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A new Eemian Interglacial to Early Vistulian site at Łanięta, central Poland

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The Łanięta site with fossil lake deposits is situated just in front of the maximum extent of Vistulian Glaciation ice. Palynological analysis shows that lake accumulation lasted through the Eemian Interglacial and almost the whole Early Vistulian, the longest record of this time interval in this part of Poland. Two warm interstadial-rank oscillations (Brörup and Odderade) and two stadials have been distinguished during the Early Vistulian. The older of these is correlated with the Herning Stadial while younger one equates with the Rederstal Stadial of the German succession.

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INTRODUCTION

The Łanięta site is located in the northeastern part of the Kłodawa Upland, about 2.5 km to the south of the maximum limit of the Vistulian Glaciation ice sheet (Fig. 1). The fossil lake deposits there were identified during mapping for the *Detailed Geologic Map of Poland* at the 1:50 000 scale, Gostynin sheet (Roman, 1999). Further palynological analysis was carried out at the Quaternary Research and Geomorphology Department, University of Łódź. This paper details the palynology of the fossil lake deposits and their geological setting, expanding on the work of Roman and Balwierz (2000).

The nearest palaebotanically documented sites with deposits of Eemian and Early Vistulian age are situated at Kaliska (Fig. 1) and at Ruszkówek, both these sites occurring within the limit of the Vistulian ice sheet (Domosławska-Baraniecka, 1965; Janczyk-Kopikowa, 1965, 1997; Kozydra and Skompski, 1995).

METHOD

The lake deposits at Łanięta were found in a 12.0 m deep WH-5 borehole. Clastic fluvial deposits, 1.5 m thick, are underlain by gyttja, clays and organic silts, mantled by a thin layer of compressed peat and peaty mud. The bottom of the lake deposits was not reached. The outline of the buried basin was reconstructed by of shallow boreholes which reached the lake deposits under a thin (up to 2.0 m) cover of glaciofluvial and fluvial deposits (Figs. 2 and 3). Palynological examination was carried out on deposits from the depth interval 1.8–11.9 m. 47 samples were collected at intervals of 5 to 90 cm, and 43 were analysed. The material did not contain carbonates. The samples were boiled in 10% KOH and then, in order to remove mineral particles, they were left in hydrochloric acid for 48 hours. Samples were then subjected to the Erdtman's acetolysis. The material was stored and counted in pure glycerine.

Percentage calculation was based on the basic pollen sum (AP and NAP) but with the exception of aquatic and swamp plants, spores of *Sphagnum*, Pteridophyta and indeterminable

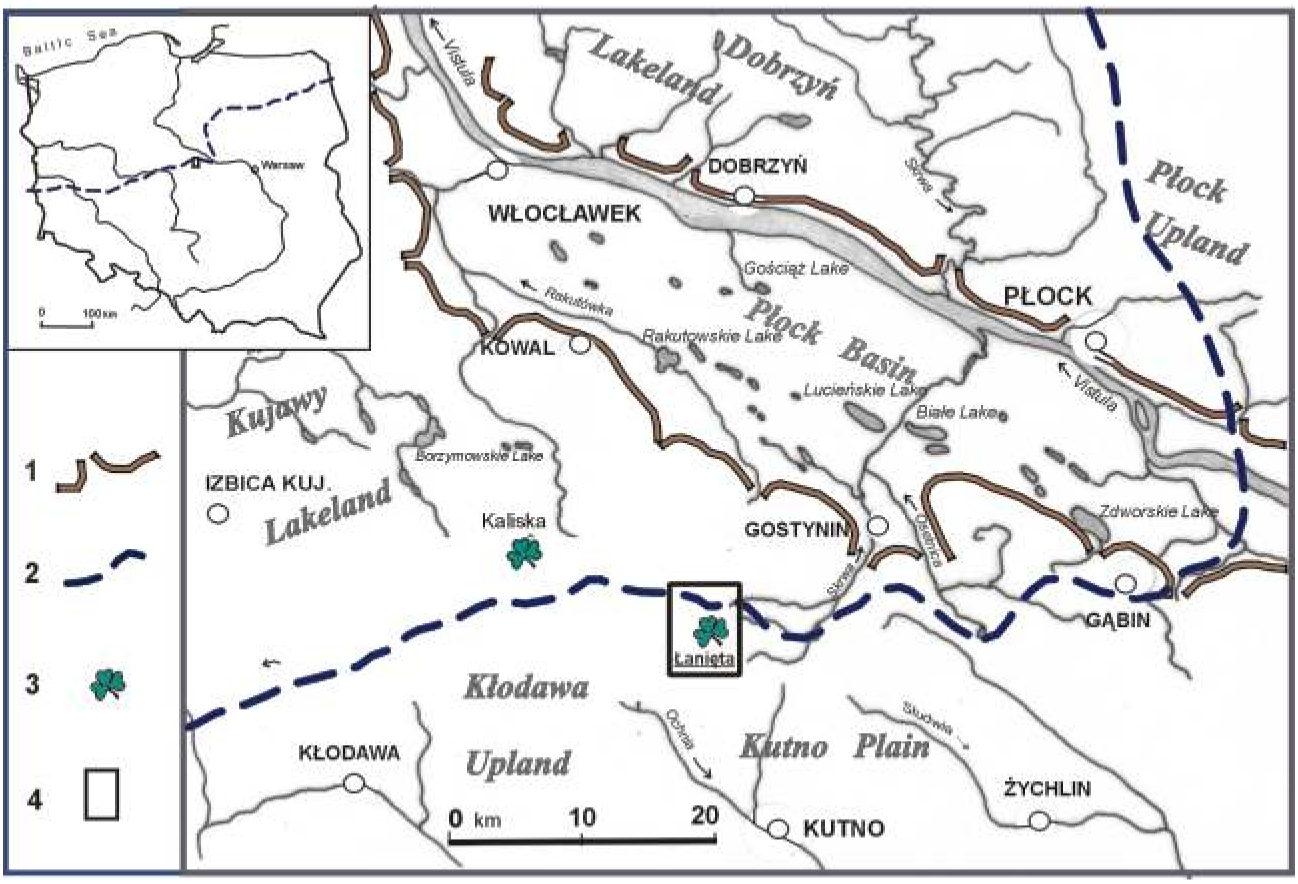

Fig. 1. Location of the Łanięta site

1 — boundary of the Płock Basin, 2 — maximum extent of the Vistulian ice sheet, 3 — sites with fossil Eemian and Early Vistulian flora, 4 — geological sketch (see Fig. 2)

grains. The contribution of excluded taxa was calculated from a total increased by the number of specific groups. The results were presented in a pollen diagram constructed with a use of the computer program Polpal for Windows (Walanus and Nalepka, 1998). The pollen diagram presented in this paper is a simplified version, curves of some taxa being omitted, while others are presented together as a single curve. The indeterminable sum contains corroded pollen grains (being the highest in this group), unknown pollen grains besides good preservation and *varia* (e.g. broken or crumpled). On the diagram black silhouettes indicate percentage values, while white ones denote permil.

GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

The N–S elongated depression running along the present Skrwa River valley is a remnant of the Łanięta basin (Fig. 2). The bottom of the depression is several metres beneath the surrounding denuded morainic plateau at 128–134 m a.s.l. The plateau is composed of till and glaciofluvial sands of the Wartanian Glaciation. In the western part of the depression there is a bench of glaciofluvial sediments which continues eastwards as an extensive outwash plain. The outwash plain was formed during the advance and steady-state position of the Vistulian ice sheet. About 2.5 km north of Łanięta there is the maximum limit of the Vistulian ice sheet. In the landscape it is expressed by slight relief diversity of the younger interfluve surface. This limit was indicated mostly on the basis of a till (Roman, 1999; Roman and Lisicki, 2000) and its age is constrained by the well known site at Kaliska (Domosławska-Baraniecka, 1965; Janczyk-Kopikowa, 1965; Baraniecka, 1989). At Łanięta the lake deposits are not overlain by till or by residual till but by fluvial and deluvial deposits only. However, in a lateral direction, between lake and deluvial deposits, there are glaciofluvial sands of the last glaciation (Fig. 3).

The depression, where fossil lake sediments have been recognised, is a remnant of a tunnel valley formed at the end of the Wartanian Glaciation. Its origin is indicated by the fossil morphology, geological setting and also by its filling at least since the beginning of the Eemian Interglacial, excluding long-lasting postglacial fluvial erosion.

The geological setting of the lake deposits at Łanięta and their relation to the geological structure of the Cainozoic floor are shown in Figures 3 and 4. The basin is located above a tectonic contact between Zechstein and Mesozoic rocks. Tectonic activity here, salt mobility and karstic phenomena developed in salt dome-related anhydrite probably influenced the Cainozoic deposits, causing a tectonic depression to develop above the

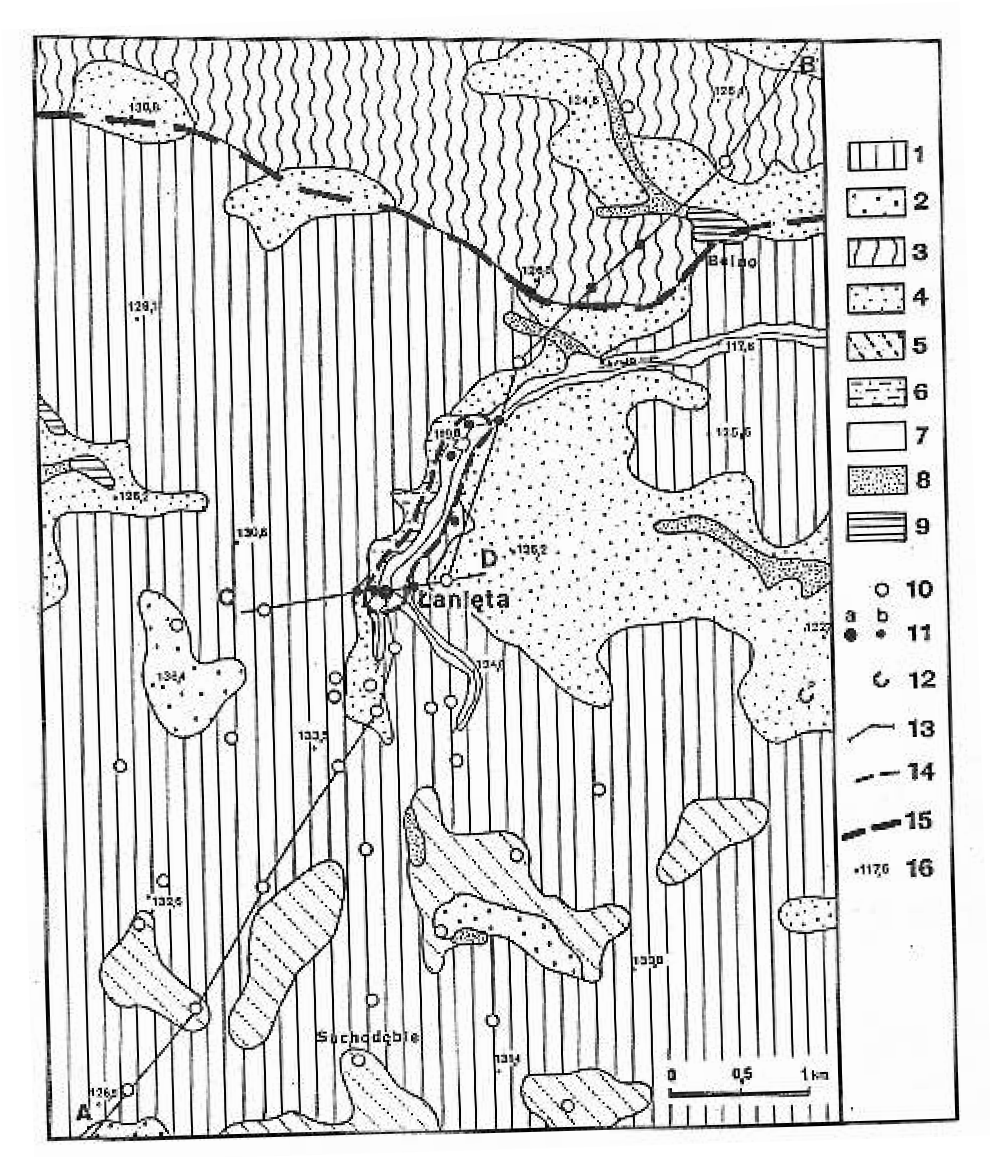

Fig. 2. Geological sketch of the Łanięta area

Wartanian Glaciation: 1 — till, 2 — glaciofluvial sand with gravel; **Vistulian Glaciation**: 3 — till, 4 — glaciofluvial sand and gravel; **Pleistocene/Holocene**: 5 — eluvial sand on a till, 6 — deluvial sand and silty sand; **Holocene**: 7 — fluvial sand and gravel, 8 — humus sand of valley floors and closed depressions, 9 — peat and peaty mud; 10 — selected boreholes; 11 — shallow boreholes: (a) with profile analysed, (b) other; 12 — sand pit; 13 — geological cross-section; 14 — probable extent of Eemian and Early Vistulian lake deposits; 15 — maximum extent of the Vistulian ice sheet (Roman, 1999); 16 — altitude in m a.s.l.

salt dome near Łanięta. During the Pleistocene it was further depressed as indicated by increased sediment thickness and lithological changes (Fig. 4). The Quaternary deposits in the depression are nearly 100 m thick but 40–55 m thick outside the basin. Within the Pleistocene deposits there are 3 to 6 stratigraphic units (Roman, 1999). They represent the Nidanian, Sanian, Odranian, Wartanian and Vistulian glaciations. The Podlasian and Mazovian interglacials are represented by fluvial sediments. Fluvial sediments of the Mazovian Interglacial are commonly overlain by glacial silts and clays (Baraniecka, 1979, 1993) forming an important lithostratigraphic horizon on the Kłodawa Upland. The Eemian Interglacial is represented by lake deposits only.

POLLEN ANALYSIS

In the diagram 12 local pollen assemblage zones (LPAZ) were distinguished.

Betula-Pinus **LPAZ**, samples 44–47. The AP curve is very high, reaching 98.1%. It mainly contains *Betula* undiff. pollen (63.6%) and *Pinus* undiff. (48.4%). There are small amounts of pollen of *Ulmus, Corylus, Alnus* and *Quercus*, increasing upwards. The participation of herbaceous plants is small; the pollen includes Poaceae undiff., *Artemisia* and Chenopodiaceae, *Calluna*, *Anthemis* t., Cichoriaceae, *Ranunculus acris* t., *Filipendula*, *Thalictrum* and Umbelliferae undiff. Of aquatic

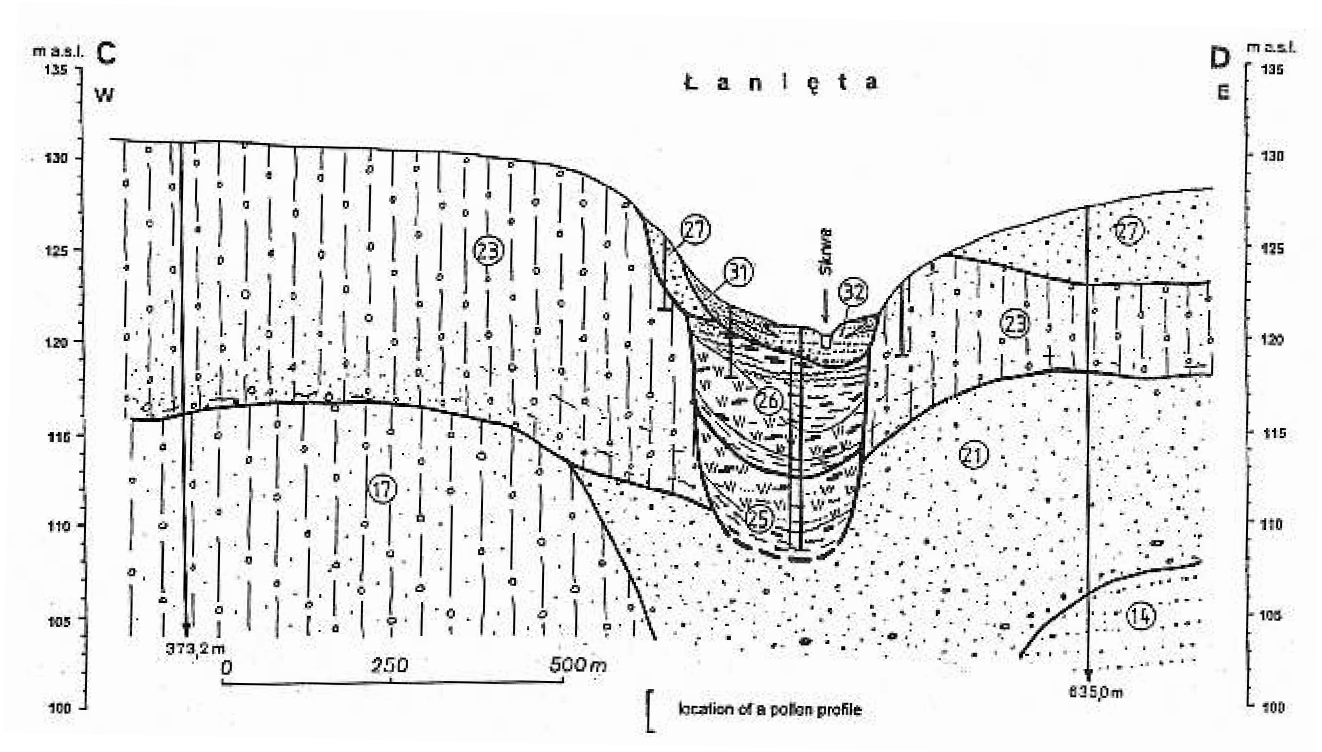

Fig. 3. Geological cross-section C–D

Explanations as in Fig. 4

and reedswamp plants there is pollen of *Typha angustifolia/Sparganium, T. latifolia, Lysimachia thyrsiflora, Myriophyllum alternifolium, M. spicatum* and algae of *Botryococcus* and *Pediastrum.* Bryophyta are represented by *Sphagnum* and Pteridophyta by Polypodiaceae undiff. spores. A decrease in *Quercus* denotes the upper limit of the zone.

Quercus-Corylus **LPAZ**, sample 42. The AP curve remains at a high level. The *Quercus* value reaches 46.1%, the maximum in the whole diagram. Participation of *Corylus* (28%) is also fairly high. Besides these taxa there is also pollen of *Ulmus* and the maximum, although still moderate amount of *Fraxinus*. In this zone the continuous curve of *Tilia* begins. Pollen grains of *Hedera helix* are present. The pollen of herbaceous plants is restricted almost entirely to Poaceae undiff. and Cyperaceae. Aquatic plants are represented by pollen of *Myriophyllum verticillatum, Nymphaea alba,* while *Ceratophyllum*-hairs and algae of *Pediastrum* occur. Reedswamp plants are represented by *Typha angustifolia/Sparganium* and *T. latifolia* and Pteridophyta by spores of *Pteridium* and Polypodiaceae undiff. The upper limit of the zone is marked by a rise of *Corylus*.

Corylus-Tilia-Alnus **LPAZ,** samples 38–41. The value of *Quercus* decreases while *Corylus* increases and reaches its absolute maximum in this zone (59.2%). The curve of *Tilia* shows its maximum although of several percentage only. Values of *Ulmus, Fraxinus* and *Acer* remain at the same level. The curve of *Alnus* increases imperceptibly. A continuous percentage curve of *Carpinus* pollen occurs. There are single pollen grains of *Hedera, Viburnum* and *Viscum*.

The participation of NAP is very low, comprising single pollen grains of Poaceae undiff. and Cyperaceae. Aquatic plants are lacking while reedswamp plants are represented by pollen of *Typha angustifolia/Sparganium* and *T. latifolia.* Spores of Polypodiaceae, *Sphagnum* and *Pteridium* represent cryptogamic plants. The upper boundary of the zone is marked by an increasing amount of *Carpinus* pollen.

Carpinus-Corylus-Alnus **LPAZ,** samples 33–37. *Carpinus* pollen reaches its maximum (60%), while the participation of *Corylus* pollen decreases. *Tilia* and *Quercus* show a declining trend. Single pollen grains of *Abies* appear, and a slightly increased participation of *Picea*, the sporadic occurrence of which was observed already in earlier zones. The curve of *Alnus* increases slightly, reaching 10.8%. Pollen grains of *Hedera helix* are still present. *Ilex* pollen appears the participation of herbaceous plants is still very low and limited to single pollen grains of *Artemisia*, Poaceae, Cyperaceae, Chenopodiaceae, Cruciferae, *Mentha* t., Rosaceae undiff. and Rubiaceae. There is pollen of *Nuphar*, *Ceratophyllum*-hairs and *Botryococcus* and *Pediastrum* algae. Single spores of Polypodiaceae undiff. and *Pteridium* appear. The upper boundary of this zone is at the increase in value of *Picea* and *Abies* pollen.

Picea-Alnus-Abies **LPAZ,** sample 32. The level of AP still exceeds 99%. There is a significant decrease in of thermophilous trees and shrubs (*Carpinus, Corylus, Quercus, Tilia, Ulmus*). *Alnus* (21%), *Picea* (24.5%) and *Abies* (6.6%) reach maxima. *Pinus* undiff. and *Betula* undiff. increase. Participation of herbaceous pollen remains low, though continuous curves of Cyperaceae and Poaceae undiff. begin together with *Pediastrum.* Pollen of aquatic and reedswamp plants is absent. The cryptogamic plants are represented exclusively by a single spores of *Sphagnum* and Polypodiaceae undiff. The upper boundary is marked by an increase in *Pinus* undiff.

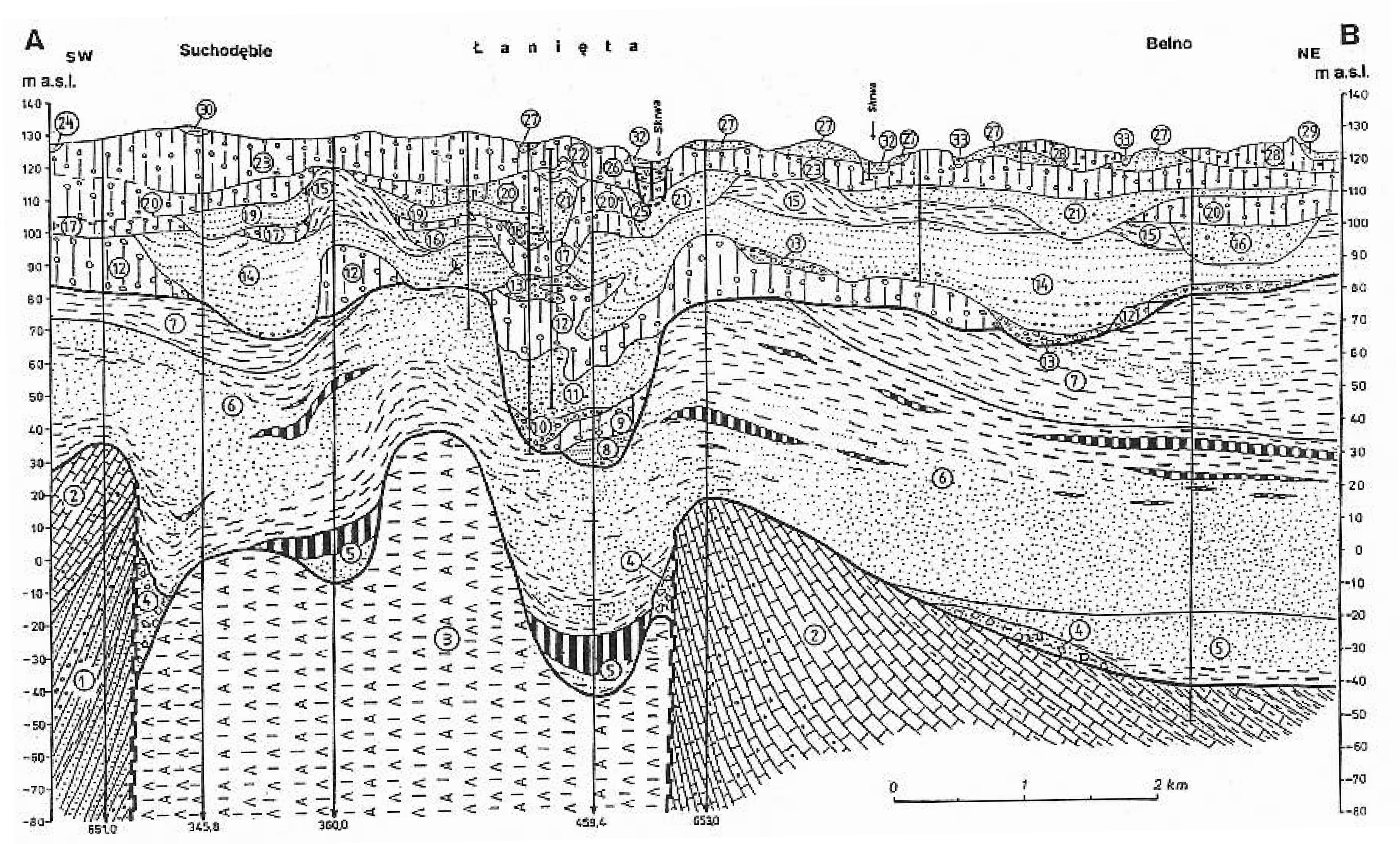

Fig. 4. Geological cross-section A–B

Middle Jurassic: 1 — sandstone, claystone and conglomerate; **Upper Jurassic**: 2 — limestone, organodetritic and marly limestone; **Upper Cretaceous/Tertiary**: 3 — clay, gypsum and anhydrite (cap of the Zechstein salt dome), 4 — breccia; **Tertiary**: *Oligocene*: 5 — sand, silt, coaly-clay and brown coal; *Miocene*: 6 — sand, silt, clay, coaly-clay and brown coal; *Pliocene*: 7 — variegated clay; **Quaternary**: *Pleistocene:* Podlasian Interglacial: 8 — fluvial sand and gravel; South Polish Glaciations: Nidanian Glaciation: 9 — till; Małopolanian Interglacial: 10 — residual gravel with boulders; Sanian Glaciation: 11 — glaciofluvial sand and gravel, 12 — till; Mazovian Interglacial: 13 — residual gravel with boulders, 14 — fluvial sand and gravel, locally silty sand with plant detritus; Middle Polish Glaciations: Odranian Glaciation: 15 — glaciolacustrine silt and clay, 16 — glaciofluvial sand and gravel, 17 — older till, 18 — residual gravel, 19 — glaciofluvial sand with gravel, 20 — younger till; Wartanian Glaciation: 21 — glaciofluvial sand and gravel, 22 — glaciolacustrine silt and clay, 23 — till, 24 — glaciofluvial sand with gravel; Eemian Interglacial: 25 — gyttja and lake silt; North Polish Glaciation (Vistulian): 26 — lake clay and silt, gyttja, peaty mud and peat, 27 — glaciofluvial sands and gravel, 28 — till, 29 — glaciofluvial sand with gravel; *Pleistocene/Holocene*: 30 — eluvial sand, 31 — deluvial sand and silty sand; *Holocene:* 32 — fluvial sand and gravel, 33 — humic sand of valley floors and closed depressions

Pinus **LPAZ**, samples 26–31. In this zone two subzones were distinguished: *Picea-Alnus* and *Isoëtes*. The AP curve is still very high, although it decreases in the upper part of the zone. Pollen of *Pinus* undiff. is dominant, reaching 81%, with *Betula* undiff. being consistently about 10%.

In the *Picea-Alnus* Subzone curves of these trees still occur but they decline and in the *Isoëtes* Subzone none of them exceeds 0.5%. The *Isoëtes* Subzone was distinguished by the high participation of spores of this genus. In addition pollen of herbaceous plants noted in earlier zones (Cyperaceae, Poaceae undiff., *Rumex acetosella,* Umbelliferae undiff., *Thalictrum, Vaccinium*) increases in this zone. There is an absolute maximum of *Juniperus* (1.3%). Spores of Polypodiaceae and *Pteridium* as well as *Botryococcus* and *Pediastrum* are present in both subzones. Pollen of aquatic and reedswamp plants (*Myriophyllum alternifolium, M. verticillatum, Phragmites, Typha angustifolia/Sparganium*) occur but in the *Isoëtes* Subzone only. The upper limit of the zone is denoted by a decrease in AP.

Betula-Artemisia **LPAZ**, samples 24, 25. AP decreases rapidly, reaching 54.2%, consisting mainly of *Betula* undiff. and *Pinus* undiff. There also appear pollen grains of *Betula* cf. *nana* and *Salix*; pollen of *Juniperus* and *Pinus cembra* persist.

In this zone pollen of herbaceous plants are numerous, and show their maximum diversity. Pollen of some taxa appear for the first time (*Polygonum bistorta, Rumex acetosa, Plantago major, Gentiana pneumonanthe* t., Cichoriaceae, *Vaccinium,* Asteraceae undiff., *Cerastium* t., *Bupleurum*), while others (Poaceae undiff., Cyperaceae, *Artemisia, Calluna,* Chenopodiaceae, *Ranunculus acris* t., *Thalictrum*) increase.

There is a variety of taxa of water and reedswamp plants (*Myriophyllum spicatum, M. verticillatum, Phragmites, Ranunculus trichophyllus* t., *Typha angustifolia/Sparganium*), and cryptogamic plants (*Lycopodium annotinum,* Polypodiaceae undiff., *Sphagnum, Isoëtes*), though in low amounts. *Sphagnum* spores reach a maximum in this zone (7.7%). The participation of *Pediastrum* and *Botryococcus* increases. The upper limit of the zone is denoted by an increase in *Betula* undiff. simultaneous with an increase in AP.

Betula **LPAZ**, samples 19–23. AP increases up to 92.2%. It contains mainly pollen of *Betula* undiff. (max. 84%) and considerably less pollen of *Pinus* undiff. Low amounts of *Betula* cf. *nana* and *Alnus* pollen remain; *Ephedra fragilis* pollen grains and *Juniperus* and *Salix* pollen were also noted. Herbaceous taxa are diverse although their contribution is small. *Artemisia,* Poaceae undiff., Cyperaceae, *Anthemis* t. curves continue, with pollen of *Ledum, Carduus* t., *Centaurea scabiosa* t., *Chamaenerion,* Chenopodiaceae, Cruciferae, *Filipendula, Polygonum bistorta, Potentilla* t., *Ranunculus acris* t., *Rumex acetosella, Thalictrum,* Umbelliferae undiff., *Botryococcus* and *Pediastrum.* Pollen of water plants is lacking while reedswamp plants are represented by single pollen grains of *Ranunculus trichophyllus* t. and *Typha angustifolia/Sparganium.* Cryptogamic plants are represented by spores of *Sphagnum* and single spores of Polypodiaceae undiff., *Pteridium* and *Botrychium.* The upper boundary occurs below the rise of *Pinus* undiff.

Pinus **LPAZ**, samples 13–18. This zone is characterised by high values of AP, a maximum of *Pinus* undiff. (89%). The curve of *Betula* undiff. decreases to 7.1%. The variety of herbaceous plants taxa decreases slightly though *Artemisia,* Poaceae undiff., Cyperaceae increase. Aquatic and reedswamp plants are represented by single pollen grains of *Utricularia* and *Phragmites.* The *Pediastrum* and *Botryococcus* curves persist. Cryptogamic plants are represented by single spores of *Pteridium, Lycopodium annotinum, L. clavatum, Equisetum* and *Botrychium.* The continuous, although low curve of *Sphagnum* begins in this zone. The upper boundary of the zone is indicated by a drop in AP.

***Artemisia*-Poaceae-*Juniperus* LPAZ**, samples 3–12. This zone is characterised by herbaceous pollen reaching their maximum value of 74%. AP comprises almost entirely pollen of *Pinus* undiff. and *Betula* undiff. *Betula* cf. *nana* reaches a maximum at 1.3%. There is a continuous curve of *Juniperus* and *Salix.* The diversity of herbaceous plants is high, with *Artemisia,* Poaceae undiff. and Cyperaceae dominant. Curves of these taxa reach maximum values of 36.0, 22.2 and 14.7%, respectively. Continuous or semi-continuous curves are represented in this zone by *Rumex acetosella,* Caryophyllaceae undiff., *Cerastium* t., Chenopodiaceae, *Anthemis* t., *Potentilla* t., *Ranunculus acris* t., Rubiaceae, *Thalictrum* and *Plantago maritima s.s.* This last taxon occurs only in this pollen zone. Moreover, there is pollen of *Armeria, Helianthemum* undiff., *Plantago major, Pleurospermum, Polygonum viviparum, P. bistorta, P. aviculare, Sanguisorba officinalis.* The *Pediastrum* curve reaches a very high value. The most abundant is *Pediastrum boryanum* subsp. *boryanum* and *P. kawraiskyi* but *P. boryanum* subsp. *longicorne, P. boryanum* subsp. *pseudoglabrum. P. boryanum* subsp. *rugulosum, P. alternans* and *P. duplex* subsp. *rugulosum* occur as well. Participation of pollen of aquatic and reedswamp plants is not high but the greatest variety of their taxa occurs. Pollen of *Phragmites, Ranunculus trichophyllus* t., *Typha angustifolia/Sparganium, T. latifolia, Potamogeton, Myriophyllum spicatum, M. verticillatum, Polygonum amphibium* is present. The diversity of cryptogamic plants is fairly high (Polypodiaceae, *Lycopodium annotinum, L. alpinum, L. clavatum, Osmunda regalis, Equisetum* and *Botrychium*), though the participation of their spores is low. *Sphagnum* appears in slightly higher amounts. The upper limit of the zone is marked by a rapid increase in the AP curve, mostly of *Betula* undiff.

Betula **LPAZ,** sample 2. The AP curve increases up to 84.3%, and pollen of *Betula* dominates (66.5%). The participation of herbaceous pollen is low. *Artemisia,* Poaceae undiff. and Cyperaceae decrease considerably while pollen of many other taxa characteristic of open and cold communities occurring in the previous pollen zone disappears. Aquatic and reedswamp plants are represented by single pollen grains of *Typha angustifolia/Sparganium, T. latifolia, Nuphar,* astrosclereides of *Nuphar* and *Ceratophyllum*-hairs. Cryptogamic plants are represented by single spores of *Isoëtes,* Polypodiaceae undiff. and *Lycopodium annotinum* only. The upper boundary of the zone is a rapid decrease in the pollen content of *Betula* undiff. and a rapid increase in *Pinus* undiff.

Pinus **LPAZ,** sample 1. The AP curve increases up to 92.2% but pollen of *Pinus* undiff. dominates (72.9%). The curve of *Betula* pollen decreases to 18.7%. As in the previous pollen zone, the participation of pollen of NAP is low, almost entirely

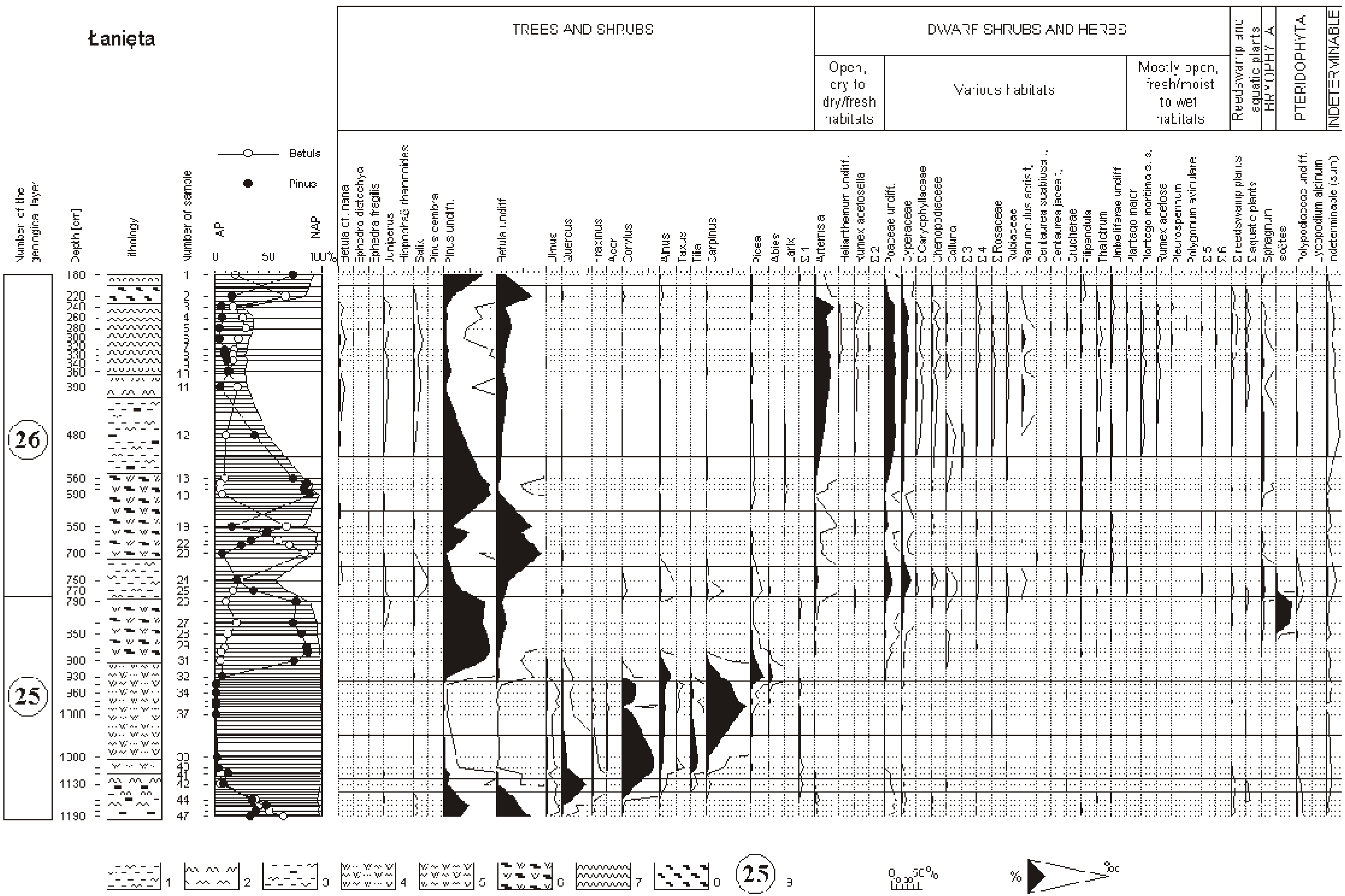

Fig. 5. Simplified pollen diagram from Łanięta (analysed by Balwierz in 2000)

1 — silt and clay; 2 — silt; 3 — organic silt and clay; 4 — silty-sandy gyttja; 5 — gyttja; 6 — peaty gyttja; 7 — mud and peaty mud; 8 — peat; 9 — bed number (see Figs. 3 and 4); Σ 1 — *Frangula, Hedera helix, Ilex, Ligustrum, Rhamnus, Sambucus racemosa, Viburnum, Viscum*; Σ 2 ¾ *Armeria* A-line, *Scleranthus annuus, Herniaria*; Σ Caryophyllaceae — Caryophyllaceae undiff., *Gypsophila, Dianthus* t., *Lychnis* t., *Cerastium* t.; Σ 3 ¾ Ericaceae undiff., *Bruckentahlia, Ledum, Vaccinium*; Σ 4 — Asteraceae undiff., *Aster* t., *Anthemis* t., *Cirsium* t., *Carduus* t.; Σ Rosaceae — Rosaceae undiff., *Potentilla* t.; Σ 5 — *Polygonum bistorta, P. bistorta/viviparum, P. viviparum*; Σ 6 — *Chamaenerion, Sanguisorba officinalis, Campanula, Spergularia*; Σ reedswamp plants — *Lysimachia thyrsiflora, Phragmites, Ranunculus trichophyllus* t., *Typha angustifolia/Sparganium*; *T. latifolia*; Σ aquatic plants — *Potamogeton, Myriophyllum alternifolium, M. spicatum, M. verticillatum, Nymphaea alba, Polygonum amphibium, Urticularia*

comprising Poaceae undiff., Cyperaceae and *Artemisia*. Pollen of aquatic and reedswamp plants is absent while cryptogamic plants are represented by single spores of *Sphagnum*.

CHRONOSTRATIGRAPHIC POSITION OF THE ŁANIĘTA POLLEN ZONES

The six lower pollen zones are characteristic of the Eemian Interglacial. All other pollen zones represent the Vistulian (Table 1). Two cold (EV1 and EV3) and two warmer oscillations Brörup and Odderade (Mamakowa, 1986, 1988, 1989; Behre and Lade, 1986; Behre, 1989) may be distinguished. Thus, the profile at Łanięta represents an uninterrupted succession of from the Eemian Interglacial into and including almost all of the Early Vistulian. The record ends during the Odderade Interstadial. The local pollen zones at Łanięta can be correlated with regional pollen assemblage zones distinguished by Mamakowa (1986, 1988, 1989) for the Eemian Interglacial and the Early Vistulian, and distinguished for the Konin region by Tobolski (1991).

VEGETATIONAL SUCCESSION AND BASIN DEVELOPMENT

The wide spacing of samples in the lower part of profile precludes precise analysis of the vegetational history, hence only a generalized outline is possible. The succession at Łanięta commenced with a predominance with forest communities. It was a birch-pine forest (*Betula-Pinus* LPAZ) with insignificant participation of oak, elm and hazel. Banks of the shallow lake were overgrown by two species of *Typha* while the water was occupied by *Myriophyllum alternifolium*, *M. spicatum* and *Nuphar*, and *Botryococcus* and *Pediastrum* algae. Communities of aquatic and reedswamp plants included *Lysimachia thyrsiflora*, a widespread species that can participate in land, reedswamp and aquatic communities (Podbielkowski and Tomaszewicz, 1979). In the basin, organic silt was deposited.

The next phase (*Quercus-Corylus* LPAZ**)** was dominated by oak forest with increasing participation of hazel. The forest consisted also of elm, ash and lime. The water level remained shallow, with occupation by *Nymphaea alba*, *Ceratophyllum*, *Myriophyllum verticillatum* and *Pediastrum*. Banks of the basin were overgrown by *Typha latifolia*, *T. angustifolia* and *Sparganium*. A narrow belt of peatbog was occupied by Cyperaceae. Further banks of the basin were overgrown by *Alnus* and *Humulus*. In the basin organic silt was deposited.

During the next phase (*Corylus-Tilia-Alnus* LPAZ), the interglacial optimum, communities of hazel prevailed, accompanied by lime. In these communities elm, oak, ash and maple still occurred, accompanied by *Taxus*, *Hedera* and *Viburnum*. Occurrence of alder was still restricted mainly to basin banks, which were overgrown by *Typha angustifolia* and *T. latifolia*. Water level probably rose, as evidenced by a lack of aquatic plants and *Pediastrum*, while in the basin first gyttja and later silty-sandy gyttja was deposited.

Communities where hazel prevailed were replaced by forest with *Carpinus* (*Carpinus-Corylus-Alnus* LPAZ). Hornbeam was a dominant tree, together with lime. *Quercus* and *Ulmus* diminished. In the forest *Ilex*, *Taxus* and *Hedera* occurred also. The belt of alder around the peatbog became wider. Aquatic vegetation appeared (*Nuphar*, *Ceratophyllum* and *Lysimachia thyrsiflora*) with *Pediastrum* while reedswamp vegetation disappeared. It is difficult be certain that appearance of aquatic plants correlated with the shallowing of the lake, because these aquatic plants do not occupy deep lakes. In the basin deposition of silty-sandy gyttja continued.

Post-optimum climate deterioration became pronounced as a spruce-fir forest (*Picea-Alnus-Abies* LPAZ) appeared in places earlier occupied by *Carpinus* communities, with slightly more herbaceous plants. The aquatic and reedswamp plants are absent which may suggest that water levels in the lake rose again. In the basin there were *Pediastrum* algae and silty-sandy gyttja was deposited.

Pine forest (*Pinus* LPAZ) prevailed subsequently with a small admixture of birch. Herbaceous communities become significant and communities of heliophytes appear. At first (*Picea-Alnus* Subzone) *Botryococcus* and *Pediastrum* algae occur, while aquatic and reedswamp plants are still absent. Later in the basin *Isoëtes* (*Isoëtes* Subzone), *Myriophyllum alternifolium* appear rapidly and among reedswamp plants *Phragmites* and *Typha* appear. The appearance of *Isoëtes* suggests a water level rise, as this genus does not appear in water 10 m deep (Podbielkowski and Tomaszewicz, 1979). On the other hand the change of silty-sandy gyttja into peaty gyttja may indicate shallowing of the lake. It is probable that overgrowing of the basin coincided with changes in water level. The pine forest phase terminated the Eemian Interglacial.

The first cooling, which occurred after the Eemian Interglacial and correlated with the first stadial of the Vistulian — EV1 (Mamakowa, 1988), caused recession of dense forest from the area (*Betula-Artemisia* LPAZ) although individual birche trees may have persisted. Shrub-tundra patches occurred and *Betula* cf. *nana* appeared on the peatbog. Here some species of willow must have grown too. Open and sandy habitats were overgrown by juniper. Herbaceous communities were of great significance. Occurrence of communities of grasses and sage-brush became more widespread, indicating the development of steppe vegetation. There appeared taxa such as *Rumex acetosella*, *R. acetosa*, Chenopodiaceae, Cruciferae, *Anthemis* t., *Ranunculus acris* t., *Polygonum bistorta*, *Plantago major* and many others associated with open habitats. *Isoëtes* communities declined but reedswamp and aquatic plants, *Botryococcus* and *Pediastrum* algae persisted. It is difficult to say whether the disappearance of *Isoëtes* out of the basin was a result of cooling or shallowing of the lake or both. In the basin silt accumulated.

An amelioration of climate correlated with the Brörup Interstadial dense forest to encroach into the area. Birch forest (*Betula* LPAZ) was succeeded by pine forest (*Pinus* LPAZ). Herbaceous plants communities declined, although open habitats communities continued throughout, and increased temporarily between the phases of birch and pine forest. Reedswamp vegetation occurred, and, at the beginning of the interstadial,

Table 1

Correlation of local pollen assemblage zones from Łanięta with regional pollen assemblage zones distinguished by Mamakowa (1986, 1988, 1989) and by Tobolski (1991) for the Konin region, with chronostratigraphy (Behre and Lade, 1986; Behre, 1989)

<table>
<tr><th>Pollen sample</th><th>Local pollen assemblage zones at Łanięta</th><th>Regional pollen assemblage zones (Mamakowa, 1986, 1988, 1989)</th><th>Konin region (Tobolski, 1991)</th><th colspan="3">Chronostratigraphy (Behre and Lade, 1986; Behre, 1989)</th></tr>
<tr><td>1</td><td>Pinus</td><td rowspan="2">EV4
Pinus-Betula</td><td>Pinus</td><td rowspan="2">Odderade Interstadial</td><td rowspan="8">Early Vistulian</td><td rowspan="8">Vistulian</td></tr>
<tr><td>2</td><td>Betula</td><td>Pinus-Betula</td></tr>
<tr><td>3–12</td><td>Artemisia-Poaceae-Juniperus</td><td>EV3
Gramineae-Artemisia-Betula nana</td><td>NAP I</td><td>Rederstall Stadial</td></tr>
<tr><td rowspan="2">13–18</td><td rowspan="2">Pinus</td><td rowspan="4">EV2
Betula-Pinus</td><td>Pinus</td><td rowspan="4">Brörup Interstadial</td></tr>
<tr><td>Betula-NAP</td></tr>
<tr><td rowspan="2">19–23</td><td rowspan="2">Betula</td><td>Betula-Larix</td></tr>
<tr><td>NAP-Betula</td></tr>
<tr><td>24, 25</td><td>Betula-Artemisia</td><td>EV1
Gramineae-Artemisia-Betula nana</td><td>Artemisia-NAP</td><td>Herning Stadial</td></tr>
<tr><td>26–31</td><td>Pinus</td><td>Pinus</td><td>Pinus</td><td colspan="2" rowspan="2">Late</td><td rowspan="6">Eemian Interglacial</td></tr>
<tr><td>32</td><td>Picea-Alnus-Abies</td><td>Picea-Abies-Alnus</td><td>Picea-Abies</td></tr>
<tr><td>33–37</td><td>Carpinus-Corylus-Alnus</td><td>Carpinus-Corylus-Alnus</td><td>Carpinus</td><td colspan="2" rowspan="3">Middle</td></tr>
<tr><td>38–41</td><td>Corylus-Tilia-Alnus</td><td>Corylus-Quercus-Tilia</td><td>Corylus</td></tr>
<tr><td>42</td><td>Quercus-Corylus</td><td>Quercus-Fraxinus</td><td>Quercus</td></tr>
<tr><td>44–47</td><td>Betula-Pinus</td><td>Pinus-Betula-Ulmus</td><td>Pinus-Betula</td><td colspan="2">Early</td></tr>
</table>

there was aquatic vegetation also. Peaty gyttja was deposited again, through overgrowing of the lake.

During the second stadial of the Early Vistulian — EV3 (Mamakowa, 1986) forest retreated from the area. Herbaceous steppe plants dominated, especially sage-brush. Shrub-tundra patches with *Betula* cf. *nana, Salix, Juniperus* and in some places also *Hippophaë* co-existed. Grass communities were common too. There were probably also plants of mostly open, fresh, moist to wet habitats (*Plantago major*, *P. maritima, Rumex acetosa*, *Polygonum bistorta, P. viviparum P. aviculare, Sanguisorba officinalis, Pleurospermum*, *Chamaenerion*, *Spergularia*) and open and dry to dry/fresh habitats (*Helianthemum, Rumex acetosella, Scleranthus annuus, Herniaria, Armeria*). Taxa which occurred earlier (Chenopodiaceae, *Cerastium* t., *Anthemis* t., *Potentilla* t., Rubiaceae, *Ranunculus acris* t., *Thalictrum*, Umbelliferae undiff.) were most numerous at that time. During the interstadial reedswamp and aquatic vegetation occurred in the lake. Taxa present earlier were jointed by *Polygonum amphibium* only. *Pediastrum* absent earlier from the basin became abundant. The most frequent species were *Pediastrum boryanum*, of wide ecological limits and *P. kawraiskyi*. The last species occurs in cold, oligotropic and mesotrophic water. In the basin organic silty clay was deposited first, then silt and peaty mud. Changes in the deposit were not reflected by changes of the aquatic and reedswamp vegetation.

The next warm oscillation, synchronous with the Odderade Interstadial (Behre and Lade; 1986; Behre, 1989) allowed forest to encroach this terrain. At first it was a birch forest (*Betula* LPAZ) and later pine forest (*Pinus* LPAZ). Occurrence of herbaceous vegetation was reduced considerably though light-demanding communities existed, mainly with *Artemisia*. During the pine phase, aquatic and reedswamp vegetation and rare *Botryococcus* and *Pediastrum* algae occurred in the basin. The size of the basin might have been considerably reduced. Its overgrowth began and as a result a thin layer of peat formed. During the birch phase the peatbog may have flooded due to water level rise, and peat began to be replaced by peaty mud. Aquatic and reedswamp plants were, though, not present then.

DISCUSSION

Accounts of Eemian deposits are common in the literature, but there are few sites that would also show Vistulian deposits in continuous succession. The list of such sites, prepared by Mamakowa (1989), was subsequently enlarged (Kupryjanowicz, 1991; Janczyk-Kopikowa, 1997; Balwierz, 1998, 1999; Granoszewski, 1999; Stankowski *et al.*, 1999). The Łanięta site is close to the Kaliska and Ruszkówek sites (Janczyk-Kopikowa, 1965, 1997). Further west of Łanięta there are sites at Władysławów (Tobolski, 1991) and Mikorzyn (Stankowski *et al.*, 1999). Both these last sites are by Konin open-cast mine.

The site at Kaliska (Janczyk-Kopikowa, 1965) contains only a part of the Early Vistulian (EV1 and part of EV2) while the site at Ruszkówek in the Kujawy Lake Region deals with two stadials of the Vistulian (EV1 and EV3) and the separating interstadial interpreted by the author (Janczyk-Kopikowa, 1997) as Amersfoort/Brörup. Sites such as Rudunki (Jastrzębska-Mamełka, 1985), with a complete Early Vistulian succession, and Horoszki (Granoszewski, 1997) and Kuców (Balwierz, 1998, 1999) with the whole Early Vistulian and much of the Middle Vistulian, are rare.

Development of vegetation communities during the Eemian Interglacial at Łanięta resembled very much the contemporaneous development of the communities at Kaliska (Janczyk-Kopikowa, 1965), Ruszkówek (Janczyk-Kopikowa, 1997), Mikorzyn (Stankowski *et al.*, 1999) and Władysławów (Tobolski, 1986). Some dissimilarities appeared during the first stadial of the Early Vistulian. Forest then disappeared from all these sites. At Mikorzyn (Stankowski *et al.*, 1999), though, pine may not entirely have abandoned that area. At Łanięta birch played a greater role. The Brörup Interstadial at Łanięta was clearly two-phase in character, first with birch forest and then with pine forest, these phases being separated by a small cold oscillation. At Mikorzyn this zone is developed similarly. At Ruszkówek, Janczyk-Kopikowa (1997) distinguished the Amersfoort/Brörup zone characterised by a predominance of pine forest. Birch-pine and then pine characterised the Brörup at Władysławów (Tobolski, 1991.) The second stadial of the Vistulian (EV3) was decidedly unforested. A distinctive feature of this interval both at Łanięta and Ruszkówek (Janczyk-Kopikowa, 1997) and at Mikorzyn (Stankowski *et al.*, 1999) was the importance of cold steppe communities as expressed by very high values of *Artemisia* reaching up to 40%. The Odderade Interstadial at Łanięta and Mikorzyn clearly show a two-phase forest character, first birch forest and then pine forest whereas at Władysławów it is characterised by pine (Tobolski, 1991).

CONCLUSIONS

The accumulation of organic deposits at Łanięta started at the beginning of the Eemian Interglacial and continued through almost the whole Early Vistulian. The profile terminates during the pine phase of the Odderade Interstadial.

Deposition took place in water almost all the time. Oscillations of water level in the lake were fairly frequent, as reflected by changes in the deposits. The lake basin disappeared or became very small, mostly during the birch phase of the Odderade Interstadial, when a thin layer of peat accumulated in the upper part of the profile. Changes in deposits were not synchronous with changes of aquatic and reedswamp plant communities; the last of these were scarce in the Łanięta basin. However, there is a good correlation of lithology with pollen assemblages, as seen by increased clastic input during cold periods. This is exemplified by the transition from organic to clastic sedimentation at the transition of the Eemian Interglacial into the Early Vistulian.

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