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Vegetation and settlement history in the area of Lake Zawada in the north-eastern part of the Świecie District (northern Poland)

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ABSTRACT. Palynological studies of bottom deposits of Lake Zawada and its surrounding peat bogs imply that the beginning of biogenic deposits accumulation in Lake Zawada goes back to the Preboreal period. In the pollen diagram seven local pollen assemblage zones were distinguished spanning the history of Holocene vegetation from the Preboreal period until present times. Correlation of the local pollen zones confirms the presence of sedimentation gaps in two profiles. Human impact on the natural environment around the lake is discussed and compared with archaeological evidence. The phases of intensified activity distinguished in pollen diagrams are linked with the Neolithic (phase 1), early Bronze Age (phase 2), late Bronze (phase 3), early Iron Age and Roman period (phase 4), early Medieval (phases 5 and 6), late Medieval and the Modern period (phase 7).

KEY WORDS: pollen analysis, Holocene, history of vegetation, prehistoric settlement, Poland

INTRODUCTION

The area of the Świecie District according to the physico-geographical division of Poland by Kondracki (1998), is located within the South Baltic Lake District. It comprises three macroregions namely the Lower Vistula River Valley, the Eastern Pomeranian Lake District and the Southern Pomeranian Lake District. The latter one comprises the Bory Tucholskie mesoregion where Lake Zawada is located (Kowalewski 2002).

The main criterion for the choice of the study area was the possibility of confronting changes in vegetation with numerous traces of settlement from the Younger Stone Age until early Medieval period. These traces were discovered during rescue research for the planned route of the A-1 highway connecting North and South Poland (Bojarski et al. 2001, Chudziak 2003).

Palynological research on the Świecie District was initiated in 2000 within the framework of the TRAKT research programme conducted by the Foundation for Polish Science (Chudziak & Noryśkiewicz 2003, Noryśkiewicz & Tobolski 2003). Lake bottom deposit profiles and biogenic deposits from archaeological excavations were analysed within the framework of this programme. In order to enrich the environmental characteristics, in 2002, the research was completed by the analyses of profiles from peat bogs located at the western (peat bog Zawada 4) and southern bank of the lake (peat bog Zawada 2).

CHARACTERISTIC OF THE AREA STUDIED

The area of the Świecie District was formed during the main stadial of the last Scandinavian glaciation (Vistulian) and the main lithological features were formed during the recession of the ice sheet. Principal among glacial landforms are moraine plateau, end moraines and dead ice moraines, and among glaciofluvial landforms including outwash, kames, eskers, and glacial channels. Dunes were formed on the sandy areas during cold periods of the late Vistulian and numerous kettles appeared in warmer periods after melting of buried ice. In the present day subglacial channels and kettles are often occupied by lakes and peat bogs.

Soil distribution in the area surrounding Lake Zawada reflects morphological and lithological variation in the studied area. We notice here the occurrence of zonal and azonal soils. The first group includes brown and podsolic soils which are typical for this part of Poland. Azonal soils in the area in question cover areas of depressions. Their distribution is identical with the position of all concave landforms forming micro-regions. There are peat soils in lake channels and some depressions, e.g. the southern part of the former lake bay or the kettle on its west side. Brown leached soils dominate the described area. They cover the total area of Świecie District both in its outwash and moraine part apart from one podsolic soil enclave.

DESCRIPTION OF SITES

Lake Zawada (53°37′N, 18°38′E) is located in the north-eastern part of Świecie District (Figs 1, 2) and is a typical channel lake. The lake is 1.75 km long and has a surface area of 35 ha with an elongated shape and a non-com-

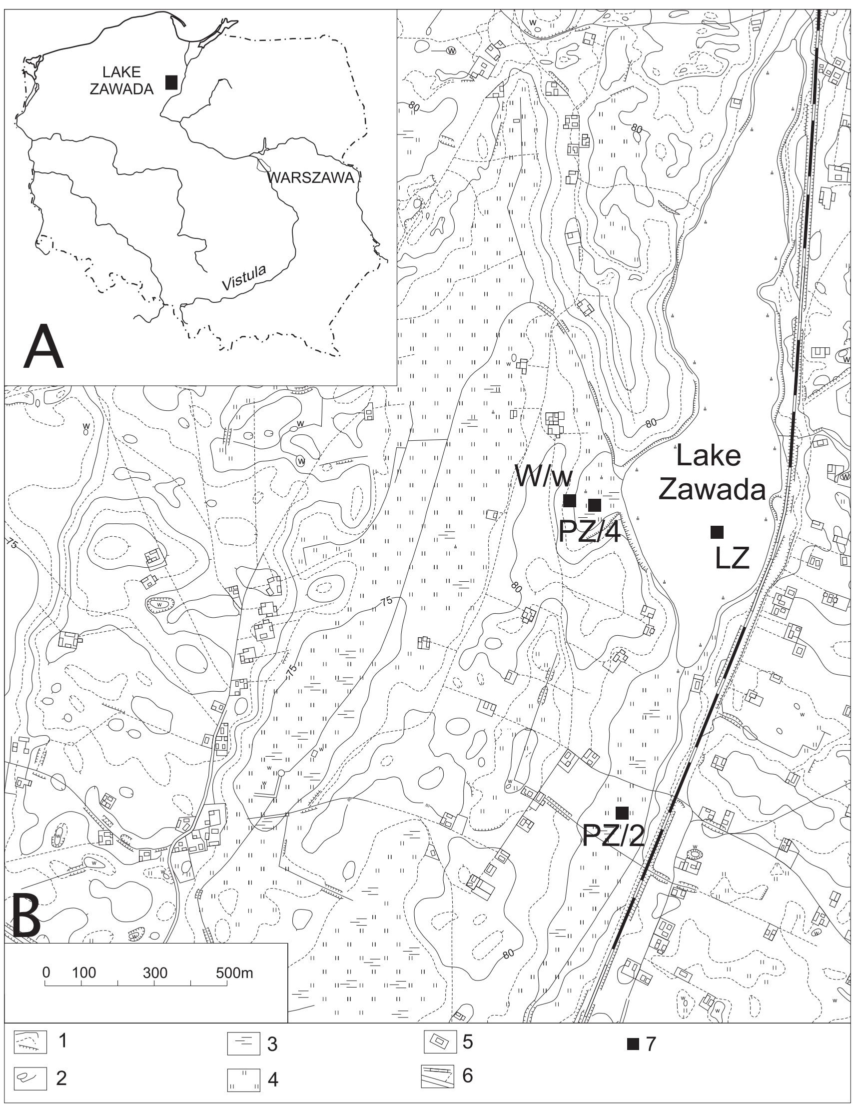

Fig. 1. **A** – position of Lake Zawada, northern Poland, **B** – Lake Zawada and its surroundings. **1** – contour lines and escarp, **2** – lakes and rivers, **3** – wet meadow areas, **4** – meadows and pastures **5** – village and farmsteads, **6** – roads and railway, **7** – location of the studied profiles

Fig. 2. Landscape of Lake Zawada taken from the air (phot. J. Pająkowski)

plicated shoreline. The maximum depth of the water is 2.7 m and the average depth 1.6 m. The lake water level is at the height of 74.2 m above sea level. The subglacial channel slopes are straight and they reach a height of 5 m and an angle of 5 to 7°. In its south-western part, the channel expands to form a bay which is currently mostly peated. In the central part of this bay (Fig. 1), a profile was taken from a core that was 1010 cm long, hereinafter called peat bog Zawada 4 (PZ/4). This peat bog is separated from the lake by an underwater threshold covered by the layer of 50 cm deep water. The profile of peat bog Zawada 2 (PZ/2) from a 700 cm long core was taken from the peat bog which comprises the lake extension from its southern part (Fig. 1) with peat surface of the 75 m a.s.l.

During archaeological research in Warlubie, on the channel slope, on the section line of: the lake Lake Zawada, the bay and the peat bog (PZ/4), a 30 cm biogenic layer was discovered (Warlubie profile W/w).

CULTURAL RELATIONSHIPS

The oldest traces of prehistoric settlement from the north-eastern part of the Świecie District date back to Late Palaeolithic. Small assemblages of flint artefacts were discovered close to Stare Marzy village, Drągacz, and are originally associated with the Sviderian culture. This place was also used later during the Middle Stone Age (7th millennium BC) by groups characterising the Chojnice-Pieńki culture (Wilke 1979, Chudziak 2001). These communities were similar to those from the Late Palaeolithic period that based their economy on hunting, fishing and colleting wild plants. There are very few findings connected with the activity of Neolithic communities within a cycle of Linear Band Pottery culture from the 5th millennium BC. Also, from the later phases of the Neolithic we know about only single traces of Linear Pottery culture, Corded Ware culture, and Late Neolithic Globular Amphorae culture (3rd millennium BC). More numerous are the traces of a settlement from the beginning of the Iron Age (Lusatian and Pomeranian culture cycle). Pomeranian culture started with village colonies and graveyards on the edge of the moraine plateau and the Vistula and Wda rivers valleys and in the north-eastern part of the Świecie District (in the area of Warlubie and Stare Marzy). The early Pre-Roman period (Oksywie culture) was marked only by insignificant amount of source material. The rescue research, however, conducted by the Institute of Archaeology, Nicholas Copernicus University in Toruń, showed traces of colonisation from the period of Roman influence including colonies from the Wielbark culture situated upon Lake Zawada (Bojarski et al. 2001, Chudziak 2003). It was determined as a result of research conducted that in the described mesoregion, people from the Wielbark culture appeared at the end of the early Roman period (second half of 2nd century) and persisted on this area until the Migration period (the beginning of 5th century) with significant regress of a local settlement connected with a country colony decline in Warlubie (Bokiniec 2000, Chudziak 2001, 2003).

Further distinct traces of colonisation including a colony from the phase of early Medieval Age (the 11th–12/13th century), located 1 km south west of Lake Zawada, date back to early Medieval Age. Colonisation of this area, initiated in the 11th century, was connected with inclusion of this territory within the influence of the early Piast State. In the later period, as archaeological and historical data show, colonisation moved closer to the Vistula river valley where, according to historical notes, the Nowe urban centre was established (Jasiński 1979). The abandoned areas were used mainly as farming fields and pastures.

METHODS

Biogenic materials for pollen analysis were collected using a piston-sampler (Więckowski 1970) and taken from a special platform at the deepest part of lake (2.7m). Material was also collected from peat bogs surrounding the lake. The 10 m long core was obtained and analysed from the peat bog at the western bank of the lake, whereas, only the early Holocene part of the profile was analysed from the peat bog located at the south off the lake. Biogenic deposits in the Warlubie profile (W/w-30 cm) were taken from the excavation made during archaeological research on the Warlubie 2 site. Pollen analysis of this deposit showed that the pollen frequency is low and preservation conditions of pollen in bottom and upper parts of the samples are very poor.

Samples for pollen analysis were processed following the guidelines proposed by Berglund and Ralska-Jasiewiczowa (1986). In the samples from Lake Zawada and in the majority of samples from the peat bog, above 1000 AP were counted. In the remaining ones at least 500 were counted. All pollen percentages were calculated on the basis of sum including trees, shrubs (AP), dwarf shrubs and herb pollen (NAP), but excluding limnophytes, telmatophytes and sporophytes. The concentration of pollen grains in 1 cm^3 of the sediment was calculated by method described by Stockmarr (1971). Two *Lycopodium* tablets were added to each sample of profile LZ.

Local pollen assemblage zones were distinguished in pollen diagrams (LPAZ) according to the Birks (1986) and Janczyk-Kopikowa (1987). The similarity of pollen records in pollen diagrams enabled to use of the same zone names for all profiles and for presenting correlation between diagrams. Insignificant differences in values of some taxa between the peat bog and the lake were caused by the composition of local flora and from different distance of particular cores from the middle of the lake. This correlation helped to distinguish levels where sedimentation gaps (hiatus) occur in the deposits from PZ/4 and Warlubie excavation profiles. The names such as Preboreal, Boreal, Atlantic, Subboreal periods were used in the sense of chronozones according to a convention suggested by Mangerud et al. (1974).

Chemical analyses were conducted by means of standard methods (Bengtsson & Enell 1986) in Sedimentological Laboratory in the Institute of Geography, Nicholas Copernicus University in Toruń (LZ profile) and in Laboratory of Polish Academy of Sciences in Toruń (PZ/4 profile). All calculations and drawing diagrams were done with POLPAL programme (Walanus & Nalepka 1999).

SEDIMENT DESCRIPTION

Lake Zawada, profile LZ

The lithology of the Lake Zawada profile was described using the Troels-Smith system by Tobolski (2000) and content of organic matter (O), carbonates (W) and minerogenic minerals (M) is given below in simplified form:

0–60 cm	fine detritus gyttja with clay and sand admixture, yellow-brown (O – 24.2–45.3%, W – 17.8–25.6%, M – 36.9–51.5%); (Dg 2, Lc1, Ag 1, G min.+)
60–85 cm	fine detritus gyttja with clay admixture (O – 47.4–54.0%, W – 25.5–26.6%, M – 19.4–27.1%); (Dg3, Lc+, Ag+)
85–130 cm	fine detritus gyttja, light-brown (O – 71.4–80.6%, W – 1.8–5.8%, M – 17.6–22.8%); (Dg 3, Lc 1, Ag +)
130–310 cm	fine detritus gyttja with sand admixture, brown-black (O – 46.8–74.7%, W – 3.7–19.4%, M – 19.8–38.2%); (Dg3, Lc 1, AG +)
310–550 cm	detritus gyttja with sand admixture, black (O – 54.2–85.5%, W – 1.3–7.0%, M – 13.2–38.8%); (Dg3, Dh 1, Gmin. +)
550–558 cm	sharp border between detritus gyttja, brown sand with herbaceous detritus (about 20% pieces of wood, herbaceous plants and fine detritus); (G min.3, D1+, Dh+, Dg +, Ag+),
558–562 cm	wood in fine sand (Dl 3, G min. 1, Dg+)
562–612 cm	sand with occasional numbers of detritus (G min. 4, Ag+, Th+)

Peat bog Zawada, profile P/Z4

0–20 cm	reed-swamp peat (O – 71.2–75.7%, W – 1.4–2.0%, M – 22.2–27.3%)
20–50 cm	swamp peat (O – 66.6–67.9%, W – 3.0–4.3%, M – 27.9–30.4%)
50–70 cm	swamp peat with great amount of mosses (O – 63.5%, W – 4.4%, M – 31.1%)
70–110 cm	coarse detritus gyttja (O – 36.0%, W – 6.1%, M – 57.9%)
110–180 cm	fine detritus gyttja (O – 27.6–32.5%, W – 3.6–8.5%, M – 63.9%)
180–300 cm	calcareous gyttja, grey-white (O – 7.7–12.8%, W – 49.3–65.3%, M – 21.9–9.7%)
300–367 cm	calcareous gyttja, light grey (O – 21–22.2%, W – 44.6–51.7%, M – 26.8–33.3%)
367–372 cm	fine detritus gyttja, grey-brown (O – 25.8%, W – 44.6%, M – 64.3%)
372–482 cm	fine detritus gyttja, grey (O – 33.2–53.4%, W – 14.7–41.0%, M – 5.6–56.6%)
482–670 cm	fine detritus gyttja, dark grey (O – 43.1–56.5%, W – 11.6–42.8%, M – 0.7–45.3%)
670–960 cm	coarse and fine detritus gyttja, dark grey, at 950–960 cm, numerous mollusc shells (O – 11.4–51.7%, W – 0.4–30.0%, M – 28.7–87.2%)
960–980 cm	peat, dark brown with pieces of wood, bark, pine-cones and fragments of brown-mosses (O – 67.9–81.1%, W – 1.7–2.2%, M – 16.7–30.2%)
980–1000 cm	humified peat, dark brown (O – 32.7–57.9%, W – 2.4–4.9%, M – 38.2–64.4%)
1000–1110 cm	sandy clay (O – 4.7%, W – 1.5%, M – 03.8%)

Peat bog Zawada, profile PZ/2

0–540 cm	not investigated
540–550 cm	calcareous gyttja, light-grey
550–690 cm	humified peat, dark-brown
690–700 cm	sand with admixture of herbaceous detritus

Warlubie, profile W/w

0–10 cm	silty sand, plant detritus admixture
10–15 cm	clayey sand, plant detritus admixture
15–30 cm	humified peat, with sand admixture
30–45 cm	silty sand with plant detritus admixture
45–50 cm	silty sand with small admixture of herbaceous detritus

Radiocarbon dates for the Lake Zawada and peat bog Zawada PZ/4

Gd-13 072	80– 82 cm	1150 ± 130 BP	Lake Zawada
Gd-10 988	110–112 cm	1690 ± 140 BP	Lake Zawada
Gd-13 083	140–142 cm	2190 ± 160 BP	Lake Zawada
Poz-3628	965–970 cm	9760 ± 60 BP	Peat bog Zawada PZ/4

DESCRIPTION OF LOCAL POLLEN ASSEMBLAGE ZONES

LAKE ZAWADA, PROFILE LZ (Figs 3, 4)

LZ-*Pinus-Betula* L PAZ (562–545 cm)

Pinus (44.8–56.9%) and *Betula* (38.3–49.5%) are the dominating pollen taxa. *Salix* (max. 0.8%), *Corylus* (max. 1.5%) and *Alnus* (max. 1.5%) occur regularly. Among herbaceous taxa, Poaceae undiff. (2.1–4.7%), Cyperaceae (0.8–1.4%), and *Artemisia* (0.3–0.8%) have continuous curves. The percentage share of Filicales monolete is max. 5.1% whereas *Equisetum* spore is 1.5%.

LZ-*Betula-Corylu-Ulmus* L PAZ (545–500 cm)

In the diagram, *Pinus* and *Betula* percentage curves have decreasing tendencies (48.7–33.2% and 43.0–32.6%), whereas *Corylus* values (max.18.7%) and *Alnus* (max. 16.2%) increase consistently. *Ulmus* (max. 3.6%) and *Quercus* (max.16.2%) are present in all samples. *Salix* (0.1–0.4%) and *Juniperus* (0.1–0.2%) occur regularly. The composition of herbaceous taxa enriched in comparison with the previous zone and new taxa were added: *Calluna vulgaris*, and Ericaceae undiff., *Urtica*, *Valeriana*, *Nymphaea* (0.1–0.2%), and *Sparganium* (0.1–0.2%) pollen represent aquatic plants. The curve of Filicales monolete spores decrease from 3.0% in the bottom and to 0.6% in the younger part of this zone and the first spores of *Pteridium aquilinum* appear.

LZ-*Ulmus-Quercus-Fraxinus* L PAZ (500–400 cm)

This zone is divided into two "a" and "b" LPAZS sub-zones. Sub-zone "a" is distinguished by maximum *Alnus* (17.6%) and high values of *Corylus*, whereas sub-level "b" with maximum *Ulmus* (5.7%) and *Quercus* (13.7%). *Viscum* pollen is present. There is a decrease of percentage curves of the *Quercus, Ulmus*, and *Corylus* in the middle part of the zone. From that layer there is an increase of *Pteridium aquilinum* spores. As to aquatic and reed-swamp vegetation, *Nymphaea*, *Sparganium*, *Potamogeton* sect. *Eupotamogeton*, and *Typha latifolia* appear singly in the whole zone.

LZ-*Corylus-Tilia-Alnus* L PAZ (400–280 cm)

This zone was divided into two sub-zones: "a" with maximum values of *Tilia* (4.5%) and relatively low value of *Pinus* (24.8–36.3%) and sub-zone "b" from where the increase of the *Carpinus* curve starts. In the zone described, *Corylus* has its Subboreal maximum (13.6%), whereas the components of *Quercetum mixtum* (*Ulmus*, *Tilia*, *Quercus*, and *Fraximus*) decrease. Herbaceous plants percentage curve (NAP), similarly to earlier zones, is still low. *Plantago lanceolata* pollen are present singly, the first pollen grains of Cerealia undiff. (0.1%) were noticed in the upper part of zone.

LZ-*Carpinus* L PAZ (280–70 cm)

A hornbeam share percentage curve is the basis for distinguishing a separate local zone and further four sub-zones with further culmination reaching values of 3.9; 9.7; 26.0, and 10.5% separated by three depressions. The flow of the *Carpinus* curve is negatively correlated with the percentage curve of herbaceous plants (NAP). Synanthropic plants are basic components of herbaceous plants. Cereals are present with, among the others, frequent *Secale cereale*, *Plantago lanceolata* and other plants characteristic for cultivation and stock breeding starting from sub-zone c. *Alnus* percentage curve retains relatively high values (11.3–21.1%).

LZ-*Pinus*-NAP L PAZ (70–2 cm)

This zone includes the highest values of herbaceous plants recognised in the entire profile (max. 41.6%) and the pine (with a maximum of 53.7%) is the dominating forest taxon. The *Juniperus* percentage curve increases (max. 1.8%) and from the beginning of the zone the curves drawn for deciduous trees (*Ulmus, Quercus, Carpinus, Fraxinus*, and *Alnus*) gradually lower.

PEAT BOG ZAWADA 4, PROFILE PZ/4 (Fig. 5)

PZ/4-*Pinus* L PAZ (1000–970 cm)

In this zone, *Pinus* reaches its absolute maximum (95.8%). *Betula*, with huge fluctuations, shows rising tendencies (2.7–3.9%), accompanied by a willow tree (*Salix* max.0.8%). *Artemisia* (0.2–1.7%) and Cyperaceae (0.6–2.5%) represent herbaceous plants by a continuous curve. Filicales monolete spores occur at the depth of 990 cm and they show a rising tendency towards the upper part of this zone (1.3–4.0%). This zone is not represented in sediments of profile Lake Zawada (LZ).

PZ/4-*Pinus- Betula* L PAZ (970–930cm)

Betula reaches its highest values (80.6%) in the whole core, while the proportion of *Pinus* falls (14.6%), with *Salix* occurring regularly (0.2–0.9%) and *Populus* appearing (0.3%). The contribution of Cyperaceae is higher than in the previous zone (max.6.6%), Filicales monolete (max.16.8%) and *Thelypteris palustris* (max.3.5%) contribution is also high. Aquatic vegetation (*Nymphaea* 0.2%, *Potamogeton* sect. *Eupotamogeton* 0.2%), and reed-swamp vegetation (*Typha latifolia* 0.2–1.8%) as well as algae (*Pediastrum* 1.5–4.1%) appear for the first time.

PZ/4-*Betula-Corylus-Ulmus* L PAZ (930–770 cm)

Pinus and *Betula* reach relatively high and stable values throughout the whole zone, *Ulmus*, *Quercus*, and *Alnus* percentage continuous curves appear and have rising tendencies. *Corylus* dominates absolutely in the end of this zone (25.7%). In the younger part, *Viscum* pollen appears for the first time. Filicles monolete (1.7–0.1%) and *Pediastrum* (2.0–0.2%) shares fall and aquatic and reed-swamp vegetation (*Nymphaea*, *Sparganium*, *Typha latifolia*) are still present.

PZ/4-*Ulmus-Quercus-Fraxinus* L PAZ (770–620 cm)

Alnus, *Ulmus*, *Tilia* and *Quercus* values increase systematically. *Viscum* pollen is frequent. The first pollen of *Plantago lanceolata* appears, *Pediastrum* occur regularly. The share and composition of aquatic vegetation are similar to the previous zone. This zone has been divided into two sub-zones: "a" and "b". The older "a" zone has been distinguished on the basis of high values of *Corylus* and *Alnus*, and low values of *Pinus*. The younger "b" level is characterized by the *Quercus*, *Ulmus*, and *Pinus* percentage curves rise.

PZ/4-*Corylus-Alnus-Tilia* L PAZ (620–180 cm)

This zone thickness is four times larger as compared to the synchronized zone of Lake Zawada deposits. It has been divided into two sub-zones at the point of characteristic increase of *Pinus* curve (410 cm deep) and gradual increase of *Corylus*. In the younger part of the zone, continuous but low *Carpinus* curve starts, and singly pollen grains of *Fagus* occur. Synantrophic plants are represented

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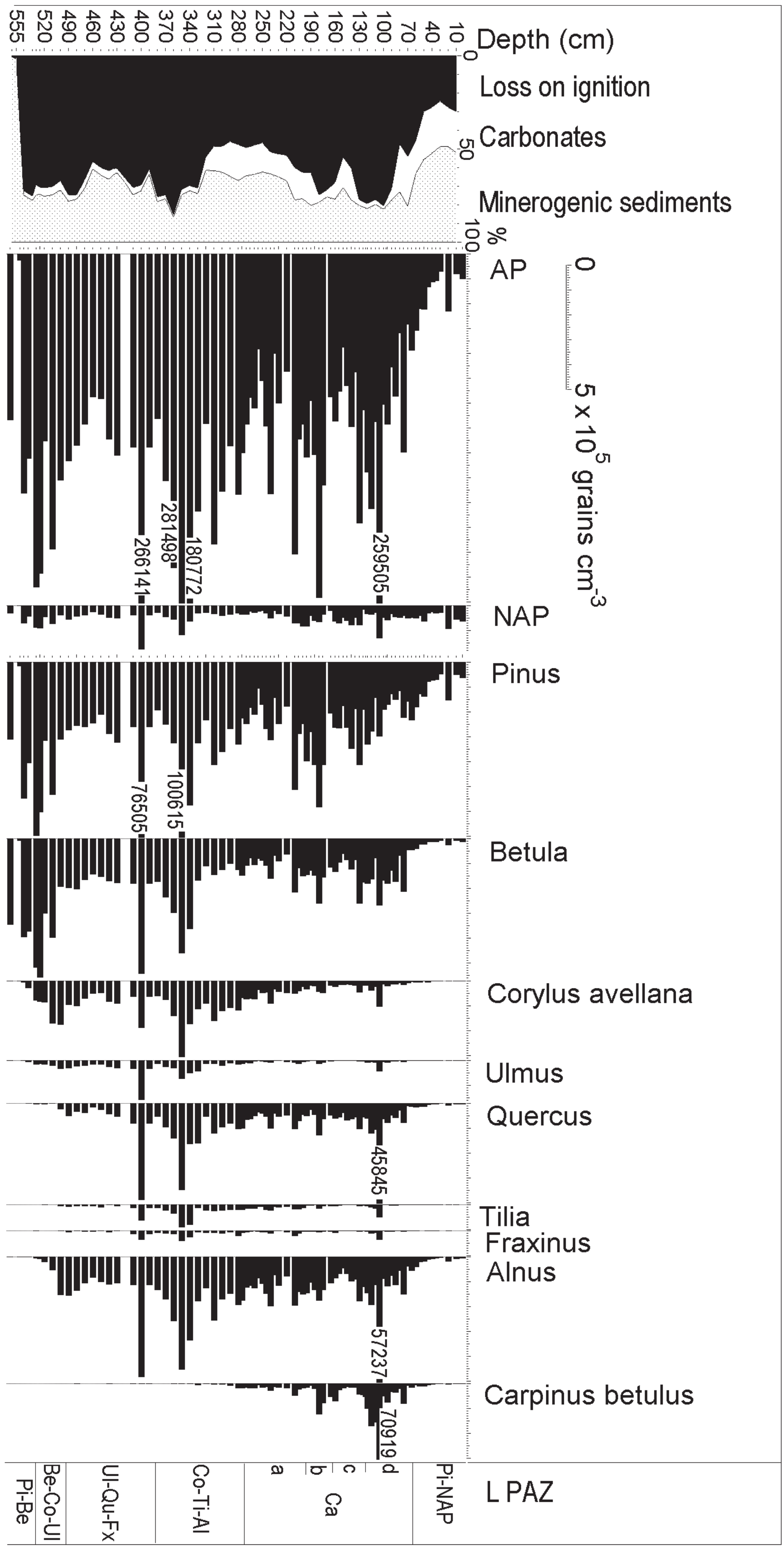

Fig. 4. Lake Zawada (LZ). Pollen concentration diagram of selected trees and shrubs

occasionally by Cerealia undiff. and singly by *Plantago lanceolata*. Aquatic and reed-swamp vegetation are enriched with *Nuphar*, *Lemna*, *Myriophyllum spicatum*, *M. verticillatum*, and *Menyanthes trifoliata* pollen. Filicales monolete spores occur regularly in small amounts, their curve increases at the upper part of zone and at the depth of 220 cm it reaches maximum of 25.7%.

PZ/4-*Carpinus* L PAZ (180–80 cm)

Comparison with the plant succession recorded in the deposits of Lake Zawada and a sharp border in the nature of the deposit and also a rapid fluctuation in the percentage curves of some plants (*Carpinus*, herbs-human indicators) indicates the existence of a sedimentation gap (hiatus) at the lower border of this zone. The preserved fragment is probably a younger part of profile LZ-*Carpinus* LPAZ. This zone is characterised by high values of *Carpinus* within the range of 1.2–5.5% and by a distinct decrease in *Corylus* significance (6.0–1.7%) as compared to a previous zone. *Tilia*, *Fraxinus*, and *Ulmus* curves lower down. *Plantago lanceolata* and Cerealia undiff. appear regularly and in its younger part *Secale cereale*. In the upper part, the *Pediastrum* curve rises rapidly (max. 25.2%)

PZ/4-*Pinus*-NAP L PAZ (80–10 cm)

Deciduous trees share decreases whereas *Pinus* increases and stabilises (average 49.4%). NAP reaches its highest values in the whole core (max. 60.7%). Human economy indicators dominate among herbs vegetation especially *Plantago lanceolata* (0.2–0.9%), *Rumex acetosa* / *acetosella* (1.1–3.6%), and Cerealia undiff. (0.8–6.0%) with separated *Secale cereale* pollen (1.1–2.6%). The contribution of Filicales monolete (0.7–29.5%) and *Pediastum* indicates great fluctuation from 4.5% to maximum amount of 42.4%.

PEAT BOG ZAWADA, PROFILE PZ/2 (Fig. 6)

Only the bottom part of the profile was studied by means of palynological analysis method. It was later correlated with deposits of Lake Zawada and the profile adjacent to it from the west part of the peat bog. The distance between these profiles is less than 500 m. In the bottom samples of sand mixed with an organic substance (690 cm) and peat (680 cm), the existence of pollen was not con-

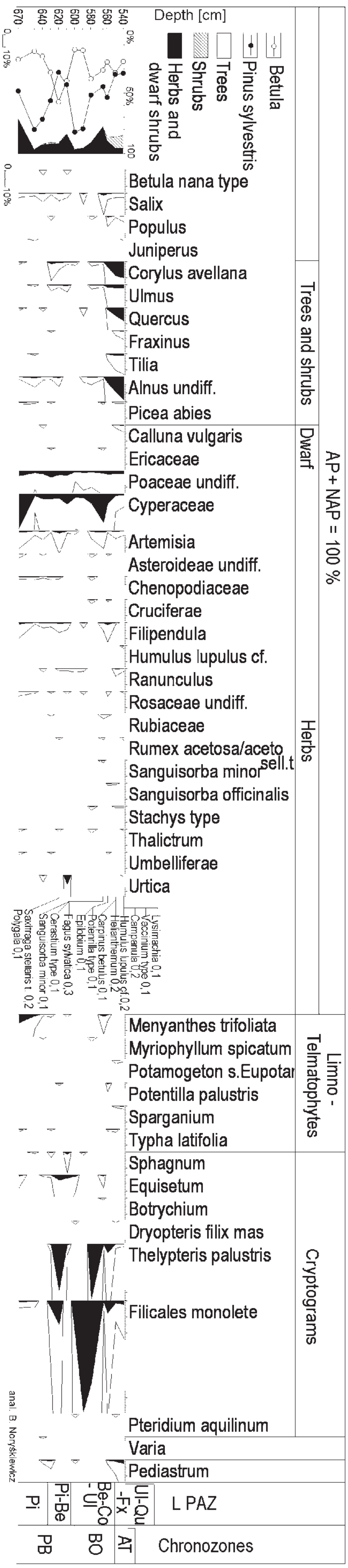

Fig. 6. Pollen percentage diagram covering the early Holocene sequence at the peat bog Zawada, profile PZ/2

firmed, however, numerous spores of brown mosses were found apart from occasional birch pollen and pine sacks.

PZ/2-*Pinus* L PAZ (670–640 cm)

In this zone pine dominates absolutely (48.3–80.5%) with some smaller share of *Betula* (15.3–22.4%) and *Salix* (0.2–0.6%). From herbaceous plants, Cyperaceae predominates (max. in bottom spectrum 21.8%), Poaceae undiff. (max. 3.2%), *Artemisia* (0.3–1.1%). Aquatic and reed-swamp plants such as *Myriophyllum spicatum* (0.1%), *Menyanthes trifoliata* (0.9–5.6%), and *Typha latifolia* (0.1%) are present.

PZ/2-*Pinus-Betula* L PAZ (640–610 cm)

Pinus (32.9–56.5%) and *Betula* (33.3–57.3%) co-dominate, other trees are represented singly or below 0.4%. The set of herbaceous plants is similar to the previous zone. The share of fern increases, Filicales monolete culmination is observed (14.8%), the majority of which belongs probably to *Thelypteris palustris* which was marked in the same spectrum (29.1%) thanks to perinia preserved. *Equisetum* percentage curve reaches maximum values (3.2%).

PZ/2-*Betula-Corylus-Ulmus* L PAZ (610–550 cm)

Pinus (34.8–82.3%) and *Betula* (max. 38.3%) dominate, *Corylus* (0.2–8.8%) and *Ulmus* (0.1–2.0%) values systematically rise. The representatives of Cyperaceae (2.2–17.9%), Poaceae undiff. (0.7–2.2%) families and *Artemisia* (0.1–1.1%) are the main components of herbaceous plants. Filicales monolete (69.1%) and *Thelypteris palustris* (34.3%) reach maximum values.

PZ/2-*Ulmus-Quercus-Fraxinus* L PAZ (550 cm)

This zone is represented by only one pollen spectrum, in which, apart from *Pinus* (33.7%) and *Betula* (24.1%), *Alnus* (14.4%), *Corylus* (10.1%), and *Quercus* (8.3%) have high values. As to other trees, *Ulmus* (2.0%) and *Tilia* (1.3%) pollen is present as well as *Fraxinus*, *Salix*, *Populus*, and *Picea*. The share of herbaceous plants lowered as compared to the previous zone especially in Cyperaceae values. The share of algae from *Pediastrum* type, which occurred earlier occasionally (0.2–0.9%), increased (2.3%).

WARLUBIE PROFILE W/W (Fig. 7)

W/w-*Pinus-Betula* L PAZ (30–20 cm)

The *Pinus* curve culminates (50.2–2.1%) and other trees occur sporadically and do not play any important role (*Salix*, *Populus*, *Ulmus*, and *Alnus*). Aquatic and reed-swamp pollen is present (*Nymphaea*, *Potamogeton*

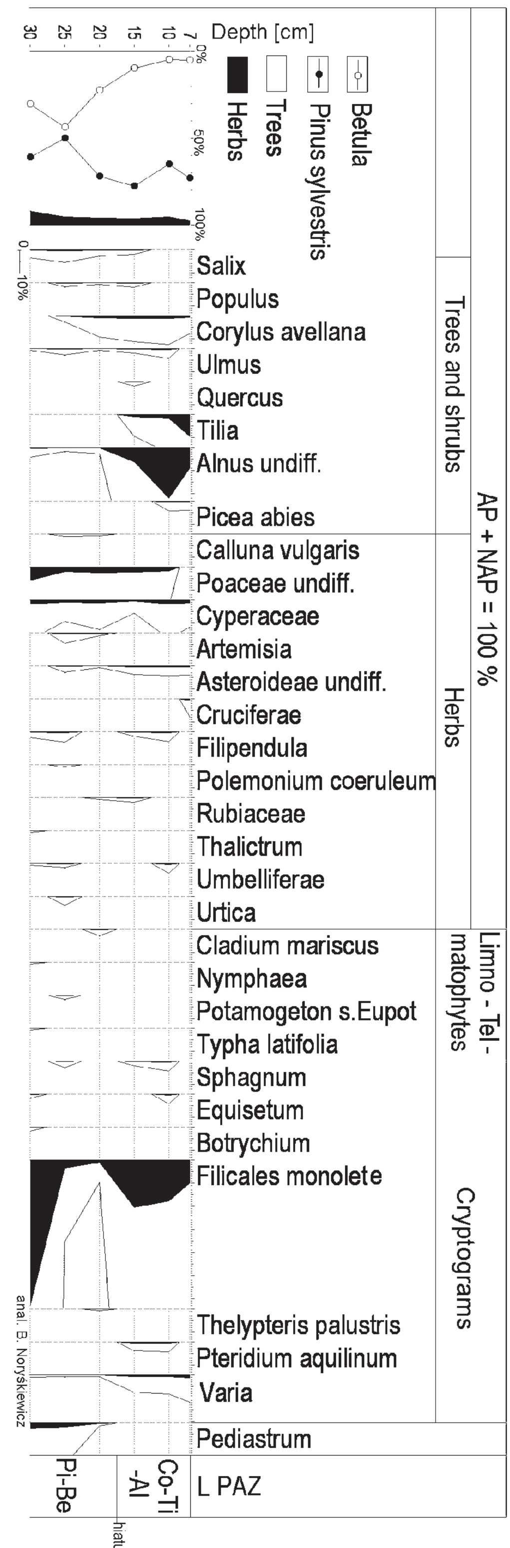

Fig. 7. Warlubie (W/w). Pollen percentage diagram

sect. *Eupotamogeton*, *Cladium mariscus*, and *Typha latifolia*). Numerous Filicales monolete spores (89%) are found in the bottom part of the zone.

W/w-*Corylus-Tilia-Alnus* L PAZ (20–7 cm)

A large proportion of sporomorphs are corroded and a process of its selective decomposition took place probably in this part of deposit. Marked sporomorphes characterize the zone with *Pinus* domination (65.0–77.8%) and high values of *Alnus* (22.1%), *Tilia* (9.4%) at the same time. *Corylus* pollen is present, *Populus, Salix, Quercus*, and *Picea* occur occasionally. Fern spores retain their average values of 15.7%.

CORRELATION OF POLLEN ZONES

The pollen assemblage zones (L PAZ) distinguished in the pollen diagrams from the lake and peat bogs have been correlated in Figures 8 and 9. All profiles contain the records of vegetation history from the early Holocene (Preboreal period). The earlier part of the Preboreal period (*Pinus* LPAZ) was distinguished and correlated only in profiles from peat bogs (PZ/4 and PZ/2), and they do not have their equivalents in the analysed deposits from the lake and other archaeological excavations. The core from Lake Zawada contains besides the lack of the earlier part of Preboreal period probably a complete sequence of the remainder of the Holocene. Likeness of palynological record included in zones: *Pinus*, *Pinus-Betula*, *Ulmus-Quercus-Fraxinus*, *Corylus-Tilia-Alnus*, enabled us to correlate them and to acknowledge that they represent the same phase of succession and, therefore, the same period in the studied profiles. The differences observed in the concentration of sporomorphs could be discerned in local conditions which existed in the peat bog. In the core from PZ/4 (peat bog), in the younger part of the Holocene (the beginning of *Carpinus* LPAZ zone) a sedimentation rhythm, expressed by long-term hiatus lasting probably from the end of Subboreal period until early Medieval Age, was disturbed.

A small thickness of deposits from the lake profile indicates that the rate of sediment accumulation in this part of the lake was rather low and the average deposition rate for the whole profile is 0.06 cm/year, thus, it is lower than for example in Lake Biskupin (profile 4) – 0.09 cm/year (Niewiarowski 1995), Lake Mały Suszek also 0.09 cm/year (Miotk-Szpiganowicz 1992). In the peat bog deposits (PZ/4) the rate of deposition is twice as high. Due to the presence of the hiatus however, it has not been possible to calculate the average rate of deposit formation in this profile. However, the chronology of pollen diagrams compared indicates that the rate of deposition was different in different periods. It is also confirmed by varied values of pollen concentration in 1 cm^3 in deposits of Lake Zawada. A comparison between a loss on ignition curve with histograms representing pollen concentration in 1 cm^3 (Fig. 4) shows positive correlation of these values. Undoubtedly, in these profile segments, where frequency and loss on ignition content tended to rise at the same time, rate of sediment accumulation was lowered. Small number of absolute dating prevents from making this reasoning precise.

The excavation diagram (profile W/w) has been divided into two pollen zones. They represent different pollen pictures. The zone *Pinus-Betula* was formed in the period when pine-birch forests dominated, at the same time as correlated deposits in the remaining profiles, namely, in the Preboreal period. The artefacts of Wielbark culture colonisation (Bokiniec 2000), found there can be explained by their migration through the deposit due to the waterlogged conditions (Piotrowski 1995). Among the overlying deposit (*Corylus-Tilia-Alnus* LPAZ) there is a sedimentation gap. This covers a period which is difficult to precisely delimit due to bad preserving conditions of sporomorphs in the top level and the lack of characteristic pollen bio-indicators which could help to specify this zone. It is the most believable to place it in the central part of the zone (*Corylus-Tilia-Alnus* LPAZ) distinguished in Lake Zawada (the end of AT beginning of SB). Sedimentation of this deposit took place with higher water levels in the lake than experienced at present, it means earlier than hiatus was formed in PZ/4. We cannot exclude, however, sedimentation time displacement within the younger Holocene, but judging from the relics of the Wielbark culture left in the deposit studied (the 2^{nd}–5^{th} century), this deposit is not younger than it.

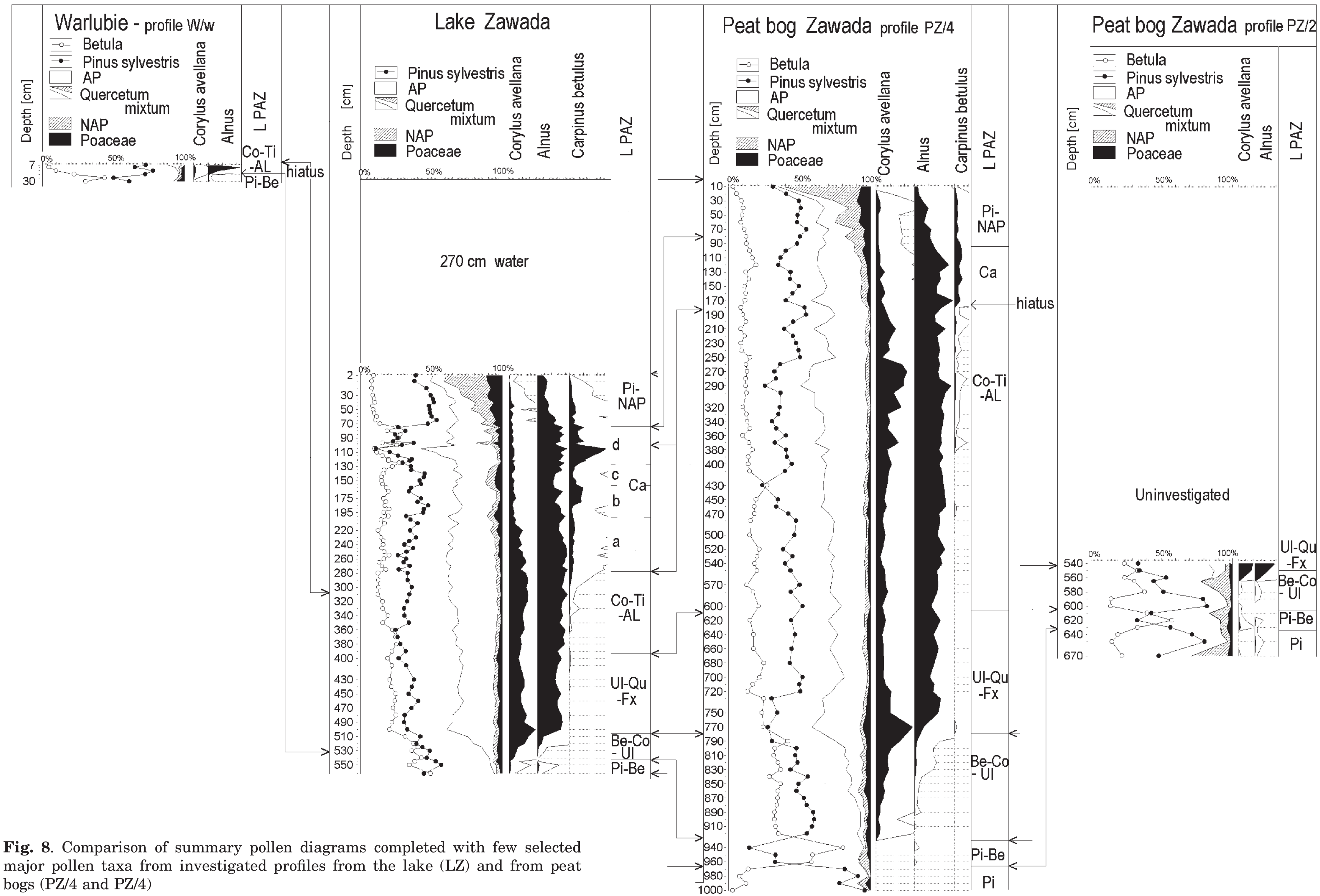

Fig. 8. Comparison of summary pollen diagrams completed with few selected major pollen taxa from investigated profiles from the lake (LZ) and from peat bogs (PZ/4 and PZ/4)

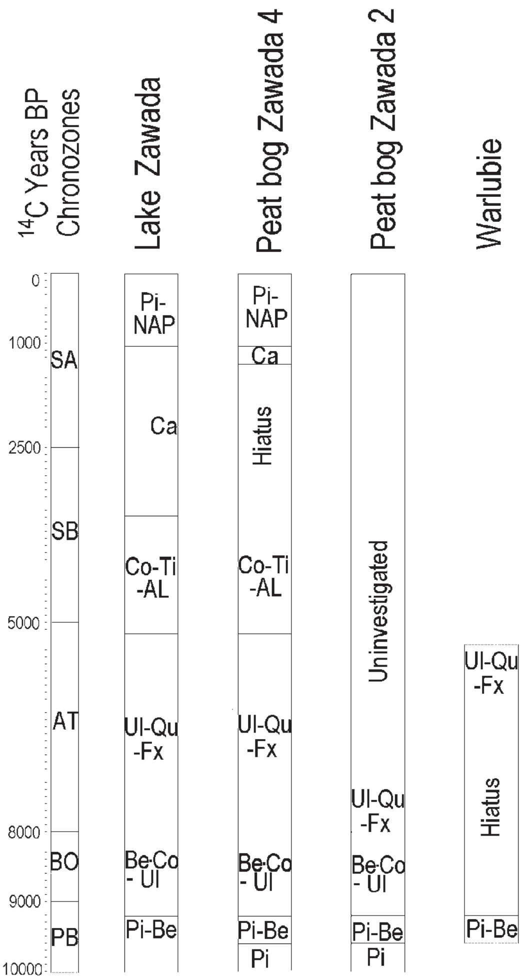

Fig. 9. Correlation of the local pollen assemblage zones distinguished in the investigated profiles Lake Zawada (LZ), peat bogs Zawada (PZ/2, PZ/4) and profile Warlubie (W/w) and plotted on the time scale

RECONSTRUCTION OF THE VEGETATION IN THE VICINITY OF LAKE ZAWADA

Palynological records included in pollen diagrams from Lake Zawada profile and PZ/4 and PZ/2 peat bogs make it possible to reconstruct the vegetation from the area surrounding the lake from the beginning of the Holocene (Preboreal period) until present times. Within the profiles chronostratigraphy was made by means of radiocarbon dating and comparison with diagrams for Bory Tucholskie (Hjelmroos-Ericsson 1981, Miotk-Szpiganowicz 1989).

Pinus (PZ/4, PZ/2, W/w) LPAZ the earlier part of Preboreal period

It is a period of maximum development of pine forests. A rapid increase in temperature about 10 000 years BP caused replacement of park landscape from the Younger Dryas by woodland. Continental climate and generally poor soils at the beginning of the Holocene furthered the expansion of pine in this early period. It was one of the components of park tundra in the area studied in the Younger Dryas (Tobolski 1972, 1976, Drozdowski 1974) and, therefore could react, in an expansive way, almost immediately to climate improvement (Hoek 1997). Such a succession correlates well with the pollen picture showed in diagrams from peat bog Rudnik located 10 km north-east of Lake Zawada (Tobolski 1972, Drozdowski 1974). They record a similar succession in the earlier Preboreal period, which could be considered as a regional feature for the area studied. The evidence of *Pinus* existence near shores of Lake Zawada are cones and fragments of *Pinus* bark preserved in the deposit studied. A radiocarbon date of a cone, from 970 cm depth, is 9760 ± 60 BP Poz-3628. Low contribution of NAP indicates the increase in density of the tree layer, although a constant presence of Poaceae undiff., Cyperaceae, and *Artemisia* pollen suggests that at some places, the remains of open, late glacial communities still kept up. The presence of aquatic and reedswamp vegetation (*Myriophyllum spicatum*, *Typha latifolia*, *Equisetum*) documents the existence of a lake of eutrophic character. At the same time, at the bay, in the southern peat bog, moss-wood peat accumulation takes place with remains of brown-mosses, wood and herbaceous plants. The peat accumulation started at the beginning of Preboreal period, above the block of a dead ice not long before its melting. Its intensive melting in the earlier stages of the Preboreal led to the lake deepening and flooding up of the previously formed layer of peat (Błaszkiewicz 2003).

Pinus – Betula (LZ, PZ/4, PZ/2) LPAZ, middle part of Preboreal period

Birch has taken favourable sites around the lake replacing pine in forest communities. This alternating domination of these two species is characteristic for the initial protocratic stadium when the climate with rather high and oscillating temperatures and considerable continental features stayed in a non-balance state with unstable vegetation (Tobolski 1976). Plant communities with *Artemisia*, *Stellaria holostea*, and *Pleurospermum austriacum*, which survived probably from Late Glacial period, dominated in poorer and drier habitats. Relatively high values of grasses and the presence of *Filipendula*, *Urtica*, *Thalictrum*, different Umbelliferae, and Rubiaceae in the profile from the peat bog indicate occurrence of herb vegetation around the lake. Reedswamp communities are represented by numerous tetrads of *Typha latifolia*, *Cladium mariscus* pollen, and *Equisetum* spores. Rise in algae (*Pediastrum*) and fern shares (Filicales monolete and *Thelypteris palustris*) and the presence of the aquatic vegetation (*Nymphaea*, *Potamogeton* sect. *Eupotamogeton* – profiles LZ and PZ/2), and simultaneous hiatus in the upper part of the zone described in deposits from W/w excavation (Fig.7) may be a reflection of water level lowering that resulted in discontinuous sedimentation in the littoral zone.

Betula-Corylus-Ulmus (LZ, PZ/4, PZ/2) LPAZ the younger part of the Preboreal period and the Boreal period

During this period, the area around the lake was overgrown by pine forest, however, it underwent changes under migration of thermophilic species. It was the period of the most dynamic changes in the development of the lake area vegetation. *Corylus avellana* expanded quickly on fresh soils of higher fertility. A hazel, as a light-demanding species, has displaced a pine and in some cases *Populus*. Expansion of *Corylus* is synchronous with appearance and systematic rise in significance of elm, oak and alder. The continuous *Ulmus* curve, initially below 1% and in the upper part of described zone in Lake Zawada even above 3%, implies its local presence in the area (Huntley & Birks 1983, Ralska-Jasiewiczowa 1983). Rise of *Quercus* and the first traces of *Tilia* signal the development of mixed deciduous forests caused by the climate warming. A distinct rise of *Alnus* and appearance of *Fraxinus* indicate forest domination in wet habitats and formation of community resembling contemporary alder carr. Heather (*Calluna*) and bracken fern (*Pteridium*) were present in the undergrowth. The litoral zone was covered by reedswamp communities with *Typha latifolia*, *Cladium mariscus*, *Sparganium*, and *Equisetum*, which are represented in profiles by smaller values than earlier. On the southern shore of the lake (PZ/2 profile), *Menyanthes trifoliata* was a component of these communities. The contribution of aquatic vegetation, represented by *Nymphaea*, *Potamogeton* sect. *Eupotamogeton*, *Myriophyllum spicatum*, and Umbelliferae, increased in relation to the previous zone.

Ulmus-Quercus-Fraxinus (LZ, PZ/4. PZ/2) LPAZ the Atlantic period

The Atlantic chronozone is characterized by exceptionally low rate of sediment accumulation. About 3000 years were recorded in 1 m (LZ profile) and 1.3 m (PZ/4 profile) of the lake deposit. Low rates of sediment accumulation in the Atlantic period are observed in numerous basins from different regions of Poland (Szczepanek 1982, Noryśkiewicz 1995) and it requires detailed, multi-disciplinary research. The Atlantic period, similarly to Preboreal and Boreal periods, is characterized by high degree of the area forestation which is testified by low curve of herbaceous pollen (NAP). A pine or mixed forest could still dominate on poorer soils but it was replaced by deciduous forests with elm, lime, oak and ash on more fertile ones. Their presence is connected with the Holocene climatic optimum, which is indicated by the presence of *Viscum* pollen. For elm, it is the period of its greatest expansion in the whole Holocene history of forest development. Mutual relationship between *Pinus* and *Alnus* may indicate that, as pine appeared close to the lake in the Boreal period (pine cones in Preboreal period in PZ/4 profile), in the Atlantic period it was replaced by alder. Share of *Alnus* in the profiles studied from the time of its expansion until the Middle Ages (*Pinus*-NAP LPAZ) underwent relatively small fluctuations, which could mean that the habitats for alder around the lake were quite stable. In the underwood, *Rhamnus cathartica*, *Salix*, and *Humulus*, as well as *Filipendula*, *Urtica*, *Thalictrum*, Umbelliferae, and other plants in the undergrowth could accompany it. The occurrence of higher values of herbaceous pollen (*Filipendula* 0.2 and 0.4%, Poaceae undiff. 4.6 and 5.7%) in the profile from the peat bog (PZ/4) is of local significance. The first pollen of *Plantago lanceolata* appears in the upper part of zone (PZ/4 profile), it may be assumed that it is a weak reflection of pasture activity run to the small or large extent within a considerable distance from the lake. Moreover, the presence of heliophilous plants such as *Artemisia*, *Calluna vulgaris*, *Rumex acetosa*/*acetosella*, *Knautia*, and *Urtica* may prove the existence of partly open forest. Additionally, one can observe a *Pteridium* continuous curve of, which provides information about the forest opening resulting from anthropogenic fires. In spectra where the number of *Pteridium* spores rises, the amount of deciduous forest components (*Ulmus*, *Tilia*, *Fraxinus*) decreases. Natural fires are rare in that type of forest (Latałowa 1994).

Corylus – Tilia – Alnus (JZ, TZ/4) LPAZ, the earlier part of Subboreal period

Diagrams from this zone present the next reconstruction of forest. Forests with large contributions of *Quercus* cover poorer soils, whereas on more fertile areas in deciduous forests, the share of elm and later ash and lime decreases. The decrease of elm is marked at the beginning of the zone and again in its second half. The fall of the elm curve in Europe at about 5000 BP was traditionally attributed to stock breeding (Iversen 1949). This phenomenon, still widely discussed, is attributed most frequently to a combination of climatic, edaphic, antropogenic and pathogenic reasons (Ralska-Jasiewiczowa & van Geel 1992). In the diagrams discussed, the convergence between *Ulmus* fall and rise of indicators of human activity cannot be displayed. The presence of occasional anthropogenic indicators is in accordance with a small number of archaeological findings from this period (Chudziak 2001).

A distinct but short synchronic rise in the amount of *Ulmus* and *Quercus* pollen in both profiles (LZ 330 cm and PZ/4 340–330 cm) is interesting. The increase of these pollen grains in diagrams corresponds with depression of other deciduous trees (*Tilia*, *Fraxinus*) and *Corylus*. Changed hydrological conditions around the lake were probably the reasons for changes in forests composition. It is indicated by comparison of intensity of changes in the composition of herb vegetation in profiles both from the lake (LZ profile) and from the peat bog (the former western bank of the lake). In the diagram, we observe distinct larger fluctuations in the percentage curves of the taxa listed. A rise in Filicales monolete spores and their maximum at the end of the zone are of local significance. An increase, in littoral zone, of aquatics (*Nymphaea*, *Potamogeton* sect. *Eupotamogeton*) enriched by new *Nuphar* and *Lemna* taxa as well as almost continuous *Typha latifolia* curve testify intensive overgrowing of shoreline. It is difficult to define changes (an effect or a reason) in the chemical composition of the deposit. Precisely, in the section where we observe a *Ulmus-Quercus* peak, in the lake – detritus gyttja, is enriched by calcium carbonate (13.3% – when earlier its average share was not higher than 3.5%). In PZ/4 profile, *U-Q* episode is also synchronic with $CaCO_3$ rise (44.6%) with a difference that in this part of the basin, carbon gyttja had been accumulated earlier and this rise in carbonates was preceded by provision of mineral material (64.3%). Synchronisation of both profiles by means of comparison of pollen diagrams (Figs 8, 9) and physico-chemical analyses (Fig. 10) results allows us to state that the beginning of detritus gyttja accumulation with $CaCO_3$ in the central part of the lake is synchronic with the beginning of calcareous gyttja sedimentation in sandy deposit at the depth of 360 cm in the bay. It is probable that at this time the water level in the lake was higher than a threshold separating these two

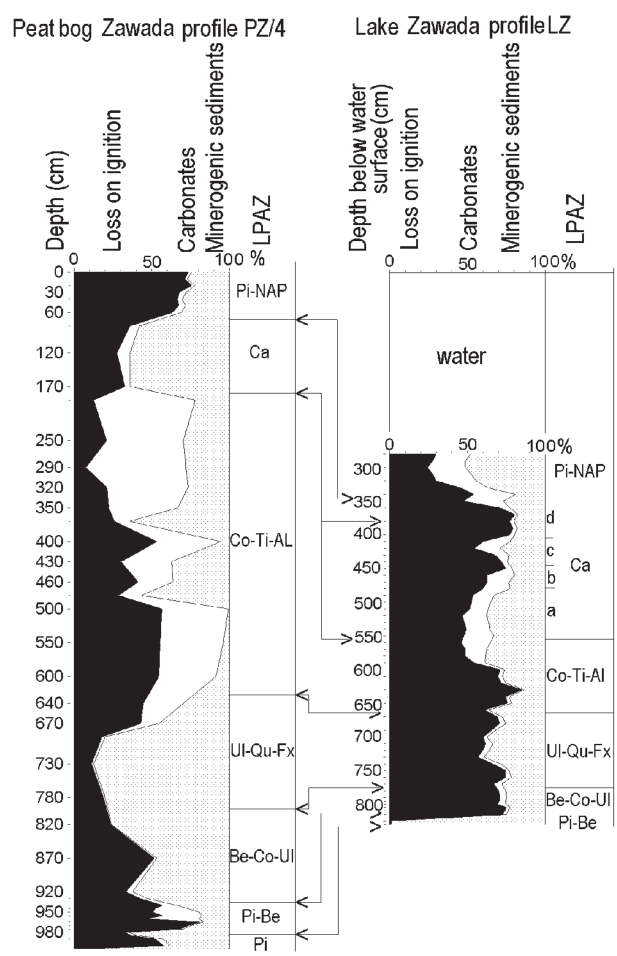

Fig. 10. Main sediment components of the Lake Zawada and peat bog Zawada 4: loss on ignition, $CaCO_3$ content in the ignition residue and minerogenic sediment

profiles, connecting them into one basin. Pine pollen, at this time, behaves in a stable way, and probably comes from the more distant transport. Hazel pollen, in the earlier part of the zone, increases reaching Subboreal maximum in order to fall gradually later. The presence of *Picea* pollen, always below 0.9%, means that this tree was in this area outside the tight limit distribution and pollen of this species comes from a long distance. The appearance and gradual rise of *Carpinus* pollen from the mid-zone, indicates the development of the *Querco-Carpinetum* type of woods.

Carpinus LPAZ (LZ 3500–1070 BP), (PZ/4 1440–1070 BP) the later part of Subboreal and earlier part of Subatlantic period

Deep changes in the structure of deciduous trees from the beginning of the zone *Carpinus* were recorded only in the lake profile (LZ). However, pollen analysis of the profile from the peat bog showed a deposit sedimentation gap (hiatus) caused probably by low water levels in the lake. Gradual lowering of water levels was registered by pollen record from the later phase of the previous zone (*Corylus-Tilia-Alnus*), expressed by rising frequency of limno- and telmatophytes. In the deposits of this profile (PZ/4), only younger part of the zone (*Carpinus*) – upper fragment of d subzone remained. Hiatus was marked by a rapid change of the deposit. Dark grey fine detritus gyttja accumulated on a cream-white calcareous gyttja. Contribution of carbonates through a distance of 10 cm falls from 65.3% to 3.3%.

The *Carpinus* and NAP curves fluctuations in the lake profile give the possibility to distinguishing 4 sub-zones (‘a”, “b”, “c” and “d”). Changes of vegetation, noted in the diagram, were caused both by natural trees succession provoked by climate changes and human economic activity. The climate became cooler and wetter. Hornbeam, favoured by climate, expands in forests communities. It enters the Świecie District relatively late and at first it was one of the minor components of deciduous forests. It forms phytocoenoses of deciduous forests with oak and lime together. In these forests there was an underwood with *Corylus avellana*, *Frangula alnus*, *Rhamnus catharticus*, *Ribes*, and *Sambucus*. It becomes more significant during forest regeneration (Fig. 3) which took place in this area after colonisation from the early Bronze Age (phase 3). The dominating role of hornbeam made the structure of these forests different from the previous prevailing ones (Tobolski 1991). In contemporary forests this species forms the highest layer of trees shadowing others which eliminated *Corylus* from the composition of these phytocenoses. Its occurrence was probably limited to the shores of the lake and forest peripheries. However, maximum expansion of hornbeam in the entire Holocene took place just after intensive colonisation in the area from the early Iron Age and Roman period (phase 4), namely, in the Migration period. Maximum development of forests with dominant *Carpinus* was belated by about 1500 BP years as compared to Wielkopolska (Tobolski 1991). This period was dated on 1690 ± 140 ^{14}C BP Gd-10 988. Great regeneration ability of this species allowed for fast expansion of hornbeam forests until the early Middle Age period (phases 5 and 6). At this time its role and forest significance in general were limited considerably (sub-zone d -LZ and PZ/4 profiles) through intensification of farming economy (Chudziak & Noryśkiewicz 2003). The upper part of this zone dates with a radiocarbon age of 1150 ± 130 BP Gd-13 072.

Pinus-NAP LPAZ (JZ, TZ/4) (1070–200 BP) the later part of Subatlantic period

The latest *Pinus*-NAP zone contains the record of greater changes in the vegetation from the area of Lake Zawada. It was influenced by indicators of both economic and sociopolitical nature. At the end of 10th century, the Świecie District used to be under influence of early Piast State (Chudziak 2001). High percentage values of herbaceous plants and especially synanthropic plants could be interpreted as pollen rain from an open area formed after heavy deforestation caused by human economic activity.

Rapid rise of pine proves that it again became a dominating component of the remaining forests. However, pine forests were hardly dense which is indicated by an increase of *Juniperus* pollen curve in the diagrams (LZ 3.9%, PZ/4 3.7%). These shrubs found good conditions for development in open forest where grazing areas were present also. Willows and alders grew in wet habitats close to the lake. However, gradual decrease in *Alnus* values proves that these humid habitats also underwent anthropopression. Area covered by deciduous forests with lime, elm and ash was considerably limited. It is only the oak that keeps constant values until modern times. Single oaks left after tree felling had probably better conditions for blooming and production of pollen (Ammann 1989). The role of *Picea* increases in the upper spectra as a result of spruce cultivation in the studied area.

Separate attention should be paid to *Pediastrum* coenobia. This genus is represented by several or more than ten percent amount values in all older LPAZes of LZ and PZ/4 profiles. Expansion of *Pediastrum* in this LPAZ is probably caused by the rise in the lake trophy.

ANTHROPOGENIC ACTIVITY IN POLLEN DIAGRAMS

Human economic activity indicators stated in the studied profiles were listed in synthetic diagrams in which *Secale cereale*, sum of the remaining cereals, meadow plants and weeds sum as well as Poaceae undiff. were separated. Changes in the curves of these sporomorphs and trees were the basis for separating 7 phases of human economic activity (Fig. 11).

The first, not so distinct, changes in pollen diagrams, interpreted as evidence of human

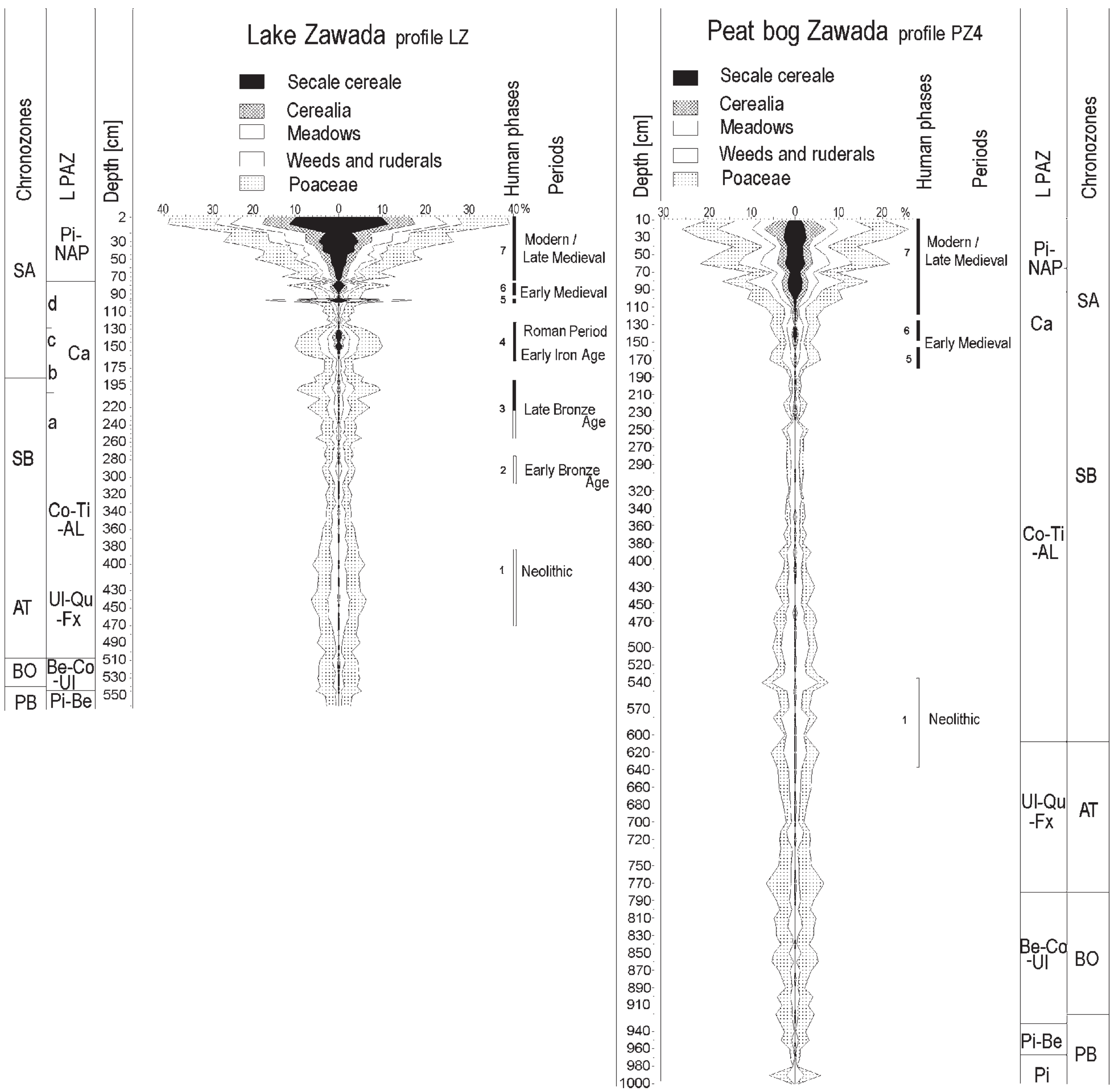

Fig. 11. Synthetic diagrams of human impact indicators and anthropogenic phases for profiles Lake Zawada and peat bog Zawada 4

activities, appear in the earlier part of *Ulmus-Quercus-Fraxinus* PAZ correlated with the Atlantic period. These are traces of mid-forest clearing with *Pteridium aquilinum* development and heliophytes mainly *Artemisia*, *Calluna vulgaris*, and *Rumex acetosa/acetosella* shown in the diagram. *Pteridium aquilinum* for spores production needs not only good light conditions but particularly soils enriched in ash (Bennett et al. 1990, Latałowa 1992). It may be assumed that a rise and weak culmination of that taxon in the diagram is an effect of overgrowing the open places caused by anthropogenic fires. Occasional pollen of *Plantago lanceolata* and rise of Poaceae undiff. noted in the upper part of the distinguished phase attributed already to the beginning of Subboreal, signal formation of communities of grassland and pasture types in deforested areas. However, the lack of distinct culmination of synanthropic species allows judging that the north-eastern part of the Świecie District was located on the outskirts of civilisation centres of the early and Late Neolithic colonisation (from Kujawy and Chełmno Land). This has been confirmed by the dispersion of registered archaeological sites both on lower Vistula terraces and in the moraine plateau (Chudziak 2001).

Anthropogenic activity indicators, more distinct than in the earlier phase, in stock raising (*Urtica*, *Hypericum*, *Plantago lanceolata*) and agricultury (occasional Cerealia) are present in phase 2 correlated with early Bronze Age (Iwno and Trzciniec cultures). They are accompanied by Cichorioideae undiff. and Rubiaceae. Decrease of percentage curves of lime, elm and short-term fluctuation of ash in the diagram indicate that a part of woodland was destroyed and replaced by pastures and probably farmlands on some small areas. A small number of archaeological sites come from this period (Chudziak 2001, 2003).

Regeneration of deciduous trees with an important role of *Carpinus* took place after this phase. This expansion is marked by small culmination (3.2%) of hornbeam thanks mostly to opening of forests communities caused by man.

Phase 3 in the pollen diagram can be linked with the activity of Lusatian culture population (younger periods of Bronze Age). It starts with regular *Plantago lanceolata*, *Rumex acetosa/acetosella*, and Cerealia undiff. curves, which show rising tendencies towards the upper part of phase 3. A frequency of plants of ruderal communities *(Artemisia*, *Urtica*, Chenopodiaceae, *Plantago media/major*) and plants of dry pasture (*Calluna vulgaris*, Ericaceae undiff.) is high. Changes in AP composition are important: in the earlier part, percentage curves decrease of *Tilia*, *Fraxinus*, and *Corylus* is distinct, whereas lowering of the remaining trees function, mainly *Carpinus*, *Quercus*, and *Fagus* does not take place until the later part. This pattern of changes is caused probably by unequally advanced human activity around the site analysed. The younger part of the settlement phase recorded probably colonisation located in some distance from the profile studied (hornbeam-oak forests remained untouched). Intensive traces of the Lusatian colonisation come from this period from the vicinity of Gruczno and Gródek located 20 km off south (Wilke 1979, Chudziak 2001). More intensive traces (higher values of Cerealia undiff., *Plantago lanceolata*, and NAP) come from the later part of the phase and they may be associated with the late Lusatian colonisation confirmed in the neighbourhood of Warlubie and Bąków (Chudziak 2001). At the end of phase 3, pollen curves of synanthropic taxa fall, which indicates economic regress. The abandoned areas were occupied for a short time by pine and later deciduous forests started to renew in the area (increase of *Quercus*, *Ulmus*, *Tilia*, and *Fraxinus*) with domination of hornbeam.

A period of farm and a settlement area exploitation took place (4 phase) after temporary limitation of human economic activity traces. A decrease in the percentage curves of all deciduous trees and a rapid increase of NAP marked this phase. It can be correlated with the early Iron Age and Roman periods. In the pollen spectra indicators of the development of husbandry are observed: *Plantago lanceolata*, *Rumex acetosa/acetosella*, Poaceae undiff., *Ranunculus*, as well as evidence of intensive land cultivation: Cerealia undiff., *Secale cereale*, and *Cannabis sativa* type. Contribution of ruderal plants: *Artemisia*, Chenopodiaceae, and *Urtica* is also considerable. Phase 4 is different from the others in bigger share of cereal pollen, presence of rye and cereal weed (*Centaurea cyanus*). It gives evidence of changes taking place also in the composition of preferred crops. It can be concluded on the basis of human activity indicators and NAP share that this phase is not homogenous and its interpretation is aggravated by low deposit sedimentation rate. The older part characterises by higher values of *Plantago lanceolata* and *Rumex acetosa/acetosella*, and the presence of cereals without *Secale cereale*, and it is maybe a record of colonisation attributed to Pomeranian culture. The overlying spectra are characterized by higher values of cereals with prevailing rye pollen among the others. This period is richly represented by numerous archaeological sites like a settlement of the Wielbark culture located on the western bank of the lake in the second part of the 2nd century until the beginning of the 5th century (Bokiniec 2000).

Recession of antropogenic vegetation and simultaneous regeneration of forests took place after phase 4. Hornbeam gained exceptionally favourable conditions, which was shown by its maximum pollen grain occurrence (26%). Such an intensive expansion was possible thanks to the economic regress and climate deterioration. The depopulation period recorded between phases 4 and 5 (Fig. 11) approximately coincides with the Migration period. The development of *Carpinus* - dominated woods, connected with a general colonisation crisis, makes it possible to consider deciduous forests with domination of hornbeam as anthropogenic communities in a historical sense (Ralska- Jasiewiczowa 1991). The hornbeam maximum is dated by radiocarbon from this period for 1690 ± 150 BP. At this time, a dense forest cover develops and remains until the early Middle Age. It is disturbed by a short term decrease of *Ulmus*, *Fraxinus*, *Carpinus*, and *Tilia* and an increase of anthropogenic taxa which could be a signal of a short settlement period dated archaeologically for the 10th century (Chudziak 2001). Transition between phases 5 and 6 is marked by NAP decrease and fluctuation of pine and birch pollen percentages. Stabilisation of their values does not take place before the late Medieval period.

Phase 6 is represented by two pollen spectra in which NAP increase appeared as the effect of human indicators culmination. The share of *Ulmus*, *Fraxinus*, and *Tilia* diminished in forest communities. We can judge from correlation of this fragment with archaeological evidence that it is a palynological picture of colonisation expansion, which took place in the 11th century. The traces of this colonisation were found in several sites, including remains of the early Medieval settlement (11th–12/13th century) located on the channel slope near the peat bog in the bottom of channel in a distance of 1 km from the lake and the second one, of similar age, close to it (Chudziak 2003).

Further development of synanthropisation and deforestation was connected with the late Medieval period (phase 7) and it is distinctly marked by rapid increase of herbaceous plants in the diagram. Total clearing of the land, characteristic for late Medieval period and lasting until modern times was initiated. All deciduous trees show declining tendencies (*Quercus*, *Ulmus*, *Almus*, *Carpinus*) or even disappear from the palynoloigcal record (*Tilia*, *Fraxinus*). Destructive human activity concerned also alder woods, the effect of which was systematic decrease of the *Alnus* percentage curve. Intensive increase in pine pollen was caused probably by blooming rise of single trees of *Pinus*, and from the other side, by appearance of this tree pollen from long distance in the conditions of an open area. Deforested areas were destined for cereals, buckwheat and hemp cultivation. In the youngest parts of two diagrams (LZ, PZ/4), high curves of Cerealia and *Secale* as well as single *Fagopyrum* and *Cannabis sativa* were noticed. Field weeds and ruderal plants (*Centaurea cyanus*, *Artemisia*, Chenopodiaceae, *Polygonum aviculare*, and *Scleranthus perennis*) accompany them. The presence of pastures is documented by high values of Poaceae undiff., *Plantago lanceolata*, and *Rumex acetosa/acetosella*. It is a phase of the greatest diversity of taxa. The archaeological sites do not reflect the record of the economical changes in the pollen diagram attributed to the late Medieval and Modern periods. Historical data indicate that settlements moved closer to the edge of the Vistula valley where Nowe town, with location rights since 1273, was settled by the Teutonic order state (Wilke 1979). Palynological research shows that the previously deforested areas were used and are still used for cultivation and as pastures.

Coenobia of algae were studied simultaneously with sporomorph analyses. In the diagrams, we noticed an interesting relationship between *Pediastrum* mass and palynological anthropogenic indicators. Simultaneous increase of *Pediastrum* values and of anthropogenic indicators contribution suggest that the colonisation intensity affected a rise in the basins fertility. The great number of *Pediastrum* in the Medieval Age and historical period most probably illustrate a rise in a throphic status and at the same time the basin shallowing.

CONCLUSION

Palynological analyses of deposit from Lake Zawada and surrounding peat bogs made it possible to characterize the natural environment from the Preboreal period until modern times. In the diagrams, 7 local pollen assemblage zones were distinguished on the basis of which we can reconstruct the history of vegetation in the vicinity of Lake Zawada during the Holocene (Figs 3–5)

Seven phases of intensive human activity have been distinguished (Fig. 11), which were linked with evidence of pre-historic and historic settlement. The record of palynological phases shows that the earliest, yet weak, traces of stock raising and farming come from the Neolithic (phase 1). A bit more distinct, in comparison to phase 1, indicators of stock raising and farming are found in phases 2 and 3, however, the disturbance intensity in vegetation cover rose dynamically in the early Iron Age and Roman periods. It coincides with the period of Wielbark settlement activity at the western part of Lake Zawada. Basic transformations of natural environment refer to the early Medieval period (phases 5 and 6) and late Medieval period as well modern times (phase 7).

All the phases of human activity, distinguished on the basis of pollen analysis showed great accordance with archaeological data.

Correlation of the local pollen zones in the cores studied (Figs 8, 9) allowed the discovery of sedimentation gaps (hiatuses) in PZ/4 and W/w profiles and determining the time of their occurrence.

Characteristics of deposit lithology in profiles from the lake and the peat bog (LZ and PZ/4 profiles) showed that the deposits from the earlier part of the Holocene are almost non-carbonate whereas the amount of carbonates rises towards the upper part of the profiles. The latest profile fragment from the peat bog is again non-carbonate (Fig. 10). However, the nature of fluctuation and the curves illustrating the changes in composition, loss in ignition, $CaCO_3$ and minerogenic components indicate that their content in Lake Zawada and peat bog Zawada deposits are different in time and space. It denotes the dependence between the deposit composition and location of the profiles in the lake.

Palynological studies of the Warlubie site (W/w profile) provided evidence that the biogenic deposit was formed in two stages (Fig. 7). The first stage was the lake episode, which took place in Preboreal period, and the second one is the stage of peat accumulation in the younger part of the Holocene. The conclusion is that archaeological inventory found in this deposit studied attributed to Wielbark culture is therefore younger than the sediments. It is also a proof that the lake, in its history, had the periods of higher water level than experienced at present.

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