–
Caryophyllaceae undiff.	P	–	P♦	P	P♦	P
Ceratophyllaceae						
Ceratophyllum L.	N	N	N	N♦	N♦	N♦
Ceratophyllum demersum L.	–	–	F♦	F♦	F	–
Ceratophyllum submersum L.	–	–	–	F♦	F♦	–
Chenopodiaceae	P	P	P	P	P	P
Chenopodium album L.	–	–	–	–	F♦	–

Table 1. Continued

	1	2	3	4	5	6
Cichoriaceae	P	–	–	P	P	P
Cistaceae						
Helianthemum canum (L.) Baumg. / *H. alpestre* (Jacq.) Dunal	–	–	–	–	–	P
Corylaceae						
Carpinus L.	–	P	P	P♣	P	P
Corylus L.	P	P	P	P♣	P	P
Cyperaceae						
Bolboschoenus maritimus (L.) Palla	–	–	F♦	F♦	F♦	–
Carex cf. *cespitosa* L.	–	–	F♦	–	–	–
Carex elata All.	–	–	–	F♦	F	–
Carex cf. *elata* All.	–	–	F	–	F	–
Carex gracilis Curtis	–	–	F♣	F	F	–
Carex cf. *gracilis* Curtis	–	–	–	F♦	F♦	–
Carex cf. *pseudocyperus* L.	–	–	F	–	–	–
Carex rostrata Stokes	–	–	F♦	F	F♣	F
Carex cf. *rostrata* Stokes	–	–	–	F♦	F♦	–
Carex sect. Acutae	–	–	F♦	F	F	–
Carex L. undiff.	–	–	F	F	F	–
Dulichium spathaceum Pers.	–	–	F♦	F	F♦	–
Eleocharis palustris (L.) Roem & Schult.	–	–	–	F♦	–	–
Eleocharis praemaximoviczii Wieliczk.	–	–	F♣	F♦	–	–
Eleocharis R.Br. undiff.	–	–	–	–	F♦	–
Schoenoplectus lacustris (L.) Palla	–	–	F	F	F	–
Schoenoplectus tabernaemontani (C. C. Gmel.) Palla	–	–	–	–	F♦	–
Scirpus atroviroides Dorof.	–	F	F	–	F♣→	–
Scirpus torreyi Olney	–	–	–	F♦	–	–
Cyperaceae undiff.	P	P	P	P	P	P
Droseraceae						
Aldrovanda vesiculosa L.	–	–	–	–	F	–
Drosera anglica Huds.	–	–	P♦	–	–	–
Elaeagnaceae						
HippophaD rhamnoides L.	P♦	–	–	–	–	P♦
Ericaceae						
Calluna vulgaris (L.) Hull	P	P♦	P	P♣	P	P
Ericaceae undiff.	P	P♦	P	P♣	P	P
Euphorbiaceae						
Euphorbia L.	–	–	–	–	–	P
Mercurialis cf. *perennis* L.	–	P♦	–	–	–	–
Fabaceae (Papilionaceae)	–	–	P♦	–	–	–
Fagaceae						
Fagus L.	–	–	–	–	P♦	–
Quercus L.	P	P	P♣	P	P	P♦
Haloragaceae						
Myriophyllum spicatum L.	P	P	P	P	PF♦	P♣
Myriophyllum cf. *spicatum* L.	–	–	–	–	F♦	–
Myriophyllum verticillatum L.	P♦	–	–	P♦	P	–
Myriophyllum L. undiff.	–	–	–	–	F♦	–
Juncaceae						
Juncus L.	–	F♦	–	–	F	–
Lamiaceae (Labiatae)						
cf. *Lycopus* L.	–	–	P	–	–	–
Lycopus europaeus L.	–	–	F♦	F	–	–
Mentha L.	–	–	F	F	–	–
Mentha L. type	P♦	–	–	–	–	P♦
Lamiaceae undiff.	–	–	–	–	F♦	–

Table 1. Continued

	1	2	3	4	5	6
Lentibulariaceae						
Utricularia L.	–	–	P♦	P	P	–
Lythraceae						
Lythrum L.	–	–	P♦	P	–	–
Menyanthaceae						
Menyanthes trifoliata L.	P♦	–	P♣F	PF	P	P♦
Nymphoides peltata (S. G. Gmel.) Kuntze	–	–	–	P	PF	–
Najadaceae						
Najas minor All.	–	–	F	F♦	–	–
Nymphaeaceae						
Brasenia schreberi J. F. Gmel.	–	–	–	–	F	–
Nuphar lutea (L.) Sibth. & Sm.	–	–	–	–	P♦	–
Nymphaea alba L.	–	–	–	P♦	P♦	–
Nymphaea candida C.Presl	–	–	P♦	–	–	–
Nymphaea L.	–	–	–	–	F♦	–
Oleaceae						
Fraxinus L.	–	–	P♦	P♦	P♦	–
Ligustrum L.	–	P♦	–	–	–	–
Parnassiaceae						
Parnassia palustris L.	P♦	–	–	–	–	P♦
Plantaginaceae						
Plantago major L.	P♦	P♦	P	P	P	P♦
Plantago maritima L. s.l.	P♦	–	P	P♦	P♦	P
Plantago maritima L. s.str.	–	–	–	–	–	P♦
Plumbaginaceae						
Armeria maritima (Mill.) Willd. (A-type)	–	–	–	–	P♦	–
Armeria maritima (Mill.) Willd. (B-type)	P♦	–	–	–	P	P♦
Poaceae (Gramineae)						
Phragmites Adans.	P♦	P♦	P	P♦	P	P
Poaceae undiff.	P	P	P	P	P	P♣
Polygonaceae						
Polygonum amphibium L.	–	–	–	–	F♦	P♦
Polygonum aviculare L. type	–	–	–	–	P	–
Polygonum bistorta L./ *P. viviparum* L.	–	P♦	–	–	–	P
Polygonum lapathifolium L.	–	–	–	–	F	–
Polygonum persicaria L. type	–	–	–	–	P♦	P♦
Rumex acetosa L. type	P	–	–	P	P	P
Rumex acetosella L. type	P	–	P♦	P♦	P	P
Rumex maritimus L.	–	–	–	–	F♦	–
Rumex sect. Acetosae	P	–	P♦	P♦	P♦	P
Potamogetonaceae						
Potamogeton dvinensis Wieliczk.	–	–	F♦	–	–	–
Potamogeton filiformis Pers.	–	–	–	F→	–	–
Potamogeton cf. *friesii* Rupr.	–	–	F♦	–	F♦	–
Potamogeton cf. *gramineus* L.	–	–	–	F♦→	–	–
Potamogeton natans L.	–	F♦	F♦	F♦	F	–
Potamogeton cf. *natans* L.	–	–	–	F♦	–	–
Potamogeton panormitanus Biv.	–	F♦	F♦	F♦→	–	–
Potamogeton cf. *panormitanus* Biv.	–	–	–	–	F♦	–
Potamogeton perfoliatus L.	–	–	–	–	F♦	–
Potamogeton praelongus Wulfen	–	–	–	F	F	F
Potamogeton cf. *praelongus* Wulfen	–	–	–	F♦→	–	–
Potamogeton pusillus L.	–	–	–	–	F	–
Potamogeton cf. *pusillus* L.	–	–	–	–	F♦→	–
Potamogeton rutilus Wolfg.	–	F♦	–	F♦	–	–
Potamogeton sarjanensis Wieliczk.	–	–	–	–	F	–

Table 1. Continued

	1	2	3	4	5	6
Potamogeton vaginatus Turcz.	–	–	–	F♦→	–	–
Potamogeton sect. Coleogeton	–	–	–	P♦	P♦	–
Potamogeton sect. Eupotamogeton	P♦	–	–	P	P	P
Potamogeton L. undiff.	–	–	F	F	F	–
Primulaceae						
Lysimachia nemorum L.	–	–	P	–	–	–
Lysimachia thyrsiflora L.	–	–	–	–	P♦	–
Ranunculaceae						
Anemone L. type	–	–	P♦	P	P	–
Batrachium (DC.) S. F. Gray	–	F♦	–	F	F	F
Caltha L. type	–	–	P♦	P	P♦	–
Ranunculus acris L. type	P	P	P♦	P	P	P
Ranunculus flammula L. type	P	P	P	P	P	P
Ranunculus sceleratus L.	–	–	–	–	F	–
Ranunculus L. undiff.	–	–	–	–	F♦	–
Thalictrum L.	P	P	P	P	P	P♣
Rhamnaceae						
Frangula alnus Mill.	P	P♦	P	P	P	P♦
Rosaceae						
Comarum palustre L.	P♦	–	–	P♦F♦	P	P♦
Filipendula Mill.	P	P	P	P	P	P
Geum L.	P♦	–	–	–	P♦	P
Potentilla L.	–	–	–	–	F	–
Potentilla L. type	P♦	–	P	P	P	–
Rosa L.	P♦	–	–	–	–	–
Sanguisorba officinalis L. 2n=28	–	–	–	–	P	P
Sanguisorba officinalis L. 2n=56	P♦	P♦	P♦	–	–	–
Rosaceae undiff.	P	P	P	P	P	P
Rubiaceae	P	P	P	P	P	P
Salicaceae						
Populus tremula L. type	–	P♦	P	P♦	P	–
Salix glauca type	P♣	P	P	P	P	P
Salix pentandra L. type	–	P	P♦	P♦	P	P♦
Saxifragaceae						
Saxifraga cernua L. type	–	–	–	–	–	P♦
Saxifraga hirculus L. type	P♦	–	–	P♦	–	–
Scrophulariaceae						
Rhinanthus L. type	P♦	–	P♦	P♦	P♦	P
Veronica L.	P♦	–	–	–	P♦	–
Sparganiaceae						
Sparganium emersum Rehmann	–	F♦	F♦	F♦	F♦	–
Sparganium L. type	P	–	P	P	P♣	P
Sparganium L. undiff.	–	F	–	F♦	F	–
Tiliaceae						
Tilia cordata Mill. type	–	–	P♦	P♣	P	–
Typhaceae						
Typha latifolia L.	P	P	P♣	P	P	P♦
Typha L.	–	F♦	F♣	F	F→	–
Ulmaceae						
Ulmus L.	P♦	P	P♣	P	P	P♦
Urticaceae						
Urtica dioica L.	–	F♦	P♦F	PF♣	–	–
Valerianaceae						
Valeriana L.	P♦	P♦	–	–	P♦	P
Violaceae						
Viola palustris L.	–	–	–	–	–	F♦

Z-2 *Pinus-Betula* L PAZ

Depth: 3.16–3.08 m; frequency: AP 98–185 grains/cm^2, NAP 11–15 grains/cm^2

The proportion of tree and shrub pollen is high (87.5–94.9%). Pollen of *Pinus sylvestris* type prevails (max. 52.3%), but after a short lived fall, *Betula* undiff. again reaches high values (to 45.3%). The pollen values of *Betula nana* decrease to 0.2%. Poaceae undiff., Cyperaceae and *Artemisia* have the highest pollen values among herbaceous plants. Noteworthy is the occurrence of *Sanguisorba officinalis* (2n=56), *Polygonum bistorta*/*P. viviparum*, *Mercurialis* cf. *perennis* and *Valeriana*.

The upper boundary of the zone is indicated by an increase in the pollen values of *Pinus sylvestris* type and *Quercus* and a fall in the proportion of *Betula* undiff.

Z-3 *Pinus-Quercus-Alnus-(Ulmus)* L PAZ

Depth: 3.08–2.83 m; frequency: AP 32–210 grains /cm^2, NAP 4–9 grains/cm^2

The proportion of tree and shrub pollen comes to 88.4–95.6%. Pollen of *Pinus sylvestris* type (max. 69.2%) is dominant, *Quercus* and *Alnus glutinosa* type have relatively high values (to 17.7 and 7.0% respectively), while *Carpinus* and *Ulmus* pollen values are low (1.5 and 1.6% respectively). *Betula nana* was present in the bottom and top samples. Cyperaceae and Poaceae undiff. prevail among the herbs. The presence of sporadic pollen grains of *Lysimachia nemorum*, *Drosera anglica*, cf. *Lycopus*, *Cirsium*, *Spergula arvensis* type, *Anemone* type, *Rhinanthus* type and of the aquatic *Utricularia* is worthy of notice.

The upper boundary of the zone is indicated by a rise in the pollen value of *Carpinus* and a fall in the proportion of *Quercus*.

The zone has been divided into two subzones: Z-3a *Pinus* and Z-3b *Quercus*.

Subzone Z-3a *Pinus* is characterized by the highest pollen values of *Pinus sylvestris* type throughout the profile. The proportions of both *Quercus* and *Alnus glutinosa* type go up to 7.0% each.

Subzone Z-3b *Quercus* is distinguishable by the high proportion of *Quercus* pollen, while values of *Pinus sylvestris* type remain high. The Filicales monolete spores reach very high values (max. 76.0%).

Z-4 *Pinus-Carpinus-Alnus* L PAZ

Depth: 2.83–2.36 m; frequency: AP 129–345 grains/cm^2, NAP 20–28 grains/cm^2

The proportion of pollen of trees and shrubs ranges between 82.3 and 93.1%. Pollen of *Pinus sylvestris* type predominates, but its values decrease in the younger part of the zone. *Alnus glutinosa* type and *Carpinus* have their maximum values: 10.7 and 8.3%. The proportion of *Quercus* approaches 4.9% and that of *Corylus* 3.2%. The pollen values of *Picea abies* are very low, only in a few samples exceeding 1%, but these are its highest values in the whole profile. *Betula nana* is again noted more frequently. Cyperaceae and Poaceae undiff. prevail among the herbaceous plants. Pollen of *Humulus lupulus* is fairly abundant and pollen of *Anemone* type, *Saxifraga hirculus* type, *Lythrum*, *Bupleurum*, etc. occurs sporadically. As regards aquatic plants, *Utricularia* and *Nymphoides peltata* occur.

The upper boundary of the zone is indicated by an increase in the proportion of *Betula* undiff. pollen and by a fall in the values of *Alnus glutinosa* type and *Carpinus*.

Z-5 *Betula-Pinus* L PAZ

Depth: 2.36–1.78 m; frequency: AP 104–209 grains/cm^2, NAP 21–32 grains/cm^2

The proportion of tree and shrub pollen is still high, varying between 75.8 and 91.3%. The pollen values of *Pinus sylvestris* type fluctuate between 39.9 and 58.8% and *Betula* undiff. between 23.8 and 35.9%. *Betula nana* is represented by a continuous per mil curve. Cyperaceae and Poaceae undiff. are dominant among the herbs but the proportion of *Artemisia* pollen rises to 1.7%. Pollen of *Centaurea* cf. *montana*, *Polygonum aviculare* type, *Sanguisorba offcinalis* (2n=28), *Geum*, *Anemone* type, *Veronica* and *Silene* type appears sporadically.

The upper boundary of the zone is indicated by a rise in the values of *Betula nana* and by a fall in the AP values induced by a decrease in *Pinus sylvestris* type and *Betula* undiff.

The zone has been divided into two subzones: Z-5a *Betula* and Z-5b *Pinus*-Poaceae.

Subzone Z-5a *Betula* is conspicuous by a rise in the pollen proportion of *Betula* undiff. The pollen values of *Salix glauca* type and *Betula nana* increase slightly.

Subzone Z-5b *Pinus*-Poaceae is characterized by a small rise in the pollen values of

Pinus sylvestris type and Poaceae undiff. and a fall in the proportion of *Betula* undiff.

Z-6 *Pinus*-NAP-*Betula nana* L PAZ

Depth: 1.78–1.60 m; frequency of pollen low: AP 25–91 grains/cm^2, NAP 21–41 grains/cm^2

The proportion of tree and shrub pollen diminishes towards the top of the zone (70.2–54.3%). The fall is caused mainly by a decrease in the pollen values of *Pinus sylvestris* type and *Betula* undiff., which in the top sample are, respectively, 36.4 and 11.7%. The values of *Betula nana* rise to reach 2.3%. Poaceae undiff. (31.7%), *Artemisia* (6.7%) and Cyperaceae (3.8%) show the highest proportions among the herbaceous plants, which are also characterized by a remarkable variety of taxa. Of these the more significant ones are: *Sanguisorba officinalis* (2n=28), *Parnassia palustris*, *Helianthemum canum*/*H. alpestre*, *Plantago maritima* s.l., *P. maritima* s.str., *Polygonum bistorta* / *P. viviparum*, *P. persicaria* type, *Geum*, *Euphorbia*, *Bupleurum*, *Valeriana*, *Rhinanthus* type, *Saxifraga cernua* type and others.

The zone has no upper boundary.

DESCRIPTION OF LOCAL MACROFOSSIL ASSEMBLAGE ZONES

The diagram of plant macrofossils has been divided into four local zones designated by the capitals ZM and numbered from the bottom of the profile upwards (Fig. 4). The correlation of these zones with the local pollen assemblage zones is shown in Table 2.

ZM-1 L MAZ (depth: 3.24–2.99 m)

Small numbers of macrofossils are present. They are mainly fruits of *Scirpus atroviroides*, *Sparganium*, *Typha*, *Carex rostrata*, *Carex* cf. *elata*, seeds of *Juncus* and endocarps of *Potamogeton natans*, *P. panormitanus* and *P. rutilus*. A single macrospore of *Isoëtes* was found in the bottom sample.

The zone has no lower boundary; the upper is placed below the rise in number of reed-swamp plant remains.

ZM-2 L MAZ (depth: 2.99–2.50 m)

Very numerous fruits of *Typha*, *Eleocharis praemaximoviczii* and *Carex gracilis* occur in the older part of the zone.

Fairly numerous are the remains of birch (nutlets, fruit scales of *Betula nana*, *B. pubescens*, *B.* cf. *pendula* and pieces of *Betula* wood) and of herbaceous plants: *Lycopus europaeus*, *Urtica dioica*, *Menyanthes trifoliata*, *Mentha,* etc. Fruits of aquatics – *Najas minor*, *Ceratophyllum demersum* and various species of *Potamogeton* – occur sporadically. Fruits of *Dulichium spathaceum* occasionally turn up.

The upper boundary of the zone is placed just below the sample in which the continuous occurrence of *Batrachium* fruits begins.

ZM-3 L MAZ (depth: 2.50–2.02 m)

In the deposits of this zone the remains of aquatic plants are the most numerous in the

Table 2. Correlation of local pollen assemblage zones (L PAZ) with local macrofossil assemblage zones (L MAZ)

<table>
<tr><th colspan="2">Local pollen assemblage zones (L PAZ)</th><th>Local macrofossil assemblage zones (L MAZ)</th></tr>
<tr><td colspan="2">Z-6 Pinus-NAP-Betula nana</td><td rowspan="2">ZM-4</td></tr>
<tr><td rowspan="2">Z-5 Betula-Pinus</td><td>b Pinus-Poaceae</td></tr>
<tr><td>a Betula</td><td rowspan="2">ZM-3</td></tr>
<tr><td colspan="2" rowspan="2">Z-4 Pinus-Carpinus-Alnus</td></tr>
<tr><td rowspan="2">ZM-2</td></tr>
<tr><td rowspan="2">Z-3 Pinus-Quercus-Alnus (Ulmus)</td><td>b Quercus</td></tr>
<tr><td>a Pinus</td><td rowspan="3">ZM-1</td></tr>
<tr><td colspan="2">Z-2 Pinus-Betula</td></tr>
<tr><td colspan="2">Z-1 Betula-Salix-NAP</td></tr>
</table>

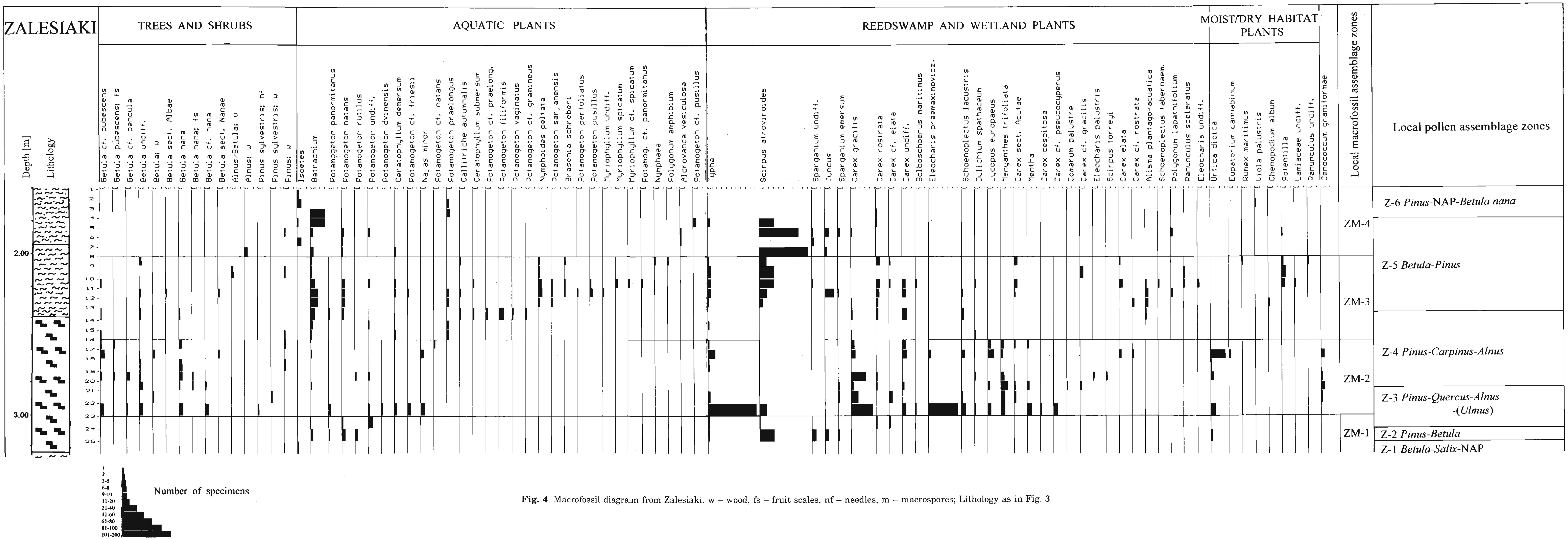

Fig. 4. Macrofossil diagram from Zalesiaki. w – wood, fs – fruit scales, nf – needles, m – macrospores; Lithology as in Fig. 3

whole profile. They are mainly endocarps of *Potamogeton* (*P. praelongus*, *P. sarjanensis*, *P. pusillus* and others), fruits of *Ceratophyllum demersum*, *C. submersum* and *Batrachium*. Remains of *Dulichium spathaceum*, *Brasenia schreberi* and *Nymphoides peltata* are present. Less numerous are those of *Typha*, *Carex gracilis* and others.

The upper boundary is indicated below the steep rise in the number of fruits of *Scirpus atroviroides* and, at the same time, above the decrease in the number of remains of aquatic plants.

ZM-4 L MAZ (depth: 2.02–1.60 m)

Fruits of *Scirpus atroviroides* occur in abundance in the older part of the zone. The remains of other plants, mainly seeds of *Juncus* and fruits of *Sparganium* and *Carex rostrata*, are not numerous. Of the aquatic plants only remains of *Batrachium* are fairly frequent. Seeds of *Aldrovanda vesiculosa* occur in the older part of the zone and some macrospores of *Isoëtes* appear.

The zone has no upper boundary.

VEGETATIONAL HISTORY

The vegetational history of the Zalesiaki region has been based on local assemblage zones, including the results of the analysis of plant macrofossils.

Development of terrestrial vegetation

Z-1 *Betula-Salix*-NAP L PAZ

The sedimentation of organic silt with which the profile of organogenic deposits begins started in a period when forest communities were already dominant though not forming a continuous cover. This is clear from the fairly high NAP values (21.4–31.0%) and the large variety of taxa of herbaceous plants.

The dominant proportion of *Betula* undiff. pollen (max. 52.8%) indicates that birch forests grew chiefly in the lake region. The role of pine in forest communities was rather small. The low pollen values of *Pinus sylvestris* type (15.7–23.9%) suggest that this tree occurred only as an admixture in birch forests. Spores of *Lycopodium annotinum* and *Botrychium* may have come from the ground cover of birch-pine forests. The occurrence of *Calluna vulgaris* and *Lycopodium clavatum* was probably associated with dry types of these forests.

The presence of *Betula nana*, documented by the occurrence of its pollen, is of essential climatic significance. It may therefore be supposed that, in the surroundings of the water body, there were still preserved stands of vegetation from the previous cold period; they were in the nature of shrub tundra with dwarf birch and shrub willows (pollen of the *Salix glauca* type). The occurrence of open shrub communities is also suggested by the presence of *Hippophaë rhamnoides*, *Juniperus* and *Rosa*.

The forest, still not very close, undoubtedly left many open habitats, occupied by herb communities. The relatively high proportion of Poaceae undiff. and *Artemisia* pollen indicates that, among the communities of herbaceous plants in open habitats, grass communities on dry and poor soils were particularly widespread. *Gypsophila fastigiata* (*G. fastigiata* type), *Rumex acetosella* (*R. acetosella* type), Chenopodiaceae and perhaps also *Thalictrum* were associated with these habitats.

Favourable conditions for the development of marshy meadows probably existed also in the direct neighbourhood of the lake. Sedges and mosses were the main constituents of these communities, but *Menyanthes trifoliata*, *Comarum palustre*, *Parnassia palustris* undoubtedly occurred there as well and perhaps also *Ranunculus flammula* (*R. flammula* type) and *Veronica*.

Pollen of *Sanguisorba officinalis* (2n=56), *Plantago major*, *Rumex acetosa* type, *Filipendula*, *Valeriana*, *Geum* and *Ranunculus acris* type is probably associated with the moist meadow communities.

The presence of pollen of *Pantago maritima* s.l. as well as of *Armeria maritima* type possibly points to the existence of favourable conditions for the development of communities of "salty meadows".

Z-2 *Pinus-Betula* L PAZ

The rapid decrease in the pollen values of herbs clearly shows the restricted role played by open communities and the development of dense forest in the Zalesiaki region. Pine (*Pinus sylvestris* type), which, to be sure, had dominated the habitats occupied by herbaceous plants before then, began to play an important role in forest communities and, more-over, successfully competed with birch. The proportion of tree birches in the forest communities was, however, still very high, as is clear from the pollen values (up to 45.3%) of *Betula* undiff. Around the water body pine and pine-birch forests, growing in various types of habitats, were dominant. The presence of a spore of *Pteridium aquilinum* is surely derived from the herb layer of pine forest and probably so too is part of the Poaceae undiff. pollen and moss spores (Musci excl. *Sphagnum*).

Forest and scrub communities with shrub and tree willows (*Salix glauca* type, S. *pentandra* type) and poplars (*Populus tremula* type) continued to grow on alluvial soils, which probably occurred in the valleys of local streams. The occurrence of *Humulus lupulus* pollen and fruits of *Urtica dioica* may be referred to the herb layer of these communities, whose range was probably limited.

The presence of pollen of *Betula nana* points to the fact that despite an improvement in the climate, dwarf birch was still growing in the vicinity of the water body. Initially it would have been accompanied by shrub willows (*Salix glauca* type), but these declined very rapidly.

The low NAP proportion and the reduced diversity of herbaceous taxa compared with zone Z-1 indicate a considerable reduction in the role of open communities. In damp meadows, which then occupied only small areas by the lake shore, probably grew *Plantago major*, *Sanguisorba officinalis* (2n=56), *Filipendula*, *Valeriana*, *Polygonum bistorta* / *P. viviparum*, etc.

The rapid fall in the pollen values of Poaceae undiff. and the lower proportion of *Artemisia* also suggest the decreasing significance of grass communities in the drier habitats.

Z-3 *Pinus-Quercus-Alnus-(Ulmus)* L PAZ

The high pollen proportion of *Pinus sylvestris* type, particularly in subzone Z-3a *Pinus*, approaching 70%, bears witness to the huge role played by pine in forest communities at that time. The rather low values of *Betula* undiff. pollen indicate that birch occurred only as a small admixture in the pine forests, which continuously occupied different habitats. Pollen grains of *Calluna vulgaris* and *Rumex acetosella* type, occurring in small numbers, and also spores of *Lycopodium clavatum* and *Pteridium aquilinum* may have come from these forest communities.

The rise in the pollen value of *Quercus* to 1.8% in the bottom sample of zone Z-3 gives evidence of the beginning of transformations which were probably about to take place in pine forests, growing in the richer habitats. It may be supposed that as a consequence of these changes, mixed pine-oak forests came into being, with their optimum development occurring in subzone Z-3b *Quercus*, as is shown by the pollen proportion of oak reaching 17.7%. The nutlet of *Betula* cf. *pendula* proves the presence of verrucose birch in communities of this type. *Frangula alnus*, *Corylus*, *Viburnum* and aspen (pollen of *Populus tremula* type) occurred singly in their understorey. *Pteridium aquilinum* (to 3.7%) and other ferns were probably pretty abundant in the forest ground cover, which is suggested by the high curve of spores of Filicales monolete. The occurrence of *Potentilla* type, *Anemone* type and *Solidago* type pollen may also be associated with the ground cover of these forests.

The increase in the pollen values of *Alnus glutinosa* type, starting halfway up subzone Z-3a *Pinus,* is indicative of the encroachment of alder upon wet habitats and the formation of woods resembling present-day wet alderwoods. In less marshy habitats, presumably in the valleys of neighbouring streams, small stands of communities similar to today's riverine forests found suitable conditions to develop. Pine, birch (in addition to pollen of *Betula* undiff. there occur also nutlets of *B.* cf. *pubescens*), elm and ash made up a small admixture in alder communities. The continuous curve of *Ulmus*, with values reaching 1.6%, does not rule out the formation of alder-elm communities. The understorey consisted, among other taxa, of *Frangula alnus*, perhaps also *Viburnum* and shrub willows. *Lycopus europaeus* (fruits and pollen cf. *Lycopus*), *Humulus lupulus*, *Urtica dioica*, perhaps also *Filipendula* and *Lysimachia nemorum* grew in the ground cover. Some of the spores of Filicales monolete may also have come from alder forests.

The very low pollen values of *Picea abies* (below 1%) suggest that this tree was probably absent from the surroundings of the lake.

The presence of nutlets and sporadic grains of *Betula nana* pollen proves that, despite climate amelioration, dwarf birch grew in the vicinity of the lake as a relict from the previous cold period.

Z-4 *Pinus-Carpinus-Alnus* L PAZ

The slight but constant drop in the pollen value of *Pinus sylvestris* type points to the restricted content of pine in some of the forest communities. Forests with dominant pine, however, continued to prevail in the landscape of the Zalesiaki region. The pollen values of *Betula* undiff., higher than in the previous zone, show a rise in the role of birch in the pine communities. The nutlets of *Betula* cf. *pendula* and *B.* cf. *pubescens* and fruit scales of *B. pubescens* show that birch accompanied pine both in dry and moist habitats. The drastic fall in the pollen value of *Quercus* in comparison with its values in zone Z-3 indicates a considerable reduction in the role of mixed pine-oak forests.

The fact that the proportion of *Carpinus* pollen increases consistently, leads us to suppose that some stands of hornbeam forest with a small admixture of oak, were then developing in fertile habitats. Small-leaved lime, maple and elm probably occurred in these forests as well, and *Corylus* and *Frangula alnus* were certainly present in their understorey.

As in the preceding zone, alder forests with a dominant proportion of *Alnus glutinosa* (pollen of *A. glutinosa* type) and a small admixture of *Betula pubescens* and *Populus tremula* (pollen of *P. tremula* type), grew in wet habitats. Spruce may also have appeared in these forests. The very low pollen values of *Picea abies* (max. 1.6%) show that spruce may indeed have been present, but only as sporadic individuals. According to Środoń (1967), pollen values of *Picea* lying within the interval 1.1–3.0% are sufficiently high to point to the presence of spruce in situ. Pollen of *Frangula alnus*, *Humulus lupulus*, *Filipendula*, some spores of *Sphagnum* and Filicales monolete and also fruits of *Urtica dioica* are most likely to have been associated with these alder communities.

The small rise in the proportion of herbaceous plant pollen in the younger part of the zone is the first sign of deteriorating climatic conditions.

Z-5 *Betula-Pinus* L PAZ

The changes that took place in forest communities in the course of zone Z-5 consisted chiefly in the complete withdrawal of thermophilous deciduous trees and a radical reduction in alder forests. The Zalesiaki area was almost exclusively dominated by pine and pine-birch forests, but the proportion of birch in them increased considerably, particularly so during subzone Z-5a *Betula*, in which the pollen values of *Betula* undiff. go up to 35.9%. *Larix* supposedly occurred in these forests, as is indicated by the continuous per mil curve of its pollen. Pollen of *Juniperus*, *Calluna vulgaris*, *Rumex acetosella* type and spores of *Lycopodium annotinum* and *Botrychium* also originate from these communities.

The pollen proportion of trees and shrubs, still high in the older part of subzone Z-5a *Betula*, shows that the forest had remained dense. It is not until the younger part of the subzone that a rise takes place in NAP values, indicating a change in the nature of the vegetation, namely, the thinning of forest and the increasing role of open communities. The somewhat higher pollen values of *Betula nana* and *Salix glauca* type are a sign of the beginning of the spread of shrubby communities.

Distinct changes occurred in the surroundings of the lake. The habitats there which succeeded the alder forests were, in all probability, occupied by communities with a dominant proportion of *Scirpus atroviroides*. The slightly higher proportion of Cyperaceae pollen and the rapid rise in the proportion of moss spores (Musci excl. *Sphagnum*) noted in the youngest part of the zone provide clear evidence of the development of moss-sedge communities by the lake shore. They were undoubtedly accompanied by *Menyanthes trifoliata*, *Comarum palustre* and *Ranunculus flammula* (*R. flammula* type). *Juncus* was present in various plant communities associated with dampt soils. Pollen of *Caltha* type, *Rumex acetosa* type, *Filipendula*, *Valeriana*, *Sanguisorba officinalis* (2n=28) and perhaps also *Geum*, *Ranunculus acris* type and *Rhinanthus* type also comes from communities of damp meadows.

The small rise in the pollen values of Poaceae undiff. and *Artemisia* suggests the beginning of the development of grass communities in dry habitats. Pollen of *Rumex acetosella* type, *Armeria maritima* type, *Centaurea* cf. montana and some of the Chenopodiaceae pollen may have had their source in these communities.

Z-6 *Pinus*-NAP-*Betula nana* L PAZ

The further rise in NAP values is attributed to the progressive spread of herbaceous communities. The pine forests with an admixture of tree birches were gradually losing their previous significance. A small increase in the pollen value of *Alnus glutinosa* type can supposedly be ascribed to redeposition.

The retreating forest created more and more open habitats, invaded by photophilous communities. The increase in the pollen proportion of *Betula nana* (max. 2.3%) indicates the expansion of communities resembling shrub-tundra; shrub willows (*Salix glauca* type) no doubt accompanied dwarf birches in them. The presence of *Hippophaë rhamnoides*, *Ephedra distachya* type and *Juniperus* pollen shows that shrub communities were also present in dry habitats.

The grass communities were also gaining in importance all through the zone, as is indicated by a continuous increase in the pollen values of Poaceae undiff. and *Artemisia*. Probably, these communities were spreading over most of the areas vacated by the retreating forest. Pollen of *Gypsophila fastigiata* type, *Rumex acetosella* type and *Helianthemum canum/H. alpestre* may have originated in them.

Communities of marshy meadows with sedges and mosses as well as *Menyanthes trifoliata*, *Comarum palustre*, *Parnassia palustris* and *Ranunculus flammula* (*R. flammula* type) persisted on wet soils. The low proportion of Cyperaceae pollen, however, suggests that communities of this type could not have occupied large areas in the Zalesiaki region. Communities of moist meadows may have expanded over part of the habitats previously occupied by damp forms of pine forest. The occurrence of numerous herbaceous plants, such as *Sanguisorba officinalis* (2n=28), *Plantago major*, *Polygonum bistorta/P. viviparum*, *Filipendula*, *Valeriana*, *Rumex acetosa* (*R. acetosa* type), *Mentha* (*Mentha* type) and others, is associated with the communities of moist meadows.

The increase of NAP values to 45.7% in the top part of zone Z-6 allows us to suppose that open communities began to prevail in the landscape of the Zalesiaki region in the youngest part of this zone. The forest communities, being more and more driven from their habitats because of the deteriorating climate, were most probably reduced to small forest stands. A landscape resembling forest-tundra became dominant in this area.

THE OCCURRENCE OF MACROFOSSILS OF WATER PLANTS WITH HIGHER THERMAL REQUIREMENTS IN THE DEPOSITS OF THE ZALESIAKI SITE.

Seeds of *Aldrovanda vesiculosa* L, *Brasenia schreberi* J. F. Gmel. and *Nymphoides peltata* (S. G. Gmel.) Kuntze as well as fruits of *Dulichium spathaceum* Pers. have been found among the plant macrofossils occurring in the deposits from Zalesiaki. Of these species only *Aldrovanda vesiculosa* and *Nymphoides peltata* occur nowadays in Poland.

Nymphoides peltata forms the rarely encountered thermophilous communities of the suboceanic-mediterranean type (Matuszkiewicz 1981). According to Tomaszewicz (1979), the present-day phytocoenoses of *Nymphoidetum peltatae* (All. 1922) Oberd. et Müller 1960 develop in shallow nutrient rich waters (0.8–1.2 m) of alkaline reaction.

Aldrovanda vesiculosa is a rare water plant in Poland. It is considered to be a relict from the Holocene climatic optimum (Szafer 1972). Its seeds are present in many interglacial fossil sites. For instance, in the Mazovian Interglacial it occurs at Ciechanki Krzesimowskie (Brem 1953), Olszewice (Sobolewska 1956), Włodawa (Stachurska 1957), Stanowice (Sobolewska 1977) and in the Eemian Interglacial, e.g., at Otapy (Bitner 1956), Góra Kalwaria (Sobolewska 1961), Smolniki and Szwajcaria near Suwałki (Borówko-Dłużakowa 1971, 1975), Władysławów and Jóźwin/76 (Tobolski 1991).

Brasenia schreberi and *Dulichichium spathaceum* died out in Poland towards the end of the Eemian Interglacial (Szafer 1930, Środoń 1987).

The number of Pleistocene sites in which seeds of *Brasenia schreberi* (=*B. purpurea*) have been found is remarkable. For the Mazovian Interglacial one can mention, e.g., Nowiny Żukowskie (Dyakowska 1952), Ciechanki Krzesinowskie (Brem 1953), Włodawa (Stachurska 1957) and Stanowice (Sobolewska

1977). At all these sites *Brasenia schreberi* appears in deposits representing pollen period III, according to Szafer's division (1953). At Stanowice and Włodawa it occurs with *Aldrovanda vesiculosa* and *Dulichium spathaceum*.

Seeds of *Brasenia schreberi* have also been found in other interglacials; they have been reported from the Ferdynandów Interglacial (Ferdynandów site (Janczyk-Kopikowa 1975)), dating from the pine-birch period and at numerous sites of the Eemian Interglacial. The Jóźwin/76 and Władysławów sites exemplify the joint occurrence of macrofossils of *Brasenia schreberi* and *Aldrovanda vesiculosa* where these plants appear, together with *Salvinia natans* and *Stratiotes aloides*. Tobolski (1991) estimates the mean July temperature at about 20–21°C, based, among other findings, on the presence of seeds of *Brasenia schreberi*.

Fruits of *Dulichium spathaceum*, first found by Szafer (1930) at Samostrzelniki, are recorded less frequently. They are present, among other periods, in the Eemian Interglacial at Józefów (Oszast 1956), Główczyn (Niklewski 1968), and Jóźwin/76 (Tobolski 1991).

Brasenia schreberi and *Dulichium spathaceum* are thermophilous plants whose occurrence has so far been exclusively confined to interglacial periods. This short, but by no means full, survey of sites proves that the foregoing aquatic plants grew mostly in the interglacial climatic optima. When they were found in cooler periods, e.g. in the pine-birch period at Ferdynandów, it may be supposed that they survived till then from the optimum.

The changes in the vegetation of the Zalesiaki region represent an almost closed vegetation developmental cycle of an interstadial nature. These thermophilous aquatic plants have not been found in interstadial periods before. The comparatively high proportion of pollen of thermophilous deciduous trees, mainly *Quercus* and *Carpinus* (max. 17.7 and 8.3%, respectively) in zones Z-3 and Z-4 certainly suggests that the climate of the optimum was fairly warm. The diversity of forest communities was, however, low, for, apart from pine forest, there was only mixed pine-oak forest and small stands of communities with hornbeam, while alder communities grew in wet habitats. The composition of the forest communities therefore distinctly shows that the prevalent temperatures were lower than in the interglacial optima.

At Zalesiaki the occurrence of remains of thermophilous aquatic plants is observed in three successive pollen zones (Table 3). First fruits of *Dulichium spathaceum* turned up in the climatic optimum, followed somewhat later by pollen of *Nymphoides peltata*. It was, however, as late as zone Z-5 (and so in the period of development of pine-birch forests) that seeds of *Brasenia schreberi*, *Aldrovanda vesiculosa* and *Nymphoides peltata* first appeared. As regards the Zalesiaki site, a striking phenomenon is not only the occurrence of pollen and macrofossils of the above-mentioned thermophilous plants in deposits comprising a typical interstadial succession of vegetation, but also the almost simultaneous occurrence of pollen and nutlets of dwarf birch. *Betula nana* pollen is present nearly throughout this profile, whereas macrofossils (nutlets and fruit scales) occur only in the climatic optimum. The first occurrence of *Brasenia schreberi* seeds coincides with the beginning of the continuous pollen curve of *Betula nana*.

An interpretation of the pollen diagram suggests that in the optimal period the climate was rather mild, but presumably still too cool

Table 3. The occurrence of pollen and macrofossils of thermophilous aquatic plants and *Betula nana* in deposits of the Zalesiaki site (P – pollen, F – seeds,fruits,fruit scales, ↑ – transition to the neighbouring zone)

ZALESIAKI	*Dulichium spathaceum*	*Nymphoides peltata*	*Brasenia schreberi*	*Aldrovanda vesiculosa*	*Betula nana*
Z-6 *Pinus*-NAP-*Betula nana*	–	–	–	–	P
Z-5 *Betula-Pinus*	F	PF	F	F	P
Z-4 *Pinus-Carpinus-Alnus*	F	P	–	–	PF↑
Z-3 *Pinus-Quercus-Alnus-(Ulmus)*	F	–	–	–	PF
Z-2 *Pinus-Betula*	–	–	–	–	P
Z-1 *Betula-Salix*-NAP	–	–	–	–	P

to satisfy the requirements of *Brasenia schreberi* and *Dulichium spathaceum*. For this reason it seems probable that these plants did not grow in the water body at that time and their remains got into it by way of redeposition. The difficulties in interpreting this phenomenon are, however, increased by the data obtained from an analysis of the deposit, for we must ask by what means was it possible for the remains to have entered the lake. In the older part of the profile the sandy laminae in the peat indicate the presence of undoubtedly small water movements (washing processes), responsible for the delivery of sandy material. In this part of the profile both the fruits of *Dulichium spathaceum* and pollen of *Nymphoides peltata* occur, however, singly. Later, when these processes were supposedly less violent (as is shown by an analysis of the granulation of deposits, Fig. 3), remains of thermophilous aquatic plants and pollen of *Nymphoides peltata* are more frequent.

At the decline of zone Z-4, the nature of deposit changed from peat to organic silt. In the light of this change redeposition seems the most likely explanation for the occurrence of the macroscopic remains of thermophilous aquatic plants and pollen of *Nymphoides peltata*. And yet it still raises a series of doubts.

1. The question of whence and from what interglacial deposits macrofossils and pollen of thermophilous plants could have been redeposited seems pertinent because no interglacial sediments have as yet been found in the close vicinity.

2. It is hard to decide whether the processes of deposition embraced only remains of the above-mentioned plants or whether they included remains of other aquatic plants, such as *Najas minor* or perhaps *Ceratophyllum submersum*, whose occurrence in zone Z-5 also raises some doubts.

3. If pollen of *Nymphoides peltata* in zone Z-5 comes from redeposition, one would expect higher pollen values of thermophilous broad-leaved trees in this zone as well.

4. What is the nature of the occurrence of macrofossils of *Betula nana*: is it a relict from the cold period here, as in the case of the sites of the Eemian Interglacial in Kalisz (Tołpa 1952) or Nakło (Noryśkiewicz 1978); or should it be treated as the result of deposit disturbance?

The geological situation of the organic deposits at Zalesiaki makes it impossible to interpret the disturbances occurring there as the effect of the redeposition of sediments as a whole by the ice sheet, as happened at the site near Rostov (Sukachev 1954), where *Betula nana* remains and peat containing the seeds of *Brasenia schreberi* had been transported by the ice sheet and deposited within a moraine.

AQUATIC AND SWAMP VEGETATION

The sedimentation of organic silt began in a small and no doubt shallow lake at Zalesiaki. This small depression was next transformed into a peatbog.

ZM-1 L MAZ

Pollen assemblage zones: Z-1, Z-2 and the older part of Z-3

The presence of a macrospore of *Isoëtes* along with the lack of macrofossils and pollen of aquatic plants and the low organic matter content of the deposits (15%) point to very poor vegetation in the initial phase of development of the lake. In the period represented by the oldest part of the zone probably only *Isoëtes* grew in the water body, whose oligotrophic nature was the agent inhibiting the development of water plants with higher nutrient requirements.

The shallow and small lake soon changed into a peatbog, as is indicated by the peat layer. Apart from Cyperaceae and mosses it probably contained many species to be found in the swampy meadows which occurred on the peatbog margins. The role of reedswamp plants was still rather small. In the lake shore zone *Sparganium* (fruits and pollen of *Sparganium* type) reed-mace (pollen of *Typha latifolia*, fruits of *Typha*) and reed (*Phragmites*) were growing.

The peatbog was probably covered by a thin layer of water. The presence of *Myriophyllum spicatum* pollen and hairs of *Ceratophyllum* may suggest the beginning of changes leading to a gradual improvement in conditions in the water body.

The variety of aquatic plants increased in the younger part of zone ZM-1. In the developing communities with pondweeds – *Potamogeton natans*, *P. rutilus* and *P. panormitanus* – there were probably also *Myriophyllum spicatum*, *M. verticillatum* and *Ceratophyllum*. The presence of endocarps of *Potamogeton na-*

tans and a rise in the number of hairs of *Ceratophyllum* may point to a further increase in the nutrient resources of the water body.

ZM-2 L MAZ

Pollen assemblage zones: younger part of Z-3, older part of Z-4

A rapid development of reedswamp communities took place in the older part of zone ZM-2.

Typha, which had been occurring rather sporadically until then, became dominant in reedswamp communities. It may be supposed on the basis of the high proportion of *Typha latifolia* pollen (samples Nos 111 and 113) that a substantial number of the fruits of *Typha* also belong to this species. *Schoenoplectus lacustris*, *Bolboschoenus maritimus*, *Sparganium* and *Phragmites* also grew in these communities. *Lycopus europaeus* and *Mentha* may have accompanied them as well.

The communities with dominant *Typha latifolia* reached their peak development in the oldest part of zone ZM-2; later they were ousted probably by rapidly expanding communities with ferns, as is indicated by the very high values of spores of Filicales monolete (76%). The single spores recorded of *Thelypteris palustris* may be taken as evidence that this was one of the species of fern growing in the peatbog at this time, possibly accompanied by *Phragmites*, *Typha latifolia*, *Lycopus europaeus* and *Carex pseudocyperus* (nutlets).

The abundant nutlets of *Carex gracilis* found in deposits of this zone are evidence of the development of communities containing this species, probably in shallows or on exposed mud.

The fairly numerous fruits of *Eleocharis praemaximoviczii* found in the older part of zone ZM-2 provide evidence of its significant presence in lake shore plant communities.

The occurrence of *Drosera anglica* pollen may be associated with low-sedge, peat forming communities, supposedly with a high proportion of mosses.

Such aquatic plants as *Potamogeton panormitanus*, *P. rutilus*, *P.* cf. *friesii* and *Batrachium* grew in small numbers in very shallow water. The presence of fruits of *Najas minor* and *Ceratophyllum demersum* and pollen of *Nymphaea alba* points not only to the eutrophic conditions, but presumably also to a pretty high water temperature.

In the younger part of the zone, fruits of *Typha* occur in somewhat larger numbers, which again suggests its higher proportion in reedswamp communities.

ZM-3 L MAZ

Pollen assemblage zones: younger part of Z-4, older part of Z-5

The layer of silt overlying the peat indicates a change in hydrological conditions and this is reflected in the composition of the macrofossils and pollen.

The aquatic plants began to increase in number. The small depth of water favoured the development of rooted plants. The relatively nutrient rich water made it possible for communities composed chiefly of *Potamogeton filiformis*, *P. praelongus* and *P. natans* to develop. They may have been accompanied by *Alisma plantago-aquatica*, *Potamogeton perfoliatus*, *P. pusillus*, *Myriophyllum spicatum*, *Batrachium*, *Sparganium*, *Phragmites*, *Ceratophyllum demersum*, *Nuphar lutea* and many other aquatic plants.

The reedswamp communities no longer played such an important role as they had done in the previous zone. Small stands of communities with *Carex gracilis* may have persisted. Their maximal development occurred in the previous zone and, somewhat later, communities with *Carex rostrata* and *C. elata* appeared. *Alisma plantago-aquatica*, *Phragmites* and *Sparganium* may also have been growing in the sedge communities.

The fairly large number of fruits of *Scirpus atroviroides* and their continued presence in the younger part of zone ZM-3 provide evidence of the development of communities with this species in the close vicinity of the lake.

ZM-4 L MAZ

Pollen assemblage zones: younger part of zone Z-5 and zone Z-6

A gradual decrease in the organic matter content of deposits indicates worsening trophic conditions in the lake and the impoverishment of communities growing in it. This is confirmed also by the appearance of macrospores of *Isoëtes* and the occurrence of few macrofossils of other aquatic plants.

A few endocarps of *Potamogeton natans* and single hairs of *Ceratophyllum* suggest, however, that these plants may have still been growing in the lake in the older part of the zone.

The very low organic matter content of the younger part of zone ZM-4 (3%) shows the poverty of vegetation growing in the water body, which is also confirmed by the presence of single remains of only three taxa: *Batrachium*, *Potamogeton praelongus* and *Isoëtes*. The high pollen values of *Myriophyllum spicatum* found in the younger part of zone ZM-4 are most probably connected with redeposition.

PLANT SUCCESSION FROM ZALESIAKI IN COMPARISON WITH OTHER INTERSTADIAL SUCCESSIONS IN POLAND

The Zalesiaki pollen succession as a succession of the interstadial nature does not have diagnostic features which would enable us to determine the stratigraphic position of the organic deposits. The geological position of these deposits, underlying grey-yellow clay, does not rule out the possibility that it is of the Pilica Interglacial/Interstadial age, while the results of the TL dating of the silt lying below the clay (155 000 ± 40 000 BP) allow us to assume that the deposits were formed before the Warta Glaciation. An attempt has therefore been made to compare the pollen succession from Zalesiaki with other successions referred to this stratigraphic position known to occur in Poland.

The rank of the period separating the Odra and Warta deposits has been a subject of dispute for many years. In more recent stratigraphic divisions the rank of interglacial is most frequently ascribed to it (Lindner 1978, 1984, 1988a, b, c, Lindner & Prószyński 1979, Lindner & Grzybowski 1982, Różycki 1978, 1980, Buraczyński 1988, Baraniecka 1990a, 1993). Earlier opinions suggested rather an interstadial nature of this unit (Różycki 1972). There were also views that even rejected the presence of a warm interstadial between the "maximal stadial" and the Warta stadial (Mojski 1985, 1986).

In this somewhat confused situation, organic deposits representing various pollen successions have been referred to this stratigraphic position. Over a period of years, however, both opinions and the choice of representative sites to be included have been changing. In spite of many studies carried out there are no deposits known so far that might be regarded as stratitypic of this period.

The first palaeobotanically studied sites which were referred to this stratigraphic position defined as the Będzin Interstadial were Brzozowica (Gilewska & Stuchlik 1958) and Łabędy (Ralska-Jasiewiczowa 1958). The bases for drawing such conclusions were geological inferences and the correlation of the pollen diagrams with those relating to this stratigraphic position in eastern and western Europe (Suraż, Neu-Ohe). The organogenic deposits of the two Polish sites are not covered by boulder clay and so their geological position cannot be univocally established; Środoń (1960), for instance, placed them in the Brörup Interstadial.

Both these sites lie in the Silesian Upland and, therefore, outside the range of the Warta ice sheet. Their similar pollen successions present a closed cycle of vegetational development with a short-lived climatic optimum of an interstadial nature. It is characterized by a relatively high proportion of pollen of thermophilous broad-leaved trees and *Corylus* as well as high values of *Picea* (Fig. 5). Ralska-Jasiewiczowa (1958) ascribes the differences occurring between the climatic optima of these two sites, above all the considerably higher pollen values of *Quercus* and *Carpinus* at Łabędy, to the location of this site opposite the Moravian Gate, which favoured a faster migration of trees from their refuges situated south of the Carpathian and Sudeten chains.

The organogenic sediments included in the Pilica Interstadial occur in the Chojny formation in the Bełchatów region (Baraniecka 1982, 1985, Hałuszczak 1982, Krzyszkowski & Brodzikowski 1987, Krzyszkowski 1990). The deposits of this formation are of great stratigraphical importance, for it is the only deposit series known in Poland lying between boulder clays of the Odra and Warta Glaciations and with organogenic deposits occurring in situ. The deposits of the Chojny formation, however, represent an environment of river sedimentation, a fact which, from the viewpoint of palaeobotanical studies, diminishes their diagnostic significance.

Organogenic deposits from several sites have been studied palynologically within the Chojny formation. The best developed profiles of organogenic deposits occur at Buczyna 4 (Janczyk-Kopikowa 1982, 1985), Buczyna 4A (Krzyszkowski & Nita 1995) and Bełchatów XIA (Jastrzębska-Mamełka 1992). All three

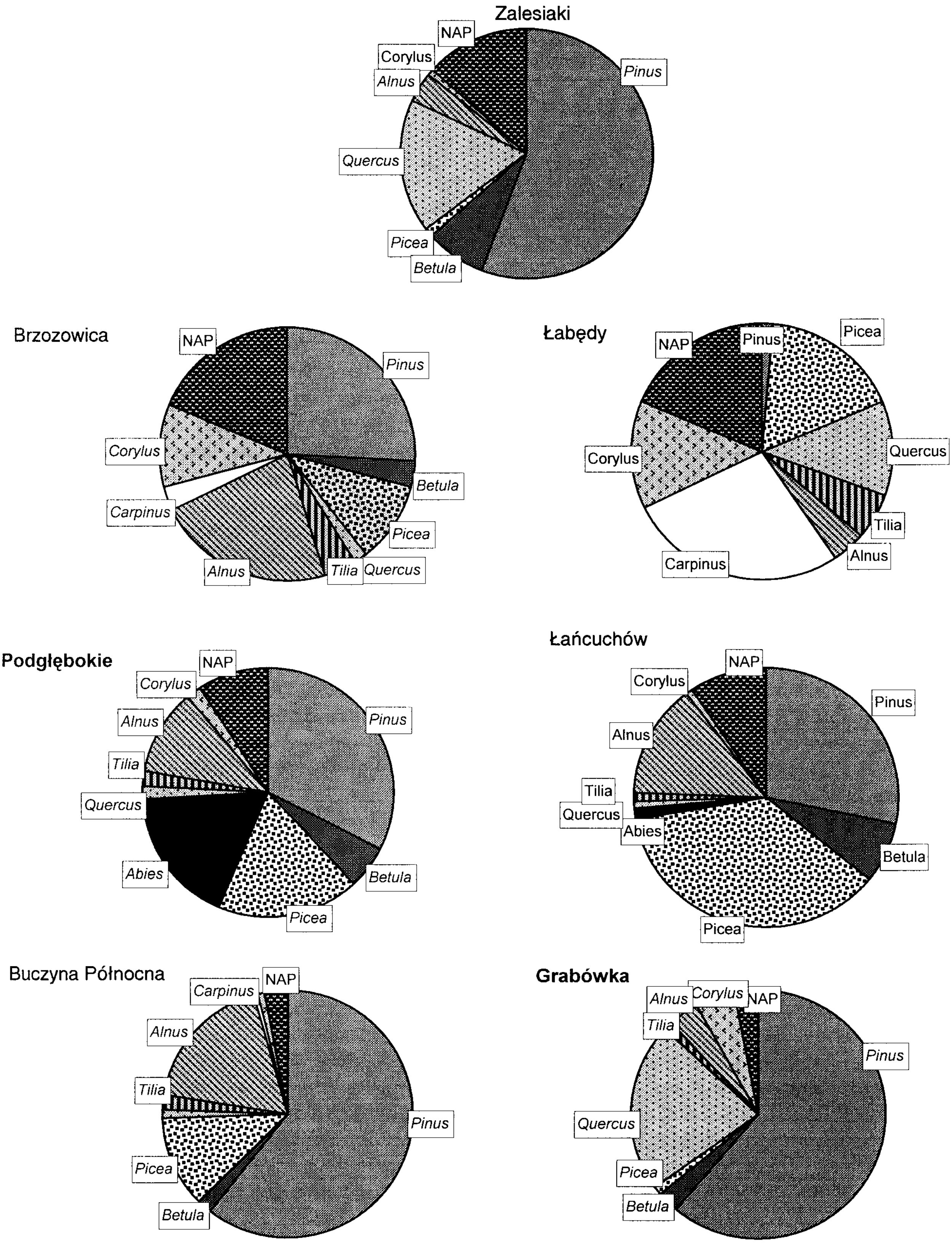

Fig. 5. Percentage of pollen of important trees, *Corylus* and NAP in samples with maximal values of thermophilous broad-leaved trees at sites: Zalesiaki, Brzozowica (Gilewska & Stuchlik 1958), Łabędy (Ralska-Jasiewiczowa 1958), Podgłębokie (Janczyk-Kopikowa 1969), Łańcuchów (Butrym et al. 1991), Buczyna Północna (Janczyk-Kopikowa 1985) and Grabówka (Makowska 1977)

sites represent a closed developmental cycle of interstadial vegetation with a cool climatic optimum. The proportion of pollen of thermophilous broad-leaved trees and *Corylus* is very low there, with the pollen values of *Picea* reaching a maximum of 15% (Bełchatów XIA) and *Alnus* 18.4% (Buczyna Północna) (Fig. 5).

A comparison of the diagrams for Buczyna 4, Buczyna 4A and Bełchatów XIA with those from the Silesian Upland shows that the proportion of pollen of thermophilous trees during the optimum of the sites of the Chojny formation was much lower. This was perhaps caused by the geographical situation of Bełchatów, about 100 km north of Brzozowica and Łabędy, which in the interstadial period may have been of essential significance.

The Zalesiaki site lies more or less equidistant from the sites in the region of Bełchatów and those in the Silesian Upland. The interstadial succession from Zalesiaki differs from the above-mentioned sites of the Chojny formation, above all, in the very low proportion of *Picea abies* pollen, the lower proportion of *Alnus,* and the high values of *Quercus*. The pollen values of *Tilia* and *Corylus* are low at both sites.

The interstadial succession from Podwinek near Bełchatów resembles the pollen successions represented at the sites from the Chojny formation (Janczyk-Kopikowa 1985). They differ only in the presence of birch forest at the beginning of the interstadial (max. 77% of *Betula* pollen), which does not occur at Buczyna 4. However, according to, Sarnacka (1982), the geological situation of the organic deposits at Podwinek indicates that their sedimentation took place in the period preceding the Odra Glaciation.

Środoń (1969) ascribed the rank of interglacial, which he called the Lublin Interglacial, to the same stratigraphical position in which Różycki (1972) saw the Pilica Interstadial. To it Środoń referred sites with successions typical of the Mazovian Interglacial, not covered by boulder clay (Nowiny Żukowskie, Ciechanki Krzesimowskie, Wylezin). His opinion, however, has not been accepted by other palaeobotanists and these sites are still regarded as the Mazovian Interglacial (Janczyk-Kopikowa 1991).

Nevertheless, Różycki (1978, 1980) changed his original opinion and accepted the rank of interglacial for the warm period between the Odra and Warta Glaciations, retaining the name of Lublin Interglacial, after Środoń. This name has been applied in stratigraphic schemes up to now (Maruszczak 1985, 1987, Baraniecka 1993). On the basis of TL datings and conclusions from geological, palaeogeographical and other studies, not only the sites representing interglacial pollen successions, but also those with interstadial successions, are still included here.

Three sites of a flora, interstadial in nature, from the Lublin Upland are associated with the stratigraphical position between the Odra and Warta Glaciations. They are at Podgłębokie, Łancuchów and Łęczna (Butrym et al. 1991). The first two were initially numbered in the Brörup Interstadial (Janczyk-Kopikowa 1969, 1979). On the basis of more recent geological studies and TL datings opinions as to the age of deposits at these three sites have been verified and the deposits, despite the interstadial nature of their pollen successions, included in the Lublin Interglacial (Butrym et al. 1991).

A comparison of the pollen diagram from Zalesiaki with the diagrams from the sites in the Lublin Upland reveals differences. Conspicuous, above all, is the presence of fir in the Lublin Upland sites (max. 19.5% at Podgłębokie but only 1.6% at Łańcuchów) and the high pollen values of *Picea* – 38.6% at Łańcuchów (Fig. 5). In Janczyk-Kopikowa's opinion (1979), some local causes were responsible for the differences in the pollen values of *Abies* between Podgłębokie and Łańcuchów.

A comparison of the pollen succession from Zalesiaki with the interstadial successions from the Silesian Upland, Bełchatów region and the Lublin Upland does not rule out the coeval nature of these sites, yet gives no convincing proofs entitling us to infer it. If the geological situations of these deposits were univocal, the differences might possibly be explained by different local conditions.

Baraniecka (1993) includes, not only the organogenic deposits from the Chojny formation (Buczyna 4 and the others) in the Lublin Interglacial, but also the profiles from Łęczna, Podgłębokie, Łańcuchów and Skorupy (they were defined earlier by Janczyk-Kopikowa 1977/1978, as the Brörup Interstadial) and the profile from Grabówka (Makowska 1977).

The organogenic deposits of the Grabówka series (Makowska 1977, Lindner 1984, 1988c) provided the basis for the distinction of the interglacial from Grabówka, in particular the pollen spectrum of a sample consisting of *Corylus* (5%), *Alnus* (5%), *Tilia* (1%) *Picea* (1%), *Pinus* (61%) and *Quercus* (22%). The organogenic deposits at Grabówka are covered by boulder clay of the Warta Glaciation, upon which organogenic deposits of the Eemian Interglacial are lying (Makowska 1977).

The pollen spectrum of one sample is unfortunately insufficient to draw correlational conclusions. This notwithstanding, it should be emphasized that there is a great similarity between this spectrum and that part of the Zalesiaki diagram in which the high pollen values of *Quercus* are accompanied by high values of *Pinus sylvestris* type (Fig. 5).

The name "interglacial from Grabówka" has been replaced by the name "Lubawa Interglacial" (Lindner 1988a) derived from the Losy site near Lubawa in the Mazurian Lake District (Krupiński & Marks 1985, 1986). In Krupiński's opinion, the plant succession from Losy shows no resemblance to other successions known from Poland and, according to these authors, it provides the basis for distinguishing a new interglacial.

The pollen succession from Zalesiaki is of an interstadial nature and for this reason it is not comparable with the succession from Losy.

The pollen values of thermophilous broad-leaved trees (*Quercus* 17.7%, *Carpinus* 8.3%) place the interstadial from Zalesiaki in the group of so-called warm interstadials. This corresponds well with Maruszczak's (1985) view, who claims that there was a warm interstadial or a cool (embryonal) interglacial between the Odra and Warta Glaciations. However, as long as the genesis of clay overlying the organogenic deposits remains unexplained, the results of the pollen analysis do not authorize us – in the light of the present state of knowledge of the Pilica Interstadial/Interglacial – to refer the organogenic deposits from Zalesiaki univocally to that stratigraphic position.

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