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# Early Vistulian vegetation history and climate change at Gutów (Wielkopolska Lowland) from pollen analysis

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Pollen assemblages in peat and silt deposits from a core drilled at Gutów, Wielkopolska Lowland, have been analysed, enabling characterization of the development of vegetation and of palaeoenviromental change. The pollen analysis shows phases with forest and open vegetation communities alternating in response to climate changes. The age of the succession can be related to the stadials and interstadials of the Early Vistulian.

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## INTRODUCTION

The beginning of the Last Glacial (the Early Weichselian) and the end of the Eemian Interglacial are intervals of special interest, showing the development of plant communities and of climate change without influence by human activity. Investigations of ice cores from Greenland and of sea floor sediments from the North Atlantic have occasioned controversy concerning the palaeoclimatic development of the last glacial-interglacial cycle (Dansgaard *et al*., 1993; Grootes *et al*., 1993; Taylor *et al*., 1993; McManus *et al*., 1994). Palaeobotanical and isotope investigations in Germany (Litt *et al*., 1996) suggest that the Eemian Interglacial was relatively stable with marked climate oscillations only during the Last Glacial (the Early Weichselian). Most palynological investigations from Europe suggest that the last interglacial was an uninterrupted warm interval with a major oscillation in winter temperatures during the mesocratic part of the interglacial (Menke and Tynni, 1984; Frenzel, 1991; Zagwijn, 1996).

Palynological data from Early Vistulian Glaciation time in the Wielkopolska Lowland is scanty. 14 sites are known in this area of Poland, of which the majority represent an incomplete Early Vistulian succession (Tołpa, 1952; Janczyk-Kopikowa, 1965; Kuszell, 1980; Kozarski *et al*., 1980; Klatkowa, 1990; Tobolski, 1991; Klatkowa and Załoba, 1991; Malkiewicz, 2002; Fig. 1). Only two sites from the Konin area (Tobolski, 1991; Stankowski and Nita, 2004) represent the full Early Vistulian succession preceded by a continuous Eemian succession. In the neighbourhood of the Wielkopolska Lowland there are 9 further sites, of which only 4 represent all stadial and interstadial periods of the Early Vistulian (Jastrzębska-Mamełka, 1985; Mamakowa, 1989; Balwierz, 2003). However, in the sites in Domasłów (Rotnicki and Tobolski, 1965), Wołów (Kuszell, 1980), Zofiówka (Kuszell, 1997), Dziadowa Kłoda and Szklarka (Kuszell and Malkiewicz, 1999; Kuszell *et al*., 2007) an incomplete succession of cold and warm phases of the Early Vistulian has been documented.

At the beginning of the 21st century subsequent sites were described which, except for the Eemian Interglacial, comprise a significant part of the Last Glacial (Weichselian) (Balwierz, 2003; Granoszewski, 2003; Kupryjanowicz, 2005, 2008). However, there are still few sites with a continuous Eemian-Vistulian succession, and each is important for understanding the development of vegetation, climate and stratigraphy of the Late Pleistocene.

During field work carried out in the early 1990's for the *Detailed Geological Map of Poland* (1:50 000 scale, Skalmierzyce sheet) several cores of biogenic deposits were obtained (Boniecki and Jeziorski, 2000). The age of these was palynologically estimated as representing the Eemian Interglacial and the Early Vistulian (Balwierz, 1993; Kuszell and

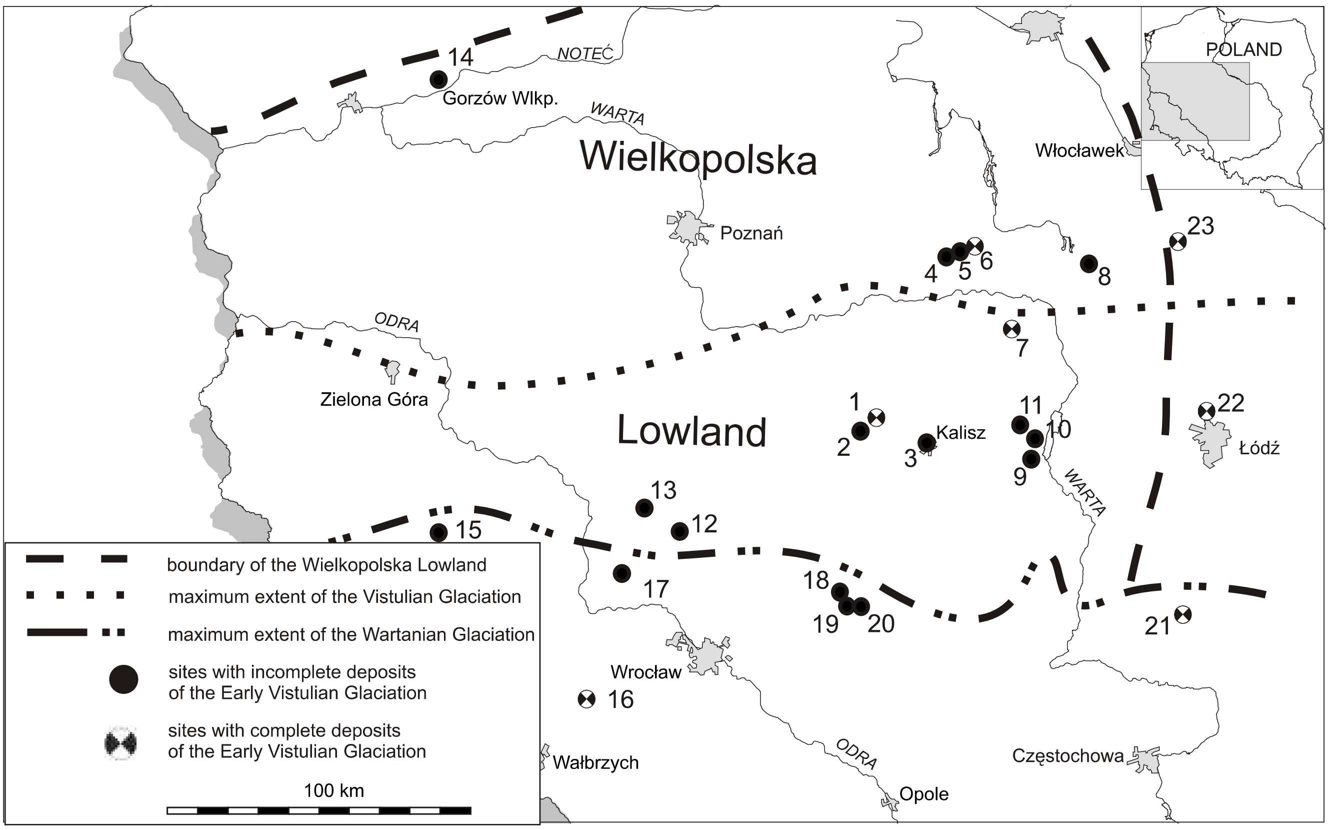


**Fig. 1. Sites of the Early Vistulian Glaciation floras in Wielkopolska Lowland and in the vicinity (Łódź Upland, Lower Silesia)**

1 – Gutów (Malkiewicz, 2008), 2 – Grudzielec Nowy (Malkiewicz, 2002), 3 – Kalisz (Tołpa, 1952), 4 – Kazimierz (Tobolski, 1991), 5 – Jóźwin (Tobolski, 1991), 6 – Mikorzyn (Stankowski and Nita, 2004), 7 – Władysławów (Tobolski, 1991), 8 – Kaliska (Janczyk-Kopikowa, 1965), 9 – Emilianów (Klatkowa and Załoba, 1991), 10 – Zagajew (Klatkowa, 1990), 11 – Ustków (Klatkowa and Załoba, 1991), 12 – Raki (Kuszell, 1980), 13 – Lechitów (Malkiewicz, 2002), 14 – Stare Kurowo (Kozarski *et al*., 1980), 15 – Zofiówka (Kuszell, 1997), 16 – Imbramowice (Mamakowa, 1989), 17 – Wołów (Kuszell, 1980), 18 – Dziadowa Kłoda (Kuszell and Malkiewicz, 1999; Kuszell *et al*., 2007), 19 – Szklarka (Kuszell and Malkiewicz, 1999), 20 – Domasłów (Rotnicki and Tobolski, 1965), 21 – Kuców (Balwierz, 2003), 22 – Zgierz-Rudunki (Jastrzębska-Mamełka, 1985), 23 – Łanięta (Balwierz, 2003)

Sadowska, 1994; Noryśkiewicz, 1995; Malkiewicz, 2002, 2003, 2008).

Especially interesting was the profile from Gutów, with 5.7 m-thick interglacial deposits, overlain by 2 m of Vistulian (Weichselian) Glaciation deposits (Kuszell and Sadowska, 1994). Due to the incomplete sampling no attempt was made at detailed biostratigraphic analysis of this succession. In 2006, though, palynological analysis of the Eemian Interglacial deposits from Gutów was carried out (Malkiewicz, 2008). This showed not only the full interglacial succession, but also the declining part of the Middle Polish Glaciations (Saalian). At the same time, palynological and biostratigraphical research of the overlying Weichselian deposits began. The research aimed to increase knowledge of the palaeoenvironmental and climatic conditions of the immediate foreland at the maximum limit of the Vistulian (Weichselian) Glaciation ice sheet.

In this paper are described the results of palynological studies of the biogenic deposits representing the final phase of the Eemian Interglacial and the Early Vistulian, and comparison of those with deposits of the same age from adjacent areas.

## THE AREA INVESTIGATED: GEOLOGY

The site of Gutów (N 51°45'42", E 17°52'10") is located on the Kalisz Upland in the southern part of the Wielkopolska Lowland (Kondracki, 2001), about 20 km to the west of Kalisz (Fig. 1).

In the area investigated, the Pleistocene deposits represent several glaciation periods. Deposits of the South Polish Glaciation (Elsterian) are the oldest Pleistocene deposits in the area (Boniecki and Jeziorski, 2000). They are found in depressions in the Neogene deposits near Miedzianówka, Czekanów, Czachor and Czechel. Locally they directly overlie Lower Neogene strata (Fig. 2). No deposits representing the Mazovian Interglacial (Holsteinian) were found in the area investigated. Deposits of the Middle Polish Glaciations (Saalian): Krznanian and Odranian with Warta Stadial (formerly Odranian and Wartanian Glatiation) (*cf.* Lindner and Marks, 1999; Lindner, 2005; Ber *et al*., 2007) are preserved locally as fluvioglacial deposits and till. The till thickness varies from 2 m between Macewo and Kucharki to over 30 m in the vicinity of

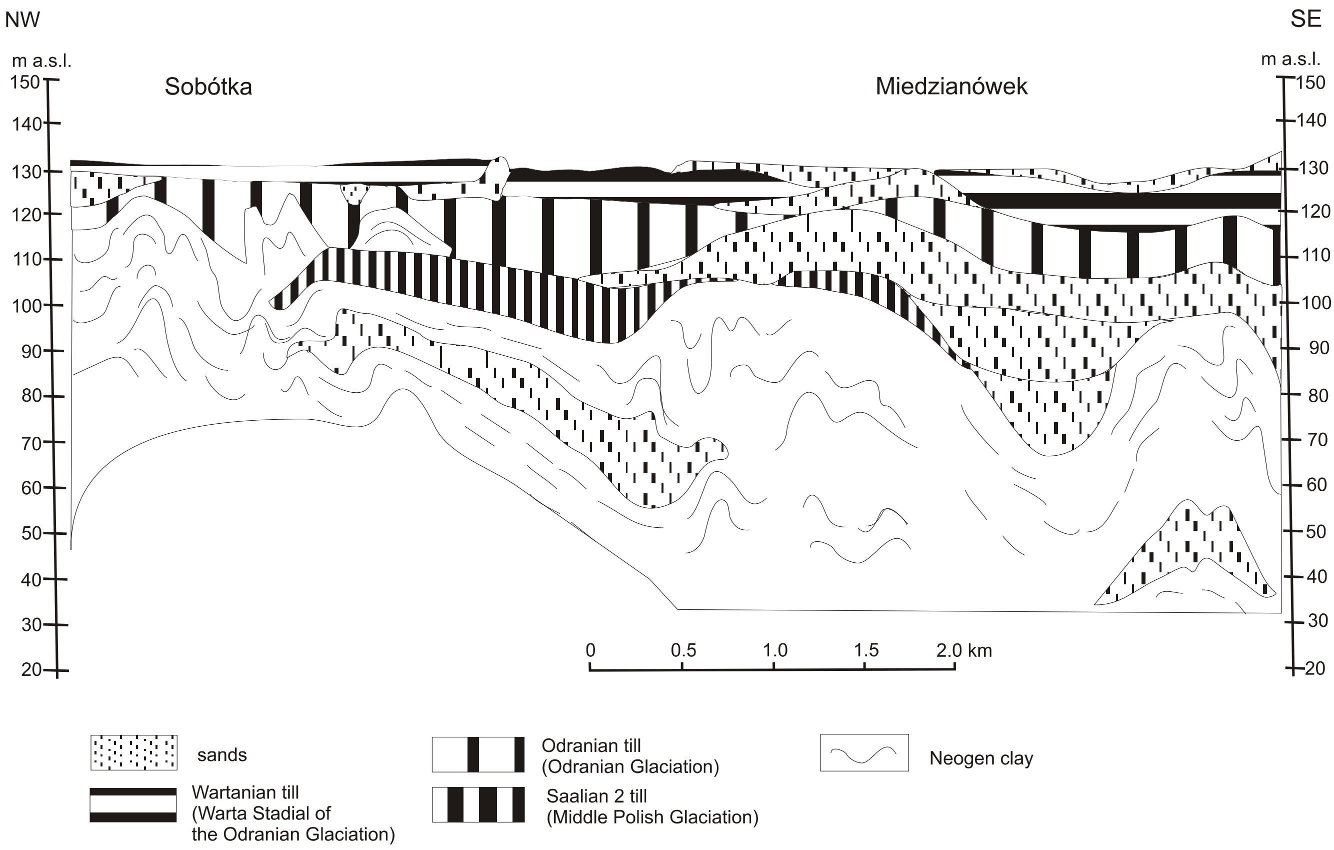


**Fig. 2. Geological cross-section NW–SE in the vicinity of the Gutów site (from Boniecki and Jeziorski, 2000)**

Czekanów. The Eemian Interglacial is represented by up to 13 m of sands and lacustrine silt near Czekanów, as well as silt, peat and gyttja documented from a subglacial trough in the area of Grudzielec Nowy–Bieganin and from hollows formed by melted dead-ice scattered across the upland. The hollows are up to several dozen metres in diameter and 10 m deep (Gutów and Kwiatków). When the region investigated was a proximal part of the glacier foreland during the Vistulian (Weichselian) Glaciation, fluvioglacial sediments up to 25 m-thick were deposited. Silt that fills the subglacial trough to the west of the site investigated and some of the depressions on the upland is of the same age. The Holocene deposits comprise mainly fluvial sand and gravel of flood plains and peat to 0.5 m-thick in the river valleys.

The palaeolake in Gutów, from which the analysed profile was taken, is located a few metres to the east of the geological section Sobótka–Gutów–Miedzianówek (Boniecki and Jeziorski, 2000; Fig. 2). The basin was small and without outflow. It formed as a result of dead-ice melting during the Warta Stadial – the final stadial of the Odranian (Late Saalian) Glaciation (formerly Wartanian Glatiation; *cf*. Lindner and Marks, 1999; Lindner 2005; Ber *et al*., 2007). The depth of the basin was about 10 metres.

A core for pollen analysis, measuring 8.5 m, was obtained, comprising peat and, organic and mineral silt (Table 1). These sediments are underlain by clayey silts and boulder clay of the Warta Stadial – the stadial of the Odranian (Saalian) Glaciation (*cf*. Lindner and Marks, 1999; Lindner, 2005; Ber *et al*., 2007). The top of the profile comprises fine sands with gravel and clayey sands, dating from the Vistulian (Weichselian) Glaciation. The deposits from the depths from 10.70 to 5.40 m were previously the focus of palynological analysis (Malkiewicz, 2008). This paper presents the results of pollen analysis of peat and silt from the depth interval 2.20 to 5.30 m.

## MATERIAL AND METHODS

56 samples were collected for palynological analysis. Peat and organic silts were boiled in 10% KOH, while samples with a considerable content of mineral material (silt and sand) were treated with concentrated hydrofluoric acid for 24 hours. Subsequently the material was macerated using Erdtman's acetolysis (1960). Pollen spectra were counted on two or three slides. On average a total of 800–1000 sporomorphs was found in each sample. The results of pollen analysis are shown on the pollen diagram (Fig. 3). The percentage calculations are based on the total sum (AP + NAP), which include trees, shrubs (AP) and herbaceous plants (NAP). Aquatic, swampy plants and spore plants were excluded from the total sum. *POLPAL* palynological software was used to make the percentage pollen diagram (Nalepka and Walanus, 2003).

Table 1

**Lithological description of the Gutów profile**

| Depth [m] | Lithology |
|---|---|
| 2.20–2.65 | silt |
| 2.65–2.97 | silty peat |
| 2.97–7.65 | peat |
| 7.65–8.15 | peaty silt |
| 8.15–9.15 | compressed silt, brownish-grey |
| 9.15–9.75 | compressed silt, pale grey |
| 9.75–10.70 | loose silt, grey and pale grey |

## RESULTS

The results of pollen analysis from Gutów are shown in a pollen diagram (Fig. 3). In this, nine local pollen assemblage zones (L PAZ) were distinguished according to criteria submitted by Janczyk-Kopikowa (1987). A description of each zone is given in Table 2.

The pollen spectra of the sequence from Gutów are correlated with chronostratigraphic units distinguished for Poland by Mamakowa (1989), for the Konin region by Tobolski (1991) and for northwestern Europe by Behre (1989) (Table 3).

## VEGETATION HISTORY AND CHRONOSTRATIGRAPHY

Local pollen zone GUT 1, represented by two samples, is characterized by a dense pine forest with birch (*Betula*). Among trees an important role is played also by spruce (*Picea*) and alder (*Alnus*). Trees and shrubs characteristic of warmer interglacial zones occur in slight amounts. The significant presence of herbaceous plants (above 20.0%) as well as the appearance of *Betula nana* and *Juniperus* indicate deterioration of the climate and the beginning of the vegetation changes in the area investigated. This vegetation succession can be correlated with the history of the end of Eemian Interglacial. Zone GUT 1 corresponds to regional pollen zone E 7 by Mamakowa (1989) and the *Pinus* zone by Tobolski (1991). The upper boundary of the GUT 1 *Pinus* L PAZ represents the Eemian–Vistulian Glaciation boundary. The criteria of this boundary definition match those applied by Andersen (1961), Zagwijn (1961) and Mamakowa (1988). It is placed where a rise in the herb pollen values indicates the decline of dense forest and the formation of more open communities with a fairly marked proportion of different heliophytes.

The vegetation in pollen zones GUT 2 and GUT 3 indicates a severe climate cooling. Peat sedimentation continued in the lake basin, but the mineral fraction value was increased. In zone GUT 2 a withdrawal of forest communities can be observed. The high percentage of heliophytes shows the spread of open communities. This is particulary visible in the 50th sample, where the herb plants percentage exceed 65%. The heliophytic communities were represented mostly by *Artemisia*, Chenopodiaceae, *Helianthemum*, Caryophyllaceae, and *Rumex*. The high proportion of Poaceae pollen points to a spread of grass communities. Damp habitats were covered by *Ranunculaceae*, *Asteraceae*, *Apiaceae*, *Thalicrtum*, *Galium*, *Equisetum*, Polypodiaceae and shrub communities with dwarf birch and shrub willow. The plant communities of that time were very poor in trees. Single pines (*Pinus*) and birch trees (*Betula*) could build up sparse groups with the occasional appearance of larch (*Larix*). The pollen picture of zone GUT 3 indicates a small change in the vegetation of the basin. The increase in values of *Betula* pollen and slight decrease in the herbaceous plants may result from the development of sparse forests. The expansion of birch in the final stage of this cold period was documented also at a near by site, Zgierz-Rudunki (Jastrzębska-Mamełka, 1985) and at many other sites. It is a result of a more temperate climate and precedes other changes in the plant communities. These zones document a treeless stadial phase and correspond to regional pollen zones EV 1 (Mamakowa, 1989) and *Artemisia*–NAP (Tobolski, 1991). These zones represent the Herning Stadial in the stratigraphic scheme of northwestern Europe (Behre, 1989).

In pollen zones GUT 4 and GUT 5 climate warming and increased humidity is followed by a more continental climate. In the lake basin investigated peat accumulation was continued, but the addition of mineral fractions was much lower. In zone GUT 4 the development of dense birch forest with addition of pine and larch was observed. The decline in herb plant pollen shows the scarcity of open habitats. Shrub communities with *Betula nana*, *Juniperus* and *Salix* as well as heliophytic communities with *Artemisia*, Chenopodiaceae, *Helianthemum* and *Rumex* were still present. However, their area was very limited. Within zone GUT 4, at a depth of 3.90–3.95 m, a brief climate cooling was observed. The decrease in values of *Betula* and a higher percentage of *Artemisia*, *Juniperus* and *Betula nana* indicates the termination of birch forest expansion and a development of open habitat communities. After this short episode the climate ameliorated, which allowed the next expansion of birch and also pine at the end of this zone. At the border of zone GUT 5 the development of birch-pine forests with an addition of larch was observed, which later yielded to pine forests with an addition of birch, larch, spruce and hazel. The small content of herb plants indicates the existence of dense forest communities at that time, with few open habitats. In the zone GUT 5 decline, peat sedimentation was interrupted. Peats gradually become peaty silts, and subsequently silts with progressively lower organic contents. Increase of the groundwater level probably caused moor undercut and flooding, and as a consequence the sediment change occurred. Local pollen zones GUT 4 and GUT 5 are correlated with EV 2 (Mamakowa, 1989) and V-I (Tobolski, 1991). Two main phases can be distinguished in the succession of this interstadial at Gutów. The first (GUT 4) is the dominance of birch forest. The second phase (GUT 5) is characterized by the development and spread of pine forest. The birch phase of the interstadial has been correlated by Kupryanowicz (2008) with the Amersfoort Interstadial and the pine phase with the Brörup *sensu stricto*. Behre and Lade (1986), Behre (1989) and other authors from Poland (Stankowski *et al*., 1999; Balwierz, 2003; Kuszell *et al*., 2007) correlate both the older and younger parts of the interstadial with the Brörup *sensu lato*.

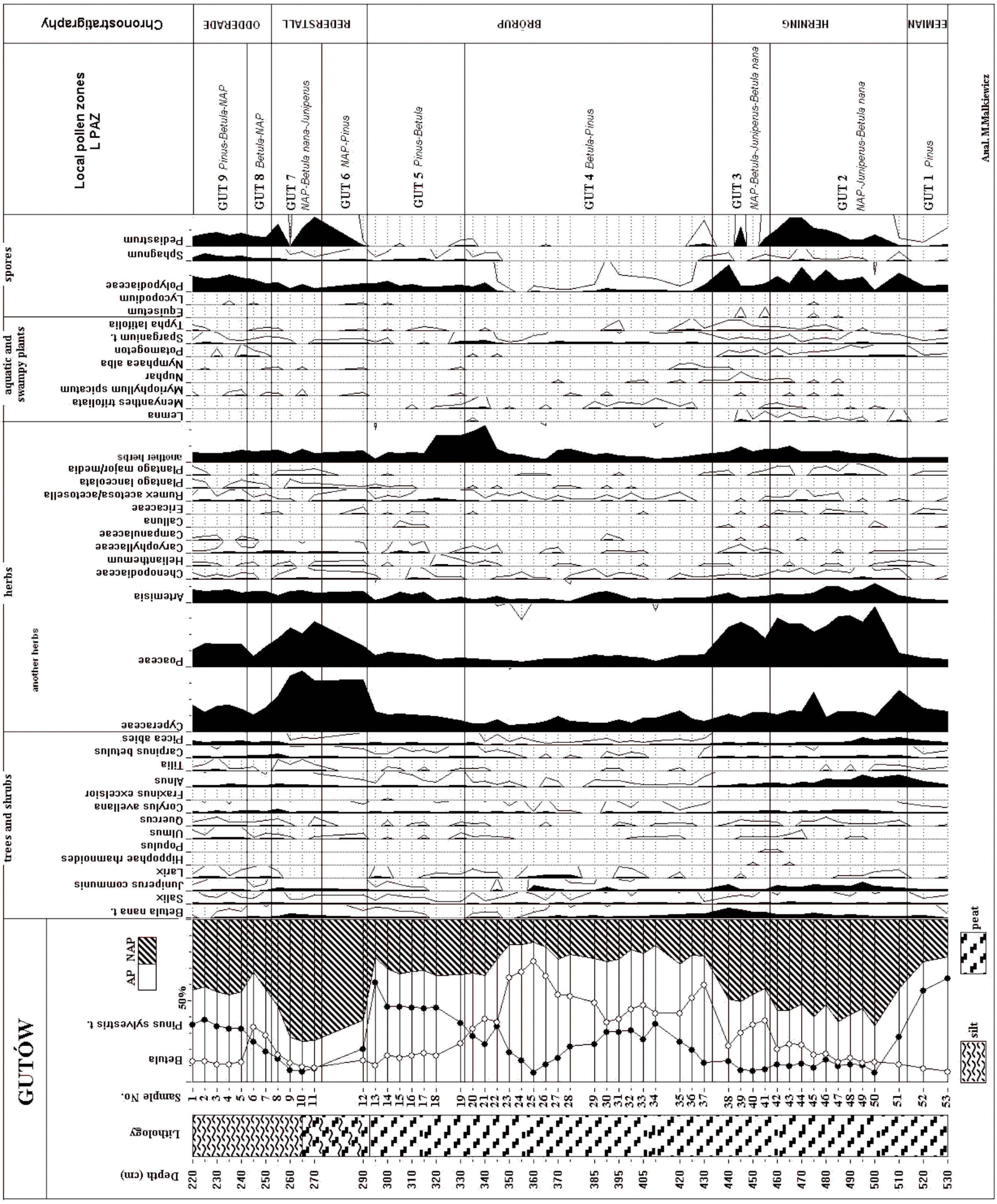


Fig. 3. Pollen diagram from Gutów

In zones GUT 6 and GUT 7, as a result of continuous climate cooling and wetting, repeated reconstruction of the Gutów area vegetation occurred. At that time, forest retreated and the landscape opened, with NAP increasing to over 70%. Probably, tundra with the addition of dwarf birch, juniper and shrub willows developed in the area. Sand and exposed habitats were dominated by heliophytic communities, with an important role of Poaceae, *Artemisia*, Chenopodiaceae, Helianthemum and Caryophyllaceae. An increase in pollen from thermophilous plants is ascribed to increased transport erosion, and suggests marked deforestation. The treeless stadial phase (local pollen zones GUT 6 and GUT 7) correspond to regional pollen zones EV 3 (Mamakowa, 1989) and NAP

Table 2

**Description of the local pollen assemblage zones from the Gutów section**

| Local pollen assemblage zones L PAZ | Depth [m] | Description of L PAZ |
|---|---|---|
| GUT 9 – *Pinus–Betula*–NAP | 2.40–2.20 | AP dominantes, with the maximum shares of *Pinus* 39.0% and *Betula* 13.0%. *Juniperus* reaches 1.0%, *Larix* and *Salix* 0.8% and *Betula nana* 0.5%. *Ulmus, Quercus, Corylus, Alnus, Carpinus* and *Tilia* present. *Picea* increase to 2.5%. In the NAP group, the highest proportions are those of Cyperaceae (16.5%), Poaceae (14.5%) and *Artemisia* (8.0%). |
| GUT 8 – *Betula*–NAP | 2.50–2.45 | *Betula* pollen (34.0%) is dominant. The following pollen of other trees occurs: *Pinus* (max. 25.0%), *Picea* (2.0%), *Carpinus* (1.4%), *Corylus* (1.3%) and *Larix* (0.8%). There are single pollen grain of *Betula nana*, *Salix* and *Juniperus*. Values of NAP decrease to average 37.9%. |
| GUT 7 – NAP–*Betula nana–Juniperus* | 2.70–2.55 | The values of NAP reach 75.2%, the highest proportions being those of Cyperaceae (38.0%), Poaceae (28.0%) and *Artemisia* (7.5%). The maximum values are reached by *Betula nana* 2.5% and *Juniperus* 2.1%. Of AP the highest values are those of *Betula* (17.0%) and *Pinus* (14.5%). |
| GUT 6 – NAP–*Pinus* | 2.90 | A marked increase in the NAP values takes place (max. 61.4%). *Artemisia*, Poaceae and Cyperaceae are dominant. The following of *Pinus* pollen (20.5%) and *Betula* pollen (13.5%) occurs. |
| GUT 5 – *Pinus–Betula* | 3.30–2.95 | The AP frequency are high, reaching average 84.4%. *Pinus* shows a distinct increase while *Betula* falls. Countinuous presence of *Juniperus*, *Betula nana*, *Salix* and *Larix*. Values of NAP reaches a maximum of 34.9%. |
| GUT 4 – *Betula–Pinus* | 4.30–3.35 | *Betula* pollen dominates (75.0%), *Pinus* reaching 36.0%. *Betula nana*, *Juniperus* and *Larix* pollen less 2.5%. NAP increase to 33.7%. |
| GUT 3 – NAP–*Betula–Juniperus–Betula nana* | 4.55–4.40 | NAP values decrese to average 46.8% and increase value of *Betula* to 38.0%. The continuous curves of *Betula nana* (max. 6.0%) and *Juniperus* (max. 3.8%) begin. Pollen of *Corylus*, *Ulmus* and *Quercus* are rarely found. |
| GUT 2 – NAP–*Juniperus–Betula nana* | 5.10–4.60 | NAP values increase to 65.3%. The highest pollen shares are those of Poaceae (to 37.0%), Cyperaceae (to 26.0%) and *Artemisia* (to 12.0%). Both *Juniperus* (max. 5.3%), *Salix* (max. 1.3%) and *Betula nana* (max. 2.8%) have relatively high values. *Pinus* oscillates from 6.1 to 28.0% and *Betula* from 11.0 to 23.5%. Of other trees, *Alnus* reaches average 4.3% and *Picea* 2.0%. *Larix*, *Hippophae* and *Populus* are noted. |
| GUT 1 – *Pinus* | 5.30–5.20 | *Pinus* pollen dominates absolutely, reaching a maximum of 64.0%. The following pollen of other trees occurs: *Betula* (max. 8.5%), *Alnus* (max. 3.4%) and *Picea* (max. 2.3%). *Juniperus*, *Betula nana*, *Salix* and *Larix* are present. The upper boundary of the zone the NAP proportion increases, to 42.0%. |

Table 3

**Correlation of the local pollen assemblage zones from Gutów with the regional pollen assemblage zones of the Eemian Interglacial and the Early Vistulian Glaciation**

| Regional pollen zones from Poland (R PAZ) Mamakowa (1989) | Local pollen zones (L PAZ) Gutów | Regional pollen zones (R PAZ) Konin region Tobolski (1991) | Chronostratigraphy NW Europe Behre (1989) | |
|---|---|---|---|---|
| EV 4 | GUT 9 – *Pinus–Betula*–NAP<br>GUT 8 – *Betula-NAP* | V-II | Odderade Interstadial | Early Vistulian Glaciation |
| EV 3 | GUT 7 – NAP–*Betula nana–Juniperus*<br>GUT 6 – NAP–*Pinus* | NAP | Rederstall Stadial | |
| EV 2 | GUT 5 – *Pinus–Betula*<br>GUT 4 – *Betula–Pinus* | V-I | Brörup Interstadial | |
| EV 1 | GUT 3 – NAP–*Betula–Juniperus–Betula nana*<br>GUT 2 – NAP–*Juniperus–Betula nana* | *Artemisia*–NAP | Herning Stadial | |
| E 7 | GUT 1 – *Pinus* | E-III *Pinus* | Eemian Interglacial | |

(Tobolski, 1991) and represent the Redestall Stadial in the stratigraphic scheme of northwestern Europe (Behre, 1989).

The vegetation in pollen zones GUT 8 and GUT 9 indicates subsequent climate warming. At this time the silt sedimentation was taking place in the lake basin. Climate warming enabled the forest communities to re-expand. In zone GUT 8 the birch forest of park-tundra type developed, whereas in zone GUT 9 boreal pine forests with the addition of birch dominated. The important elements of these forests were larch and spruce. A significant herbaceous plant value (45%) suggest open plant communities in the area.

These zones correspond to the succession of an interstadial character. This is the younger interstadial of the early glacial of the Vistulian Glaciation, representing the Odderade Interstadial (Behre, 1989) and EV 4 (Mamakowa, 1989), V-II (Tobolski, 1991).

## DISCUSSION

Gutów is the third site in the Wielkopolska Lowland, where the full record of an Early Vistulian succession preceded by a continuous Eemian succession can be found. Two previously-described sites are in the Konin area (Tobolski, 1991; Stankowski and Nita, 2004). In the neighbourhood of the Wielkopolska Lowland there are 9 further sites, of which only 4 represent all stadial and interstadial periods of the Early Vistulian (Jastrzębska-Mamełka, 1985; Mamakowa, 1989; Balwierz, 2003).

Forest communities of the end of the Eemian Interglacial at Gutów were characterized by the presence of hornbeam (*Carpinus*), oak (*Quercus*), hazel (*Corylus*) and lime (*Tilia*). They survived probably in all of southwestern Poland until the beginning the Early Vistulian. Their presence has also been confirmed in other sites in the Wielkopolska Lowland (Tobolski, 1991; Kuszell, 1997; Malkiewicz, 2002, 2008; Stankowski and Nita, 2004), Lódź Upland (Jastrzębska-Mamełka, 1985; Klatkowa and Winter, 1990; Załoba and Jastrzębska-Mamełka, 1990*a*, *b*), Lower Silesia (Kuszell, 1980; Mamakowa, 1989) and Western Pomerania (Urbański and Winter, 2005; Winter *et al*., 2008). Values of *Alnus* and *Picea* pollen suggest that spruce and alder were present in the area investigated during the final part of the Eemian Interglacial. *Alnus* was probably building alder forest communities, still growing in the near by Prosna valley. Spruce is supposed to appear in drier as well as wetter habitats. A similar vegetation landscape has been recorded also in other sites in southwestern Poland (Kuszell, 1980, 1997; Mamakowa, 1986, 1989; Tobolski, 1991; Malkiewicz, 2002, 2003, 2008; Stankowski and Nita, 2004).

The present investigations show that there is no doubt about the withdrawal of dense forest from the central part of the Wielkopolska Lowland during the Herning Stadial. Nevertheless it is debatable whether or not pine and birch trees withdrew from this area completely. The percentage of AP in Gutów, fluctuating between 40 and 58%, consists almost exclusively of *Pinus* and *Betula* pollen. The 10% share of pine pollen may mostly result from long-distance transportation, however the percentage of *Betula* pollen, reaching 30%, may be evidence of isolated birch trees. Even if pines did not grow in the area, they may have been present in the near neighbourhood. The presence of pine in the early stage of the Herning Stadial in the area of Mikorzyn was not excluded by Nita (Stankowski *et al*., 1999). Tobolski (1991), however, documented the presence of steppe in the Konin area. The higher significance of *Pinus* and *Betula* in plant communities of that time was documented in sites located south of Gutów (Mamakowa, 1989; Malkiewicz, 2002; Kuszell *et al*., 2007). It is possible that a part of the pollen in GUT 2 and GUT 3 comes from redeposition, which is also indicated by the significant presence of *Picea* and *Alnus* as well as the other pollen of thermophilous trees. The upland nature of the site and the low water level in the littoral zone of the lake could have contributed to extensive erosion of the sediments deposited during the Eemian Interglacial. On the other hand, the presence of *Larix* at this time indicates the existence of the open and well-lit habitats. Larch is one of the most light-demanding tree species in the moderate climate zone. For normal growth it requires a full top light and a good side light (Olaczek, 1986). The vegetation of this stadial, documented in the Gutów spectrum as well as in other spectra from Central Poland (Jastrzębska-Mamełka, 1985; Tobolski, 1991; Malkiewicz, 2002; Stankowski and Nita, 2004) and southwestern Poland (Malkiewicz, 2002; Kuszell *et al*., 2007) allows one to assume that the climate was subarctic with some continental features. In Central Poland the average July temperature might have varied between 8 and 10°C during this period. In sites located more to the west, the average temperature of the coldest month decreased perhaps to –12°C (Aalbersberg and Litt, 1998).

The present investigations indicate a short break in the birch forest expansion within the Brörup Interstadial shown by a decrease in values of birch and a slight increase of NAP. This cold oscillation has been recorded in only few pollen diagrams from Poland. So far it has been documented in the Wielkopolska Lowland only in the record from Mikorzyn (Stankowski *et al*., 1999), and from the adjacent areas only in individual records from the Lódź Upland (Jastrzębska-Mamełka, 1985; Balwierz, 2003) and Lower Silesia (Mamakowa, 1989). This cold climate fluctuation has also been recorded from Eastern Poland (Kupryanowicz, 1991, 2008; Granoszewski, 2003). This phenomenon does not appear to be local, because it has also been documented in some profiles from Western Europe (Robertsson, 1988; Behre, 1989; Reille *et al*., 1992; Müller *et al*., 2003). During the Brörup, in almost all of Poland, a significant temperature increase took place, probably to 15°C (Tobolski, 1991; Aalbersberg and Litt, 1998; Granoszewski, 2003). Flora of this interval indicates that the climate of Central Poland was boreal, more humid during the first half of the interstadial, and more continental during the second. Pine occurrence may suggest the warmest month mean temperature was above 12°C (Granoszewski, 2003). On the other hand, the occurence of *Typha latifolia* shows that the July mean temperature was not lower than 14°C (Tobolski, 1991). This value may even have been higher, if we consider the presence of *Larix*. The minimum July temperature for *Larix* decidua is 17°C (Granoszewski, 2003). The pollen of *Betula nana* seem to point to better climatic conditions and may suggest the cessation of continental influence in this zone (Tobolski, 1986). Winter temperatures were still low, at approximately –13°C in Eastern Germany and Western Poland. The occurrence of *Calluna* and *Larix* in most profiles in northwestern Europe indicates that minimum January temperatures were around this value and indicates precipitation was about 400–600 mm (Aalbersberg and Litt, 1998). Only in Great Britain the temperature seemed to be higher, up to –6°C. Following the birch period (depth 3.90–3.95 m) a return of open communities is observed. The higher values of *Artemisia*, Poaceae and Chenopodiaceae, as well as the increase of *Betula nana* and *Juniperus*, depict worse conditions and more continental features of the climate. In this period the mean July temperature did not fall below 10°C (Granoszewski, 2003).

The percentage of NAP exceeding 70% indicate very marked landscape opening and non-forest tundra development in the Redestal Stadial. A similar landscape was detected at Mikorzyn (Stankowski *et al*., 1999) and Łanięta (Balwierz, 2003). In sites located further south of Gutów (Mamakowa, 1989; Kuszell *et al*., 2007) the importance of herbaceous plant was lesser. As in the Redestall Stadial, the absence of forests indicates that the mean summer temperatures were around 10°C. In this stadial the forest communities were replaced by herbaceous plants. The development of a shrub tundra and the increase in values of *Betula nana* indicate climate deterioration in the Gutów region. The shrub tundra communities with *Betula nana* indicate milder continental climate conditions (Tobolski, 1986; Bińka and Nitychoruk, 1996). The value between 8–12°C indicated by beetles for northwestern Europe is a good match with the suggested July temperature of 10°C (Aalbersberg and Litt, 1998).

The palynological investigations of the Gutów sediments indicate the somewhat different characteristics of the Odderade Interstadial as compared to the Brörup and the existence of a short birch episode within it. The Odderade Interstadial, characterized by open pine forest domination, was probably preceded by a short period of open birch park-like forest domination. This short birch episode is not easily visible in most pollen diagrams. In the Wielkopolska Lowland it has been known so far only from one sample from Mikorzyn (Stankowski *et al*., 1999). It is similarly developed in Kuców and Łanięta in the Lódź Upland (Balwierz, 2003) and in the Podlasie region (Kupryanowicz, 2008). It appears that it has also been recorded in one sample from Zgierz-Rudunki, but the author included this segment in the Redestall Stadial (Jastrzębska-Mamełka, 1985). The birch episode is very well documented in Horoszki in Podlasie (Granoszewski, 2003), where macroscopic fragments indicate the presence of birch forests at that time. It has also been found in many diagrams from Central Europe (Erd, 1973; Menke and Tynni, 1984; Behre and Lade, 1986; Caspers, 1997). The phenomenon is not likely to be limited only to the area of Poland. The return of birch and pine-birch forest in the Odderade Interstadial is an evidence of increasing warmest-month temperatures to around 15°C. Taking into account the presence of *Typha latifolia* and *Nymphaea alba*, the July temperature may have been 12 to 14°C (Huijzer and Isarin, 1997). The presence of larch could indicate the summer temperatures up to 17°C, similar to the Brörup Interstadial conditions. The minimum mean January temperatures are comparable to those of the Brörup Interstadial also (Aalbersberg and Litt, 1998). The highest temperature of the coldest month definitely did not exceed 0°C. These conditions are suggested by the presence of *Betula nana*. The conterporary range of dwarf birch matches the range of maximum January temperature up to 0°C (Granoszewski, 2003).

## CONCLUSIONS

The Gutów profile comprises one of the longer Upper Pleistocene interglacial-glacial successions in the Wielkopolska Lowland. These investigations contribute to the general knowledge of the natural environment of stadial and interstadial periods of the Early Vistulian in the central part of the Wielkopolska Lowland.

1. The deposits from Gutów a record four climate fluctuations of the Early Vistulian, two stadials – Herning and Redestall – and two interstadials – Brörup and Odderade.

2. Four climate changes following the Eemian Interglacial were recorded – from the subarctic, continental climate, through boreal, again subarctic, up to again boreal. This indicates a transition from a subarctic steppe, through forest communities of boreal climate to tundra vegetation, and then again to boreal forest communities.

3. In the Brörup Interstadial a cooling event has been recorded.

4. A different character of the Odderade Interstadial compared to the Brörup Interstadial was noticed.

5. The birch phase of the Odderade Interstadial was shorter than the birch phase of the Brörup Interstadial and may suggest a generally greater continentality of the climate.

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