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Kontrowers – a new locality of the Eemian interglacial and the Early Vistulian at Żelechów Upland (eastern Poland)

MIROSŁAWA KUPRYJANOWICZ[1], MARCIN ŻARSKI[2] and DANUTA DRZYMULSKA[1]

1 University of Białystok, Institute of Biology, Department of Botany, 15–950 Białystok, Świerkowa 20 B, Poland; e-mail: kuprbot@uwb.edu.pl, drzym@uwb.edu.pl
[2] Polish Geological Institute, 00–975 Warszawa, Rakowiecka 4, Poland; e-mail: mzar@pgi.waw.pl

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ABSTRACT. Fossil lake deposits were identified at Kontrowers in the southern part of Mazovian Lowland during mapping for the Detailed Geological Map of Poland at the 1:50 000 scale, Żelechów sheet. Palynological study shows that lake accumulation lasted through the Eemian interglacial and the Early Vistulian. One warm interstadial-rank oscillation (Brörup) and two stadials have been distinguished during the Early Vistulian. The oldest of these is correlated with the Herning stadial while younger one equates with the Rederstall stadial.

KEY WORDS: pollen analysis, palynostratigraphy, plant macrofossil analysis, Eemian interglacial, Vistulian, Brörup interstadial, Wartanian glaciation, Poland

INTRODUCTION

Eemian and Vistulian deposits were identified at Kontrowers during mapping for the Detailed Geological Map of Poland at the 1:50000 scale, Żelechów sheet (Żarski 2002). The site is located 10 kilometres west of Żelechów (Fig. 1). It documents one of numerous reservoirs of Eemian Lakeland in the southern part of Mazovian Lowland (Żarski 1989, Bruj & Krupiński 2001, Krupiński & Kucharska 2001). The Eemian lakes formed at Żelechów Upland after the Warta deglaciation. The Kontrowers site is important in delimitation of the maximum range of the ice sheet of the Wartanian Glaciation.

The first pollen investigations at the Kontrowers site were done by Krupiński (2001). He stated the Eemian age of these deposits. Later, on the same place two boreholes were done by mechanic (W1) and stroke sondes (W2). The distance between W1 and W2 is few metres only. Palynological analysis of both cores was carried out at the University of Białystok. The main goal of this research was to confirm the Eemian age of the deposits and to reconstruct the vegetational changes during the deposition of the sediments. Very high pollen values of *Pinus* and *Picea* (Kupryjanowicz 2002), found in several pollen spectra from depths of 3.35–2.30 m at W2 profile made interpretation of the palynological record difficult. In order to test the supposition, that it might be connected with the local pollen overrepresentation of these plants, analysis was made of plant macrofossil remains in the deposits from W2 profile.

SITE DESCRIPTION

The Kontrowers site is located on a morainic plateau, which is composed of tills and fluvioglacial sands of the Wartanian Glaciation and eolian sands of the Vistulian (Żarski 2002). The Wartanian deposits are 4–15 m thick. The morainic plateau is at 180–185 m a.s.l. and on the surface of there are dead ice moraines, crevasse forms, dunes, hollows without flow and small valleys (Fig. 1).

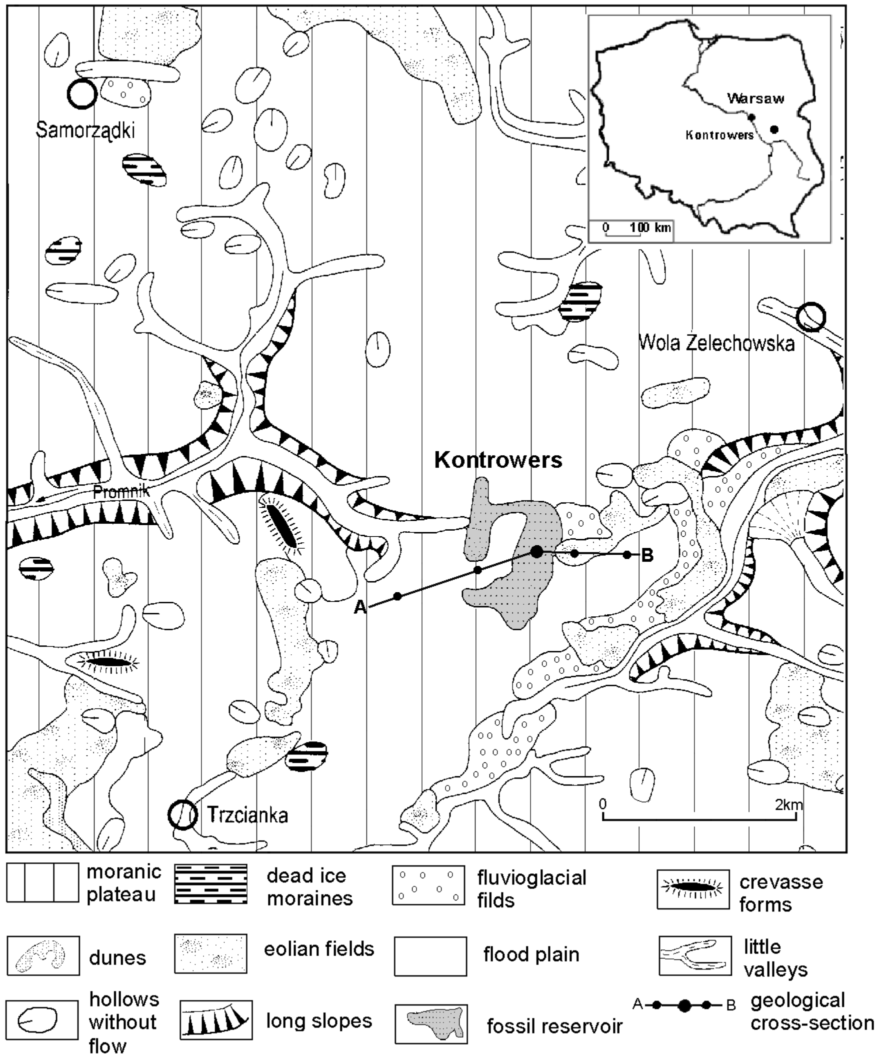

Fig. 1. Geomorphologic and geological setting

The fossil lake sediments at Kontrowers fill the depression on the morainic plateau. The depression is about 1 km wide and 1.5 km long. It was formed after melting of dead ice at the end of the Wartanian glaciation. The surface of depression covered Holocene peat and sands. The Promnik river begins from the Kontrowers depression. The geological sequence of sediments in both profiles W1 and W2 is presented on Fig. 2. Pollen analyses were made of samples from borehole W2 and random samples from borehole W1. The distance between W1 and W2 is about 5 m.

The Eemian deposits cover Wartanian tills in borehole W2 and ice dammed silts in W1. Their thickness varies from 2.40 to 2.69 m). Humic sands are in the bottom of the lake deposits in borehole W2. Above the sands there are bituminous shales, brown gyttja and wood peat and sedge peat, 2.55 m thick. Top of the Eemian part of the profile is 2.29 m deep below the ground level. The Eemian deposits in borehole W1 consist of highly decomposed moss peat and gyttja. The top of series is 2.2 m deep below the ground level.

The Eemian series in borehole W2 underlay the Vistulian lake silts, *Sphagnum* peat, silt and sand, 2.09 m thick. The Holocene peat covers the Vistulian series. The Vistulian deposits in borehole W1 consist of silts, peat, silts and sandy silts, 2 m thick. The top of this series is 0.2 m deep below ground level. Pollen analysis has not been examined in the series from this profile.

Peat samples from a borehole W1 were ^{14}C dated at 35 900 +3470 –2540 (Gd-12290) and 32 600 ±1400 (Gd-11585) years BP (Pazdur 2001). These dates point to the Grudziądz in-

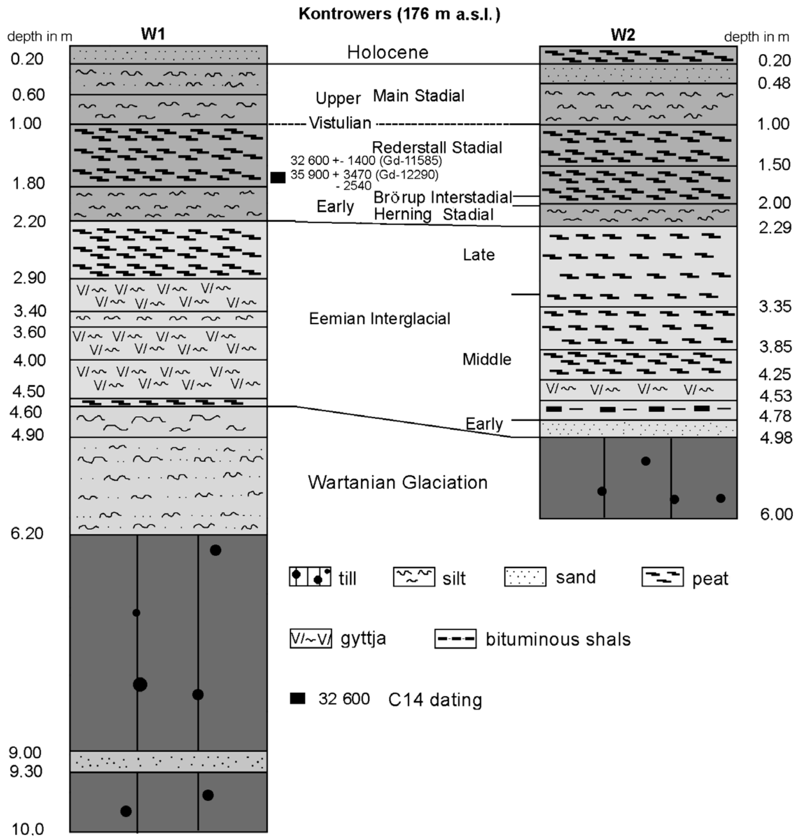

Fig. 2. Geological profile of W1 and W2

terstadial (Krzywicki 2002). This age of peat is quite different from the pollen age of peat in a borehole W2 at the same depth. It is possible that 14C dating are rejuvenated by soil processes which disturbed dating result. The Vistulian series in the borehole W1 are covered by Holocene sands.

In marginal zones of the fossil lake (borehole III) the Eemian silts underlay fluvial and eolian Vistulian sands (Fig. 3).

DEVELOPMENT OF THE BASIN AT KONTROWERS

A depression is formed after deglaciation of Wartanian ice sheet at Kontrowers (Żarski 2002). Ice dammed silts accumulated there (Fig. 3). During the Eemian interglacial, the lake was bigger than that in the late Wartanian glaciation. The humic sands accumulate in the Early Eemian. The lake was overgrowing with plants quickly in the Middle and Late

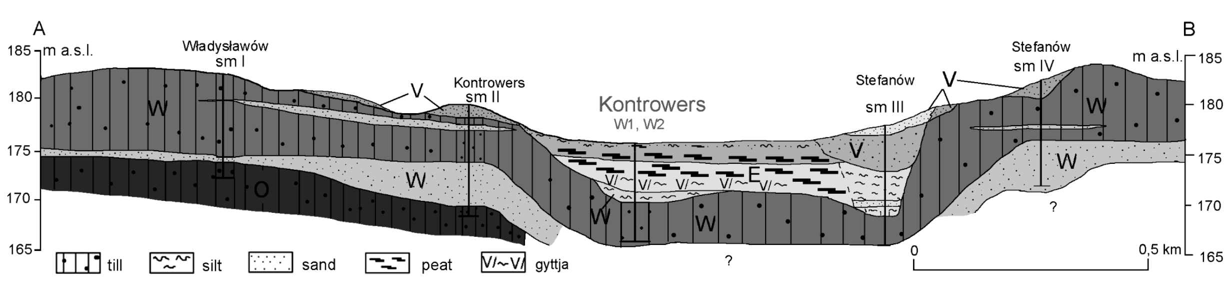

Fig. 3. Geological cross-section A-B across depression at Kontrowers. **O** – Odranian glaciation, **W** – Wartanian glaciation, **V** – Vistulian glaciation

Eemian. The bituminous shales, gyttja and peat accumulate in the interglacial lake. The lake continues changing in the Vistulian. In the Early Vistulian (Herning stadial) silt accumulates there. The climate was cold. The temperature in the Brörup Interstadial was higher comparing to the Herning. Vegetation develops in this period and plants cover the lake. The climate changes into cold in the Redestall stadial. Peat accumulates then. The climate changed into very cold in Main stadial. Peat, sands and dusty sands continue accumulating at this time. The eastern part of the lake is filled up with sands (Fig. 3). At the end of the Vistulian, eolian sands accumulate in the eastern part of the depression. In the Early Holocene at Kontrowers, the lake is shallow, and quickly becomes overgrown with plants. Peat and organic sands accumulate. Nowadays, peat, silts, and sands cover the surface of the depression.

METHODS OF PALAEOBOTANICAL ANALYSES

Samples designed for pollen analysis were boiled in 5% KOH. Then, mineral and organic fractions were separated in water solutions of cadmium and potassium iodides (density ca. 2.1 g/cm^3) and the organic fraction subjected to Erdtman's acetolysis (Erdtman 1943). Pollen spectra from each sample were counted on two slides. They were always counted all over the area of a slide. The tree pollen sum (AP) fluctuates from 500 to over 1000 grains. The basic pollen sum, on which the percentage calculations were based, consisted of tree, shrub and terrestrial herb pollen. The proportion of pollen of aquatic and reedswamp plants, spores of Pteridophyta and *Sphagnum* and indeterminable sporomorphs was computed in relation to the basic amount. Pollen diagrams (Figs 4,5) have been drawn using the POLPAL programme (Walanus & Nalepka 1999).

From selected samples, 50 cm^3 of deposits was used for plant macroscopic analyses. The material was boiled in water with an addition of 10% solution of KOH and rinsed on 0.2 mm mesh sieves with water. Seeds and fruits were picked out and placed in glycerine-thymol mixture. Stereoscopic microscope was used for generative macrofossil analysis. Analysis of vegetative plant remains was carried under a light microscope. Scoured peat was placed on object glass in glycerine and covered by cover glass. After that, botanical composition analysis was made, and proportion of every taxon tissues in global tissue mass, in ten select fields of vision was estimated for every sample. Only remains with cellular structure were considered.

RESULTS OF POLLEN ANALYSIS

KONTROWERS W1

Altogether 7 samples from the depth of 4.55–3.00 m were subjected to pollen analysis. In sample from depth 3.60 m no sporomorphs were present. All other samples contained sporomorphs and their frequency was high or very high. The results are presented on diagram (Fig. 4) and table (Tab. 1).

Table 1. Description of pollen spectra from Kontrowers W1 profile

Sample number	Depth (m)	Description of pollen spectra
1	4.55	*Pinus sylvestris*-type pollen predominates (92.9%). Percentages of *Picea abies* and *Quercus* are relatively high. Pollen of other trees and *Corylus* appears sporadically. NAP values are very low
2	4.30	The proportion of *Pinus sylvestris*-type falls to 20%. Percentage values of *Quercus*, *Ulmus* and *Corylus* are high. Pollen of *Fraxinus*, *Tilia cordata*-type, *Taxus baccata*, *Hedera helix* and *Viscum* appear for the first time
3	4.15	Pollen value of *Corylus* attains maximum (61.9%). The proportion of *Quercus* and *Ulmus* is high
4, 5	4.05 3.90	Percentages of *Corylus* are considerably lower than in the previous sample. Values of *Quercus* and *Ulmus* decrease. Proportions *Alnus*, *Carpinus betulus* and *Tilia cordata*-type rise. Pollen grains of *Pinus sylvestris*-type, *Betula alba*-type, *Fraxinus*, *Acer*, *Tilia cordata*-type, *Taxus baccata*, *Picea abies* and *Acer* are present, but their frequency is low
7	3.00	Pollen values of *Pinus sylvestris*-type and *Picea abies* are high. Proportion of *Carpinus betulus* and *Abies alba* is relatively high. The percentages of *Corylus* and *Alnus* are considerably lower than in previous samples. The proportion of NAP attains10%

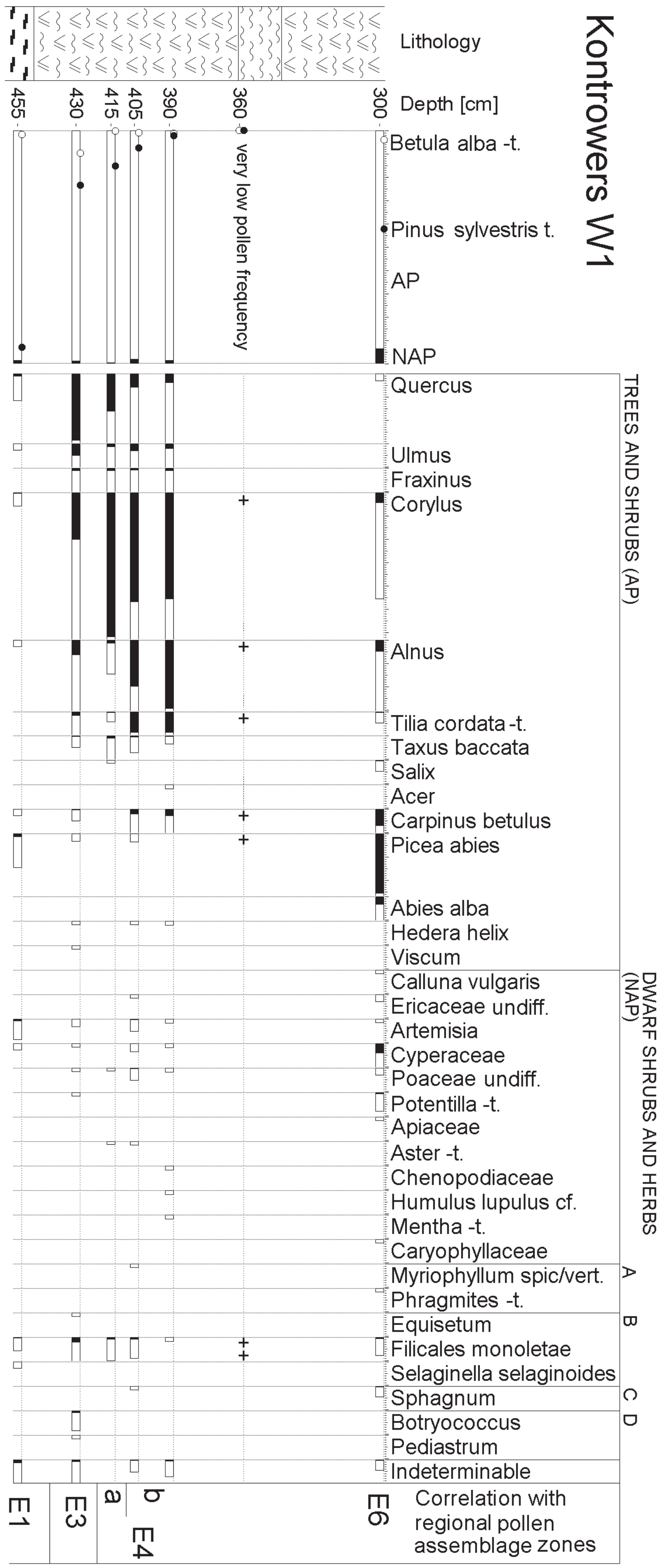

Fig. 4. Percentage pollen diagram from Kontrowers W1 (analysed by Kupryjanowicz in 2002). Lithological explanation as in Fig. 2

KONTROWERS W2

Altogether 53 samples from the depth of 4.90–0.90 m were subjected to pollen analysis. In 6 samples (3.40 m, 3.60 m, 3.80 m, 3.90 m, 4.00 m and 4.10 m) sporomorphs are either absent or abundant but extremely destroyed (numerous spores of *Thelypteris palustris* and Filicales monolete, single pollen grains of some trees). In samples from the silt (depth 2.25–2.05 m and 0.90 m) small quantities of sporomorphs was noted. All other samples contained sporomorphs and their frequency was high or very high.

Results of pollen analysis are presented on diagram (Fig. 5) and table (Tab. 2). The pollen

Table 2. Description of local pollen assemblage zones (L PAZ) from Kontrowers W2 profile

Local pollen assemblage zone (L PAZ)		Depth (m)	Description of pollen spectra
K-1	***Pinus–Betula***	4.90	*Pinus sylvestris*-type and *Betula alba*-type predominate. Pollen of other trees and *Corylus* appears sporadically. NAP values are very low (2%)
K-2	***Pinus–Betula–Ulmus***	4.85–4.80	There is a peak of *Betula alba*-type (37.4%). Values of *Pinus sylvestris*-type are high (about 57%). The percentages of *Ulmus* and *Quercus* are slightly higher than that in the preceding zone. *Picea abies* pollen is present
K-3	***Quercus–Ulmus–Fraxinus***	4.70	The maximum of *Quercus*, *Ulmus* and *Fraxinus* is present. Values of *Pinus sylvestris*-type and *Corylus* are relatively high. Pollen of *Alnus*, *Tilia cordata*-type and *Taxus baccata* is present. Pollen grains of *Hedera helix* appear for the first time
K-4	***Corylus–Alnus–Tilia***	4.60–4.15	Pollen values of *Corylus* are very high. Percentages of *Alnus* and *Tilia cordata*-type increase
K-4a	***Tilia–Quercus–Ulmus***	4.60–4.40	Absolute maximum of *Corylus* (59.4%); culmination of *Tilia cordata*-type (10.4%); decrease of *Quercus* percentage to 4.4%; *Ulmus* pollen values still relatively high (2.2–2.7%)
K-4b	***Carpinus***	4.20–4.15	Rise of *Carpinus betulus* values to 27.6%. The proportion of *Corylus* decreases to 30%. Pollen grains of *Viscum* appear for the first time
K-5	***Carpinus–Picea–Corylus–Alnus***	3.35–3.25	The maximum of *Carpinus betulus* (45%), the high values of *Picea abies* and relatively high proportion of *Corylus* and *Alnus* are characteristic. Pollen grains of *Abies alba* appear for the first time. The percentages of *Quercus* and *Tilia cordata*-type are slightly lower than in the preceding zone
K–6	***Picea–Pinus–Abies***	3.20–2.50	Pollen values of *Picea abies* and *Pinus sylvestris*-type are very high. *Abies alba* is continuously present
K-6a	***Picea***	3.20	Absolute maximum of *Picea abies* (73.9%); a small peak of *Abies alba* (2.6%)
K-6b	***Pinus–Betula***	3.15–2.75	Rise in values of *Pinus sylvestris*-type and *Betula alba*-type; depression of *Picea abies* curve
K-6c	***Picea–Abies***	2.70–2.50	The second peak of *Picea abies* (52.4%); absolute maximum of *Abies alba* (8.2%)
K-7	***Pinus***	2.45–2.30	Pollen of *Pinus sylvestris*-type is dominant (about 70%). *Picea abies* values fall to about 10%. Pollen of *Carpinus betulus*, *Alnus*, *Abies alba* and *Corylus* are present
K-8	***Artemisia–Betula nana–Salix***	2.25–2.05	NAP attains the absolute maximum (25%). There are peaks of *Artemisia* (6.3%), Poaceae undiff. (3.6%), Cyperaceae (7.7%) and Ranunculaceae undiff. (1.9%). Pollen of *Helianthemum nummularium*-type and *Pleurospermum austriacum* are present. *Betula nana*-type (max. 1.8%), *Salix* (max. 1.3%) and *Juniperus* (0.5%) culminate. *Betula alba*-type and *Pinus sylvestris*-type values are pretty high
K-9	***Betula–Pinus***	1.95–1.65	*Pinus sylvestris*-type and *Betula alba*-type predominate. Pollen of other trees appears sporadically. NAP values are rather high (5–16%)
K-9a	***Betula***	1.95	Absolute maximum of *Betula alba*-type (43.1%)
K-9b	***Pinus***	1.90–1.65	Peak of *Pinus sylvestris*-type (76.8%); depression of *Betula alba*-type (15.2%)
K-10	***Pinus–Betula*–NAP**	1.55–0.90	*Pinus sylvestris*-type values are still rather high, but gradually decrease to 53.2%. *Betula alba*-type curve oscillates from 20.5% to 24.5%. NAP proportion continuously rises to about 20%

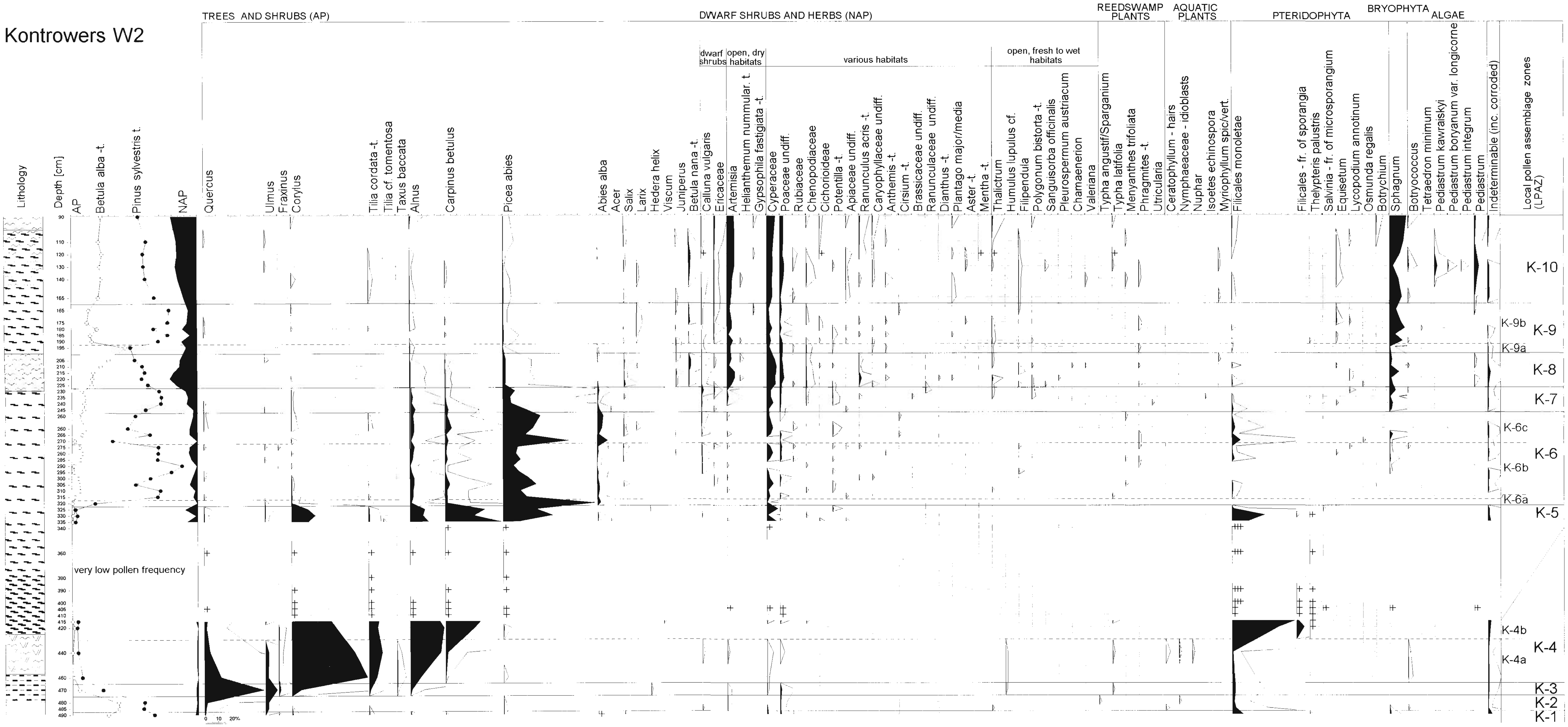

Fig. 5. Percentage pollen diagram from Kontrowers W2 (analysed by Kupryjanowicz in 2002). Lithological explanation as in Fig. 2

diagram has been divided into 10 local pollen assemblage zones – L PAZ. In three zones subzones of pollen assemblages have been distinguished.

ANALYSIS OF MACROFOSSILS

Altogether 13 samples from depth 4.20–2.40 m at the profile Kontrowers W2 were subjected to plant macrofossil remains analysis. Five local macrofossil assemblage zones (L MAZ) can be distinguished in the diagram (Fig. 6).

In the lowest **zone Km-1** (4.20–3.60 m) high amount of alder bark and nutlets is a characteristic feature. Deciduous wood attains reaches great abundance. *Carex* sp. and *Dryopteris thelypteris* tissues appear numerously. The presence of water plant remains (*Najas marina* – fruits, Nymphaeaceae – tissue) is distinctive.

Next **zone Km-2** (3.40–3.20 m) is characterized by the little proportion of deciduous wood. There are remains of *Pinus sylvestris*, cf. *Picea abies* and Ericaceae. Radicles of *Carex* sp. and *Carex* cf. *elata* are abundant. Nutlets of tree birches (sect. *Albae*) are numerous. The remains of Bryales and *Sphagnum* sect. *Cuspidata* are vestigial.

In the third zone **Km-3** (3.10–3.00 m) *Sphagnum* sect. *Subsecunda* remains occur for the first time. Ericaceae and pine remains are still present. There is also coniferous wood. Sedge tissues attain great quantities.

The upper zone **Km-4** (2.80–2.60 m) contains bog-mosses of three different sections (*Subsecunda*, *Cuspidata* and, for the first time, *Palustria*). The participation of deciduous wood and *Betula* sp. bark is rather distinct. *Dryopteris thelypteris* tissues are only vestigial.

Top zone **Km-5** (2.50–2.40 m) is characterized by a high quantity of *Carex* cf. *elata* remains. *Pinus sylvestris* bark and coniferous wood are more abundantly represented, when compared with the previous zone. There are remains of *Menyanthes trifoliata* and *Phragmites australis*. The presence of *Potamogeton* sp. stone is also typical of this zone.

AGE OF THE SEDIMENTS

The results of pollen analysis indicate that the lowest part of the profile Kontrowers W2 (the seven lower pollen zones) shows the pattern of interglacial succession. It is not a complete succession. However, its characteristic features such as: very high *Corylus* pollen values (maximum 60%) and the order of expansion of trees and hazel (i.e. *Betula–Pinus*, *Ulmus*, *Quercus*, *Corylus*, *Alnus–Tilia*, *Carpinus*, *Picea–Pinus*) suggest correlation of the pollen succession from Kontrowers W2 with the scheme of Eemian interglacial (Mamakowa 1989, Janczyk-Kopikowa 1991). The local pollen assemblage zones from K-1 to K-7 well correlate with the regional pollen zones (R PAZ) of the Eemian (Tab. 3), established by Mamakowa (1989).

The local zone K-3 *Quercus–Ulmus–Fraxinus*, which is characterized by a rather high *Corylus* pollen value and presence of *Alnus* and *Tilia cordata*-type pollen, should be correlated with only the higher subzone (*Corylus*) of the E-3 *Quercus–Fraxinus–Ulmus* R PAZ. The local zone K-5 *Carpinus–Picea*, basing on high pollen values of *Picea*, are associated with only the upper part of the regional zone E-5 *Carpinus–Corylus–Alnus*. At profile Kontrowers W2 pollen record of this zone is incomplete. The barren layer of deposits from depth 4.10–3.40 m may correspond to the lower part of E5 regional pollen zone. Finding correlation of the local pollen zone K-6 *Picea–Abies* with the regional pollen stratigraphy is very difficult. High pollen values of *Picea* and *Abies alba* may indicate correlation with the E-6 *Picea–Abies–Alnus* regional zone. However, in most samples of this zone, the frequency of *Pinus* pollen is very high (max. about 90%). Most probably it is connected with local over-representation.

The upper boundary of the local pollen zone K-7 *Pinus* constitutes also the Eemian–Early Vistulian boundary. It was placed at such a rise in the pollen values of herbs that it indicates a decline of closed forests and the formation of open communities. Change in deposits around the boundary into more minerogenic ones indicates an intensification of erosional processes connected with the increasing openness of the landscape and uncovering of soils. The foregoing criteria agree with those applied

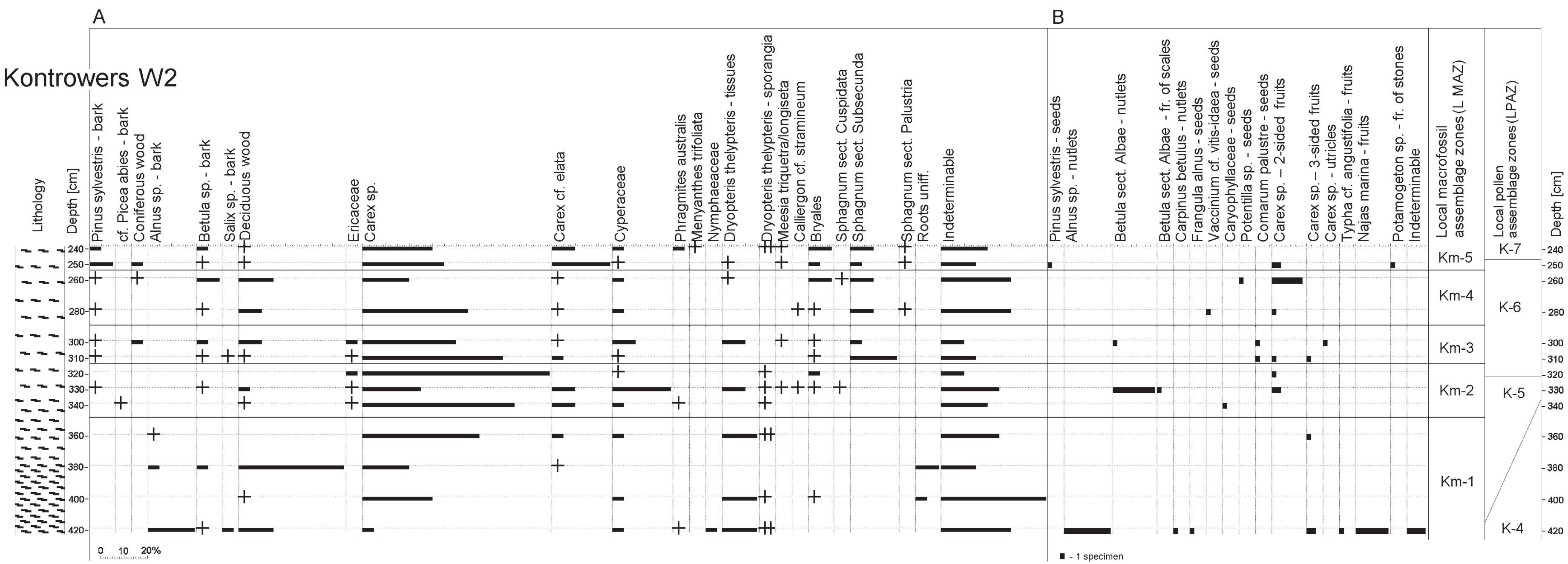

Fig. 6. Diagram of vegetative **(A)** and generative **(B)** plant remains from Kontrowers W2 (analysed by Drzymulska in 2002). Lithological explanation as in Fig. 2. + presence of remains, ++ frequent appearance of remains, +++ very frequent appearance of remains

Table 3. Correlation of the local pollen assemblage zones (L PAZ) from profile Kontrowers W2 and pollen spectra from profile Kontrowers W1 with the regional pollen assemblage zones (Mamakowa 1989) and chronostratigraphy (Behre & Lade 1986, Behre 1989)

Kontrowers		Regional pollen assemblage zones (R PAZ)	Chronostratigraphy	
W2	W1			
K-10 *Pinus–Betula*–NAP	–	EV-3 Poaceae–*Artemisia–Betula nana*	Rederstall stadial	EARLY VISTULIAN
K-9 *Betula–Pinus*	–	EV-2 *Betula–Pinus*	Brörup interstadial	
K-8 *Artemisia–Betula nana–Salix*	–	EV-1 Poaceae–*Artemisia–Betula nana*	Herning stadial	
K-7 *Pinus*	–	E-7 *Pinus*	Late	EEMIAN INTERGLACIAL
K-6 *Picea–Pinus–Abies*	7	E-6 *Picea–Abies–Alnus*		
K-5 *Carpinus–Picea–Corylus–Alnus*	–	E-5 *Carpinus–Corylus–Alnus*	Middle	
K-4 *Corylus–Alnus–Tilia*	3, 4, 5	E-4 *Corylus–Quercus–Tilia*		
K-3 *Quercus–Ulmus–Fraxinus*	2	E-3 *Quercus–Fraxinus–Ulmus*		
K-2 *Pinus–Betula–Ulmus*	1	E-2 *Pinus–Betula–Ulmus*	Early	
K-1 *Pinus–Betula*	–	E-1 *Pinus–Betula*		

by Mamakowa (1989) for the pollen stratigraphy of the Eemian interglacial in Poland.

The local pollen assemblage zones K-8, K-9 and K-10 from the profile Kontrowers W2 probably represent the Vistulian glaciation. All those zones are characterized by low pollen values of *Picea* and *Alnus*, what excludes their reference to E-7 *Pinus* R PAZ of Eemian interglacial. At Imbramowice *Alnus* attains 14.4% and *Picea* 6.4% during this regional zone. At Zgierz-Rudunki II their percentages are 3.3% and 5.1% respectively. The *Picea* values are higher at many Polish sites; they range from 20 to 30% (Mamakowa 1989). Two colder (K-8 and K-10 L PAZ) and one warmer (K-9 L PAZ) oscillations can be distinguished at Vistulian part of the profile W2. The high values of *Artemisia* (with maximum of 6%) suggest correlation the local pollen zone K-8 *Artemisia–Betula nana–Salix* to the regional zone EV-1 Poaceae–*Artemisia–Betula nana* (Table 3). Culmination of *Salix* and *Betula nana*-type, appearance of *Juniperus* and variety of herb taxa, despite relatively low NAP values, confirm such a correlation. However, as can be seen for central and eastern Poland e.g. in pollen diagrams from Główczyn (Niklewski 1968), Zgierz-Rudunki (Jastrzębska-Mamełka 1985), Władysławów (Tobolski 1991), Łomżyca (Krupiński 1992, Niklewski & Krupiński 1992), a severe deforestation took place in the Herning. In particular the values of grasses have to be very much. This points that pollen record of the local zone K-8 may be incomplete.

Correlation of the local pollen zones K-9 and K-10 is difficult to establish. The peat from depth 1.80 m at the profile Kontrowers W1 was dated by the ^{14}C method to 32 600 ± 1 400 and 35 900 + 3 470 – 2 540 years B.P. It suggests possibility of correlation with Middle Plenivistulian. Since sediments in the profiles W1 and W2 were formed more or less synchronically, it can be assumed, that the sediments from the depth of around 1.8 m in Kontrowers W2 (K-9L PAZ and lower part of K-10 L PAZ) are of the same age. Unfortunately it is in contrary to palynological dating. Pollen record of both pollen zones of this section from the profile Kontrowers W2 (K-9 L PAZ and K-10 L PAZ) is characterized by high percentages of *Pinus sylvestris*-type. Such values of pine have not been noted in any periods of Plenivistulian, neither in Polish sites (Balwierz 1995, Kupryjanowicz 1995, Granoszewski 1998, 2001), nor other sites in central or western Europe (Behre 1989, Zagwijn 1989, Reille & de Beaulieu 1990). Such high values of pine around Vistulian appear in this region at interstadials of Early and Late Vistulian only (Mamakowa 1989, Zagwijn 1989). The ^{14}C dates not to be correct. In a depth of less than 2 m below the surface one has to expect contamination with younger material, which is quite usual. Basing on the whole pollen record of the profile Kontrowers W2, the local pollen zone K-9 *Pinus–Betula* can be correlated with EV-2 *Betula–Pinus* R PAZ corresponding to Brörup Interstadial and K-10 *Pinus–Betula*–NAP with EV-3 Poaceae–*Artemisia–Betula nana* R PAZ (Table 3).

All the samples from the profile Kontrowers W1, excluding the one, not containing pollen, correlate well with the regional pollen zones of the Polish Eemian scheme (Table 3).

DEVELOPMENT OF VEGETATION

On the basis of palaeobotanical analyses described above an attempt was made to reconstruct the changes in vegetation. The vegetational history of the surroundings of the Kontrowers is presented with reference to the regional pollen assemblage zones (R PAZ) of the Eemian interglacial (Mamakowa 1989).

E-1, *Pinus–Betula* R PAZ (K-1 L PAZ). Predomination of AP in the pollen spectra indicates that forest communities prevailed at that time. However, diversity of tree and shrub taxa was very poor. The absolute domination of *Pinus sylvestris*-type pollen supports the assumption that pine spread upon all habitats accessible to it. Rather high pollen value of *Betula alba*-type points to significant role of birch in pine forests. The occurrence of *Quercus* in pollen spectra reflects most probably its presence in the pine communities developed on richer soils. The appearance of *Pteridium aquilinum* spores is probably connected with the herb layer of these forests. *Ulmus* pollen may have originated from the elm or elm-oak riverine forest type. Spores of Filicales monolete might come, at least partly, from these forests.

E-2, *Pinus–Betula–Ulmus* R PAZ (K-2 L PAZ), sample 1 from the profile W1). Pine-birch forests dominate. Small increase in the pollen values of *Quercus* reflects some changes that are already taking place in these communities on richer soils. The expansion of elm starts. It can occur on fertile, moist habitats and in riverine forest. The sedimentation basin was a lake of that time. Reed-swamp communities with *Typha angustifolia*/*Sparganium* and aquatic communities with Nymphaeaceae and *Ceratophyllum* occur in its inshore zone. *Botryococcus* represent alga communities.

E-3, *Quercus–Fraxinus–Ulmus* R PAZ (K-3 L PAZ), sample 2 from the profile W1). This zone is a period of the maximum expansion of oak. On more fertile soils, oak-pine mixed forest is formed, perhaps similar to the modern association *Pino–Quercetum* (Matuszkiewicz 2001). Its undergrowth contains hazel. The role of *Ulmus* and *Fraxinus* is very important. The moist eutrophic habitats are probably supporting riverine elm-ash communities. Alder can occur in these forests only sporadically (low percentages of *Alnus* pollen). The appearance of *Hedera helix* and *Viscum* reveals the climate warming (Iversen 1944). The aquatic vegetation is probably similar to that in the previous zone. *Typha latifolia* appears.

E-4, *Corylus–Quercus–Tilia* R PAZ (K-4 L PAZ, samples 3–5 from the profile W1; Km-1 L MAZ, sample 3.60 m from Km-2 L MAZ). The most characteristic feature of forests throughout this zone is the absolute domination of hazel. The expansion of lime in forest communities begins in the previous zone. However, it has not reached its maximum until the older part of this zone (K-4a L PAZ). In addition to the communities already existing, a formation of species-rich, deciduous and mixed forests begins at that time, presumably with a high proportion of lime and hazel. On the other hand, the very high pollen values of hazel suggest that it must have had some other sources too (Mamakowa 1989). Presumably, there are communities of thermophilous thickets or even hazel woods. Relatively high values of *Quercus* and *Ulmus* and presence of *Fraxinus* pollen indicate still considerable role of mixed oak forests and riverine forest communities. The presence of yew trees is confirmed by the small culmination of *Taxus* pollen values. Requirements of this tree suggest that it could create understorey of open oak forests (Mamakowa 1989). A distinct change in these forests causes the expansion of *Alnus*. The rise of the *Alnus* pollen values indicates development of alder-dominated communities in vicinity of the lake. Starting from the younger subzone, thermophilous mixed forests were enriched with a new component – hornbeam (*Carpinus*), which is evidenced by the rapid rise of its pollen values. The role of pine and birch in stands of the whole zone was insignificant. This zone was the climatic optimum of the interglacial. The presence of *Hedera helix* and *Viscum* also proves the high temperature at that time (Iversen 1944).

The maximum values of Filicales monoletae spores, as well as presence of bark and nutlets of *Alnus* sp., spores, fragments of sporangia and tissues of *Thelypteris palustris* in the sediment basin, indicate dominating it by alder communities with pteridophyte and creating their undergrowth there, at the end of hazel zone. Most probably their expansion was due to shallowing of the basin (or its part) and its conversion into a peat bog. It is documented by a change in sediment from gyttja to peat. The reason of this change could be filling the hollow with bottom sediment or/and lowering the underground water. As a result of shallowing, a periodical drying the sediments up may have taken place, which may result in considerable destruction of the sporomorphs deposited there.

Very low frequency of sporomorphs as well as poor state of preservation of the pollen-spores material at depth 4.10–3.40 m, indicate that the sediment has been dried up. This layer most probably corresponds to the younger part of regional pollen zone E-4 and/or older part of zone E-5. Therefore it is impossible to reconstruct the changes in vegetation that appeared at that time around the basin in Kontrowers. The results of the remains macroscopic analysis – the high participation of bark and nutlets of *Alnus* sp., great quantity of wood of deciduous trees and numerous appearance of *Carex* sp. (radicles) and *Dryopteris thelypteris* (fragments of leaves and sporangia) – shows that its surface was most probably occupied by alder community. Layers without pollen that can be correlated with hornbeam zone, appear also in some other pollen profiles from southern part of Mazowian Lowland (Bruj & Krupiński 2001) and from NE Poland e.g. from Haćki near Bielsk Podlaski (Brud & Kupryjanowicz 2002) and Michałowo (Kupryjanowicz & Drzymulska 2002).

E-5, *Carpinus–Corylus–Alnus* R PAZ (K-5 L PAZ, sample 3.40 m from Km-2 L MAZ). Hornbeam is the dominant tree. Its expansion must have brought about a regrouping in the communities of the mixed deciduous forests, in which it has gained predominance, presumably forming a second tree layer, and also partly eliminating hazel from the brushwood. The high values of *Picea* and presence of *Abies alba* signal the start of major changes in the forest communities. However high values of *Picea* pollen may be a result of its local over-representation.

The disappearance of *Alnus* sp. remains in the sediment and the appearance of *Picea abies* and *Pinus sylvestris* bark, remains of Ericacae and *Sphagnum* sect. *Cuspidata*, suggest that at the beginning of this period, change in community in the sedimentary basin may have taken place.

As a result of hydrological and/or trophic changes alder appearing so far was dislodged by spruce, which was later replaced by pine. Alder forest, probably first changed into boreal peat spruce forest, and later into swamp forest. These changes may have been connected with continuous cooling of climate and acidification of habitats. Now, peat spruce wood has its place in the ecotone zone between alder communities and bog pinewood (Matuszkiewicz 2001) which makes the assumed reconstruction highly probable.

E-6, ***Picea–Abies–Alnus* R PAZ (K-6 L PAZ,** sample 7 from the profile W1; sample 3.20 m from Km-2, Km-3, Km-4, sample 2.50 m from Km-5 L MAZ). Post-optimum climate deterioration becomes visible as spruce-fir forests appear in places occupied earlier by hornbeam communities. Spruce may have encroached upon riverine forests and wet alderwoods. Re-expansion of pine takes place as early as the beginning of the K-6 zone. It is facilitated by local conditions, chiefly new habitats formed by floods and swamping. The continuous occurrence of macrofossil remains of *Pinus*, *Betula* sp., Ericaceae, *Sphagnum* and coniferous wood, suggest that peat bog was dominated by bog pinewood at that time.

E-7, *Pinus* R PAZ (K-7 L PAZ, sample 2.40 m from Km-5 L MAZ). Changes in vegetation are marked by expansion of pine forests, probably with an admixture of birch, and by simultaneous regression of other forest communities. The relatively high pollen values of

Picea abies suggest that the spruce was still abundant in the Kontrowers vicinity. Its role in the expanding pine forests may have been prominent, especially in bog pinewoods (Matuszkiewicz 2001). The regression of the alder community is indicated by the decrease of the *Alnus* pollen values. The very small rise in pollen values of *Artemisia* and Poaceae undiff. may indicate some opening of forests and appearance of steppe-like and grassland communities. Their development means some cooling and increased continentality of the climate. Bog pinewood probably still appeared in the region of sedimentary basin.

EV-1, Poaceae–*Artemisia–Betula nana* R PAZ (K-8 L PAZ). The first post-Eemian cooling brings about recession of dense forest. Culmination of the NAP values is an evidence for expansion of open habitats occupied by herbaceous plants. Increase of the pollen values of *Artemisia*, Cyperaceae and Poaceae undiff. suggests increasing importance of open communities, mainly steppe-like in nature. Pollen of *Helianthemum nummularium*-type is probably associated with these communities. Shrub communities in dry sandy habitats are confirmed by the occurrence of *Juniperus* pollen. In moist habitats, *Salix* occurs more abundantly than in the previous zone. The high proportion of Cyperaceae pollen documents development of wet communities with sedges.

From the beginning of this zone, the water level rises significantly, which is shown by the change in deposit type from peat to organic silt and by appearance of pollen of reedswamp (*Phragmites*-type), aquatic plants (*Myriophyllum spicatum/verticillatum*) and green algae *Pediastrum*.

EV-2, *Betula–Pinus* R PAZ (K-9 L PAZ). Due to amelioration of climate, birch-pine forests encroach into the area. They are succeeded by pine forest. Herbaceous plant communities were still present. Change in deposit from organic silt to peat and increased values of *Sphagnum* are an evidence of shallowing of the basin and formation of peat bog.

EV-3, Poaceae–*Artemisia–Betula nana* R PAZ (K-10 L PAZ). Pinewoods grow thinner. Herbaceous steppe plant, especially sedge–brush are of great importance. Shrub-tundra with *Betula nana*-type, *Salix*, *Calluna vulgaris* and Ericaceae undiff., and grass communities are common too. There are probably also plants of mostly open, fresh, moist and wet habitats (*Thalictrum*, *Filipendula*, *Polygonum bistorta*-type, *Sanguisorba officinalis*, *Pleurospermum*, *Chamaenerion*) as well as open and dry habitats (*Helianthemum nummularium*-type, *Gypsophila fastigiata*-type). Taxa which occurred earlier (Chenopodiaceae, Cichorioideae, *Ranunculus acris*-type, Caryophyllaceae undiff., *Anthemis*-type, *Plantago major/media*) are the most frequent at that time. From the middle part of this zone the water level rises, which is recorded as the change in deposit type from peat to silty peat, and later into silt. Reed-swamp vegetation with *Phragmites*-type, *Typha latifolia* and *Menyanthes trifoliata*, and aquatic vegetation with *Myriophyllum spicatum/verticillatum* and green algae *Botryococccus* and *Pediastrum* occupy the inshore zone of the lake. These changes probably are a result of the constant cooling of climate, which indicates appearance of *Pediastrum kawraiskyi*, *P. boryanum var. longicorne*, and *P. integrum* (Jankovská & Komarek 2000).

CONCLUSIONS

1. The fossil Eemian lake at Kontrowers was formed after deglaciation of Wartanian ice sheet at Żelechów Upland. The occurrence of this Eemian buried lake, overlaining artian tills, indicates to the ice sheet of the Wartanian Glaciation.

2. The accumulation of organic deposits took place in Eemian interglacial, Early and Upper Vistulian (Main stadial) and Early Holocene.

3. Pollen record contained in organic deposits from profiles W1 and W2 enabled reconstruction of plants of nearly all stages of the Eemian interglacial period;

– the only missing record is the one of pollen from the older part of hornbeam stage of this interglacial – there is no pollen preserved in sediments from that time;

– pine pollen over-representation is characteristic of spruce phase. It is a result of appearing bog pinewood.

4. The part of profile Kontrowers W2 between 2.25 m and 0.90 m corresponds to the Early Vistulian and documents existence of subarctic open vegetation (K-8 L PAZ), boreal pine-birch and birch-pine forests (K-9 and K-10 L PAZ).

5. The lake at Kontrowers disappeared in late Holocene.

6. Changes in deposits are synchronised with climate changes.

7. The Eemian and Vistulian fossil lake is reflected in present relief.

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