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Early Vistulian climate oscillations in the light of pollen analysis of deposits from Dziadowa Kłoda (Silesian Lowland, Poland)

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The stratigraphy and palaeogeography of Quaternary deposits underlying the Oleśnica Plain were investigated during mapping of the Syców sheet of the *Detailed Geological Map of Poland* on the scale of 1:50 000. The Oleśnica Plain is part of the southern foreland of the Trzebnica Ridge, the latter representing a frontal moraine of the South and Middle Polish Glaciations. Neopleistocene deposits found at the Dziadowa Kłoda site were analyzed for their pollen content. These lacustrine to swamp deposits represent a continuous and undisturbed sequence spanning the Eemian Interglacial to Brörup Interstadial interval. The Early Vistulian deposits have been the subject of detailed palynological investigations. The reconstructed pattern of vegetation changes has allowed a precise determination of the upper boundary of the last interglacial as well as the recognition of stadial-interstadial horizons. Three climatic oscillations have been noted, corresponding to the Herning and Rederstall stadials and the Brörup Interstadial. In the climatic optimum of the interstadial, dense boreal pine-birch forests accompanied by a minor admixture of alder and spruce were predominant. Cold stadials were dominated by open vegetation with tundra and steppe elements.The pollen sequence from Dziadowa Kłoda is the first site on the Silesian Lowland that shows the first fully developed Early Vistulian warm oscillation that correlates with the Brörup Interstadial. A distinctive feature of this site is a long, continuous pollen sequence of the Eemian passing into deposits of the Vistulian Glaciation in the same profile.

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Key words: Silesian Lowland, Eemian Interglacial, Early Vistulian, Brörup Interstadial, climate oscillations, palynology.

INTRODUCTION

In 1964 the first boreholes drilled at the Dziadowa Kłoda site revealed a thick sequence of lacustrine deposits. The preliminary results showed an interglacial succession, although detailed stratigraphic conclusions were not possible at the time. The next stage of the research was related to mapping on the Syców sheet of the *Detailed Geological Map of Poland* on the scale of 1:50 000 (Chmal, 1998*a*, *b*). For mapping purposes, a test borehole was drilled at this site and a continuous core of lacustrine and swamp deposits was taken to a depth of 18.4 m. The first results of pollen analysis of the upper part of the core (from 2.25 to 9.25 m) made in 1995–1998 showed an Eemian and Vistulian age for this section (Kuszell, 1998). At that time we focused palynological attention on the interglacial succession in the depth range of 5.50–9.25 m. In this paper we give palynological results of the remaining seation, from the depth interval 5.95–2.05 m, representing the transitional phases of the final Eemian Interglacial and the Early Vistulian, and we compare this with intervals of the same age from adjacent areas.

THE AREA OF INVESTIGATION

According to the geographical scheme of Walczak (1970) and Kondracki (1994) the site examined is located on the Silesian Lowland in the mesoregion of the Oleśnica Plain. To the north, this plain adjoins the "Syców Hills", part of the Twardogóra Hills mesoregion. The latter hills are, geologically, a part of the Trzebnica Ridge (Fig. 1), a frontal push moraine, produced by the South Polish Glaciations and partly, also, during the Middle Polish (Odranian) Glaciation (Dyjor, 1993). The Odranian Glaciation resulted in superposition of fissure deposition structures and kames on older glaciotectonic structures. The Odra ice-sheet reached only as far to the south as the northern part of the Syców Hills, where a depositional

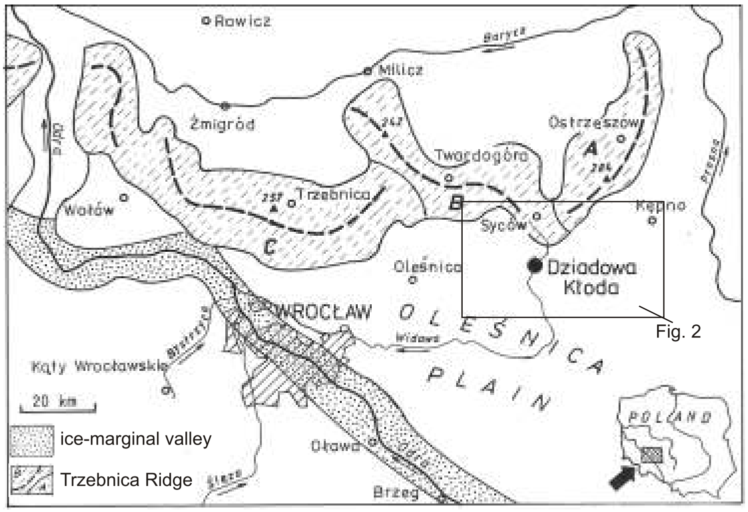

Fig. 1. Map of the Dziadowa Kłoda area (Kondracki, 1994)

A — Ostrzeszów Hills, B — Twardogóra Hills, C — Trzebnica Hills

end-moraine, culminating at 221 m a.s.l., was formed. At the same time, the northwestern part of the Oleśnica Plain became an outwash plain, fed by a newly formed valley system of the River Widawa and its confluents, draining the southern part of the Twardogóra Ridge and of the Syców Hills.

In the upper course of the Widawa River, there is only one flood-plain terrace, whereas in the area around Dziadowa Kłoda (Fig. 2) as many as two terraces can be distinguished: the lower, flood-plain terrace (t II) and the upper terrace (t I). The flood-plain terrace is approximately 3 m high and 200–300 m wide in the vicinity Dziadowa Kłoda. The upper terrace is up to 750 m wide and extends over the whole width (*ca*. 2.2. km) of the area between the Widawa River and its confluent, the Czarna Widawa. Below the debouchment of the Czarna Widawa River to that of the Widawa, the terrace disappears and the flood-plain bottom of the valley (t II) directly adjoins uplands composed of morainic and glaciofluvial deposits. The flood-plain terrace (t II) is covered by eolian sands and well developed dunes.

On the upper terrace (t I), composed of Vistulian deposits, the borehole examined is located at a height of 169.9 m a.s.l., 1 km east of the Widawa River, in which fluvial, lacustrine and swamp deposits were encountered at a depth of 0.0 to 18.4 m. A geomorphological analysis of the area under discussion allows a conjecture to be made that, during the Wartanian Glaciation, an ice-marginal valley must have approached the environs of Dziadowa Kłoda from the east.

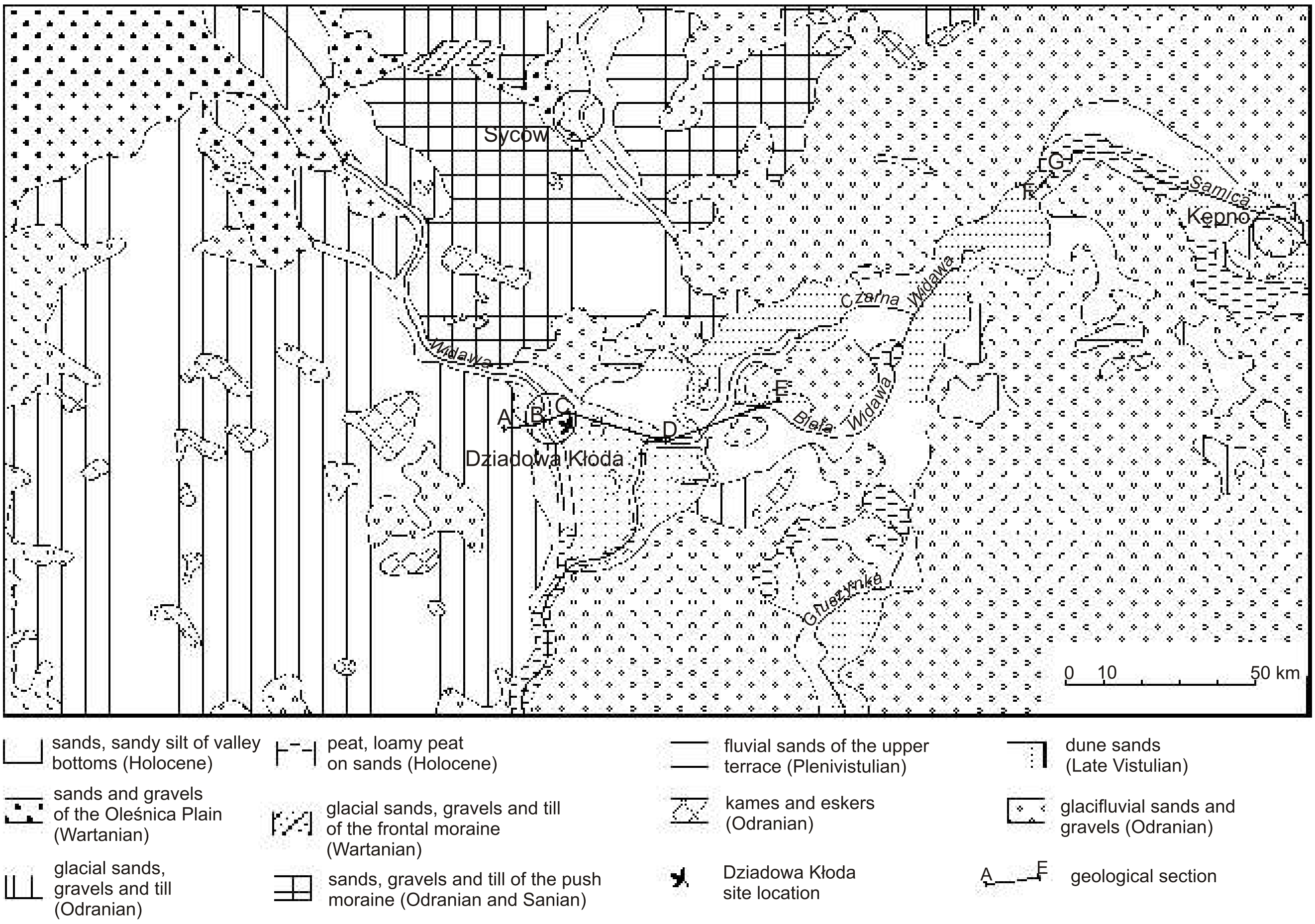

Fig. 2. Simplified geomorphological sketch derived from the *Detailed Geological Map of Poland* Syców sheet (Chmal, 1998*a*) and Kępno sheet (Winnicki, 2002)

This valley was subsequently used by the Czarna Widawa River, which nowadays is a set of catch-drain ditches (draining a chain of peat-bogs), rather than a true river. The lithological section reveals that the flow of proglacial-stream waters occurred at a level located *ca*. 9.6 m below the borehole level, as indicated by medium-grained sands and fine gravels that, underlie the Eemian deposits. In a parallel, second-order valley at Szklarka, *ca*. 2 km north of Dziadowa Kłoda, the base of contemporaneous deposits occurs at a similar depth, about 9 m (Chmal, 1998*b*; Kuszell, 1998). Therefore, it is assumed that after deglaciation of the Warta ice-sheet, the outlet of the Prosna drainage basin was directed northwards, replacing the earlier E–W trending drainage pattern. In the bottom of the ice-marginal valley, the Eemian Interglacial organic and, partly, mineral sediments were laid down in a river channel. Similar sedimentation continued during Vistulian, when, however, mineral deposits prevailed. In the nearby Ostrzeszów Hills, the process of slope-wash and creeping waste formation in a periglacial environment was described by Rotnicki (1966). During the cold phases of the Plenivistulian, due to intensified periglacial denudation of slopes of the Twardogóra Hills, the Widawa River accumulated medium-grained sands near Dziadowa Kłoda, which resulted in the development of a 3 m high terrace there. Geomorphologically, the upper surface of that terrace corresponds to that of the alluvial fan of the Widawa River, dissected during the late Vistulian Glaciation. Intense erosion at that time was documented for the neighbouring Prosna valley by Kozarski and Rotnicki (1978). At the final stage of the Late Vistulian, dunes developed on the upper terrace. In the Holocene the bottom of the valley widened as the river meandered river, beds of sand, sandy mud and peat accumulating at this time.

Ca. 4 km north of the Dziadowa Kłoda site, glacitectonic structures affect Miocene clays, Pliocene sands and gravels and the south Polish glacial tills, as well as glacial to glaciofluvial sands and gravels that are intensely folded and thrust-faulted. The thickness of the Quaternary deposits in the area of the Dziadowa Kłoda is approx. 80 m (Fig. 3). Over the Oleśnica Lowland, where the tills and glacifluvial sands and gravels are horizontal, the base of the Quaternary deposits occurs, on average, at a depth of 60 m.

The Holocene flood-plain terraces at the valley bottoms (t II), are composed of muddy sands, silt peat and peat, up to 2–3 m thick. In valleys, characterized by episodic water flow, the lowest terraces are usually built of sandy-clayey material. Only the upper part of these terraces (up to 1.5 m depth) is of Holocene age; below these layers are Vistulian fine sands and silts of slope wash origin. They are underlain by Eemian Interglacial organic deposits, at a depth of about 6 m.

The Pleistocene upper terrace (t I) of the River Widawa near Dziadowa Kłoda is composed of Upper Vistulian medium-grained sands up to a depth of 2–3 m. Below that depth, to 9.5–12.0 m, there are Early Vistulian and Eemian sands, silts and peat, underlain by sands with fine-grained glaciofluvial gravels, probably formed during the Middle Poland Glaciation (Fig. 4). In the lower part of the Dziadowa Kłoda profile no deposits of glacial origin were found.

MATERIAL AND METHOD

The lithological succession of the deposits cored at Dziadowa Kłoda is as follows:

0.00–0.40 m. Medium sand with fine gravel, dark yellowish brown (10YR 4/2).
0.40–1.20 m. Medium sand, light bluish-gray (5B 7/1), with iron concretions in the form of spots 0.5–2.0 cm in diameter.
1.20–2.05 m. Medium sand, light bluish-gray (5B 7/1).
2.05–2.25 m. Sandy silt, olive-gray (5Y 3/2).
2.25–2.45 m. Sandy silt, olive-gray (5Y 3/2), with traces of sand.
2.45–2.65 m. Medium sand, light bluish-gray (5B 7/1).
2.65–3.00 m. Medium sands, olive-gray (5Y 3/2).
3.00–3.50 m. Loamy silt with laminated sand, olive-gray (5Y 3/2).
3.50–3.60 m. Medium sands, greenish-gray (5G 6/1), with organic matter.
3.60–4.10 m. Medium sands, light bluish-gray (5B 7/1).
4.10–4.40 m. Sandy silt, brownish-gray (5YR 4/1).
4.40–4.85 m. Loamy peat, strongly decomposed, brownish-black (5YR 2/1).
4.85–6.00 m. Loamy silt, brownish-black (5YR 2/1), with organic matter; at depth of about 5.30–5.45 m sandy silt.
6.00–7.00 m. Peat, strongly decomposed, brownish-black (5YR 2/1).
7.00–7.20 m. Loamy silt with laminae of organic matter and malacofauna, brownish-black (5YR 2/1).
7.20–8.50 m. Jointed clay, greenish-black (5GY 2/1).
8.50–10.80 m. Medium sands with fine gravels, greenish-gray (5G 6/1).
10.80–13.20 m. Medium sands, greenish-gray (5G 6/1); with of laminae of fine sand, light bluish-gray (5B 7/1).
13.20–13.70 m. Fine sands, light bluish-gray (5B 7/1)
13.70–18.40 m. Medium sands with fine gravels, light bluish-gray (5B 7/1).

45 samples were collected for pollen analysis at a depth of 2.05–5.95 m. Peat and organic silts were boiled in 10% KOH, whereas mineral samples were treated with hydrofluoric acid. Standard Erdtman's acetolysis was the final stage of sample preparation in the laboratory. Two pollen slides and about 700 to 1600 pollen grains were counted in each sample. The preservation of pollen and spores was generally good. The frequency of sporomorphs was highest in peat layers and organic silts. Only *in situ* pollen was found in the material analyzed.

The results of pollen analysis are shown on the pollen diagram (Fig. 5).

The diagram has been subdivided into five local pollen assemblage zones (L PAZ), and marked with the first letters of the locality name (D 7 and DK 1 to DK 4).

The main palaeogeographical phases and the boundaries of the Vistulian Glaciation were established in the profile (*cf.* Zagwijn, 1961; Mamakowa, 1986).

VEGETATION HISTORY AND BIOSTRATIGRAPHY

Five pollen zones were distinguished in the pollen diagram (Fig. 5): the first of these (D 7) represents the very end of the

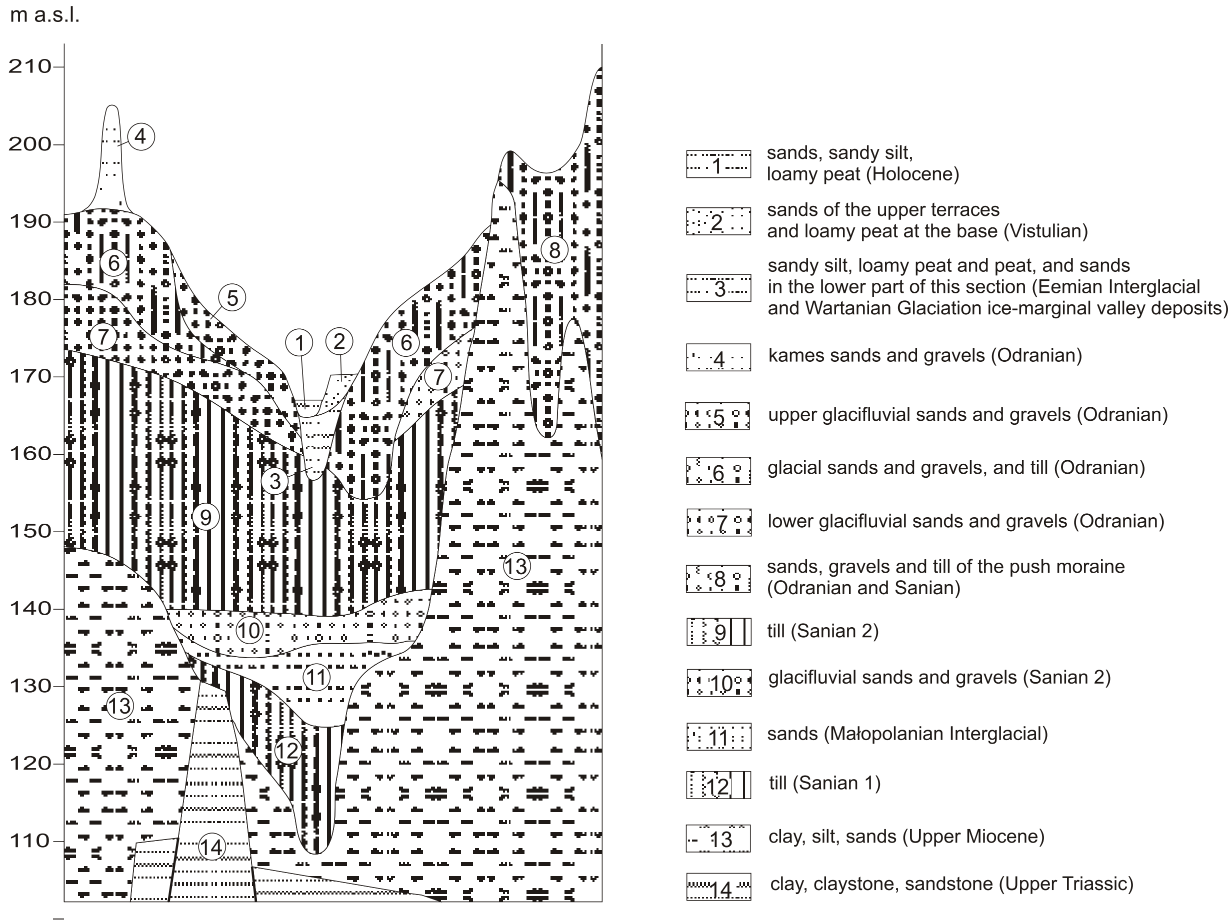

Fig. 3. Synthetic geological profile of the Dziadowa Kłoda area (within a radius of 5 km, simplified) (Chmal, 1998*a*; Winnicki, 2002)

Eemian Interglacial, the succeding four (DK 1–DK 4) can be ascribed to phases of the Early Vistulian.

LATE EEMIAN

Zone D 7 is dominated by closed boreal forest taxa with pine or pine and birch. *Picea* and *Alnus* were also important trees in the communities. Taxa from temperate phases of the interglacial — such as *Corylus*, *Quercus*, *Tilia* and *Carpinus* — which probably survived in southwestern Poland until the onset of the Vistulian were also present nearby. Relatively high values of *Picea* indicate the presence of this tree in the area investigated, as in other profiles in southwestern Poland (Mamakowa, 1986, 1989; Tobolski, 1991; Kuszell, 1997). The percentages of *Alnus* also suggest the presence of this tree in the terminal Eemian of the area studied. It likely dominated damper areas in the river valleys. Amounts of pollen of herbaceous plants are low in this zone as in other profiles in the Wielkopolska Lowland and in Lower Silesia (Kuszell, 1980; Mamakowa, 1989; Tobolski, 1991; Malkiewicz 2002). The lake was mainly inhabited by *Pediastrum* (Fig. 5). These patterns indicate a moderately cool climate of boreal type in the area studied.

EARLY VISTULIAN

In the transitional sample (41, at a depth 5.5 m) we can see signs of deterioration of climate: a decline of all thermophilous elements and a clear change in the type of accumulation into a more minerogenic one.

Zone DK 1, represented by two samples only, is characterized by more open conditions. It was the time of non-forest vegetation dominance. Birch is probably the only tree that colonized small patches of persistent forest. There is a general increase in herbaceous pollen of many types, derived either from grassland or from an increasingly open forest floor, visible particularly in sample 38 in which the NAP attain over 60%. *Artemisia*, Chenopodiaceae, *Rumex*, *Helianthemum*, Poaceae and Cyperaceae are the main pollen types and they were probably derived from xerothermic grass communities. Shrub communities with *Betula nana*, *Juniperus* and *Salix* began to develop in swampy areas. The small quantity of pollen as well as the small number of species indicate a scanty flora in the lacustrine basin. The higher frequency of pollen of *Myriophyllum* in this zone suggests the lake was 3–5 m deep (Podbielkowski and Tomaszewicz, 1996). The lower proportion of *Pediastrum* algae indicates water flow and a rise of lake level (Tołpa,1961). The change observed in zone DK 1 must here been related to

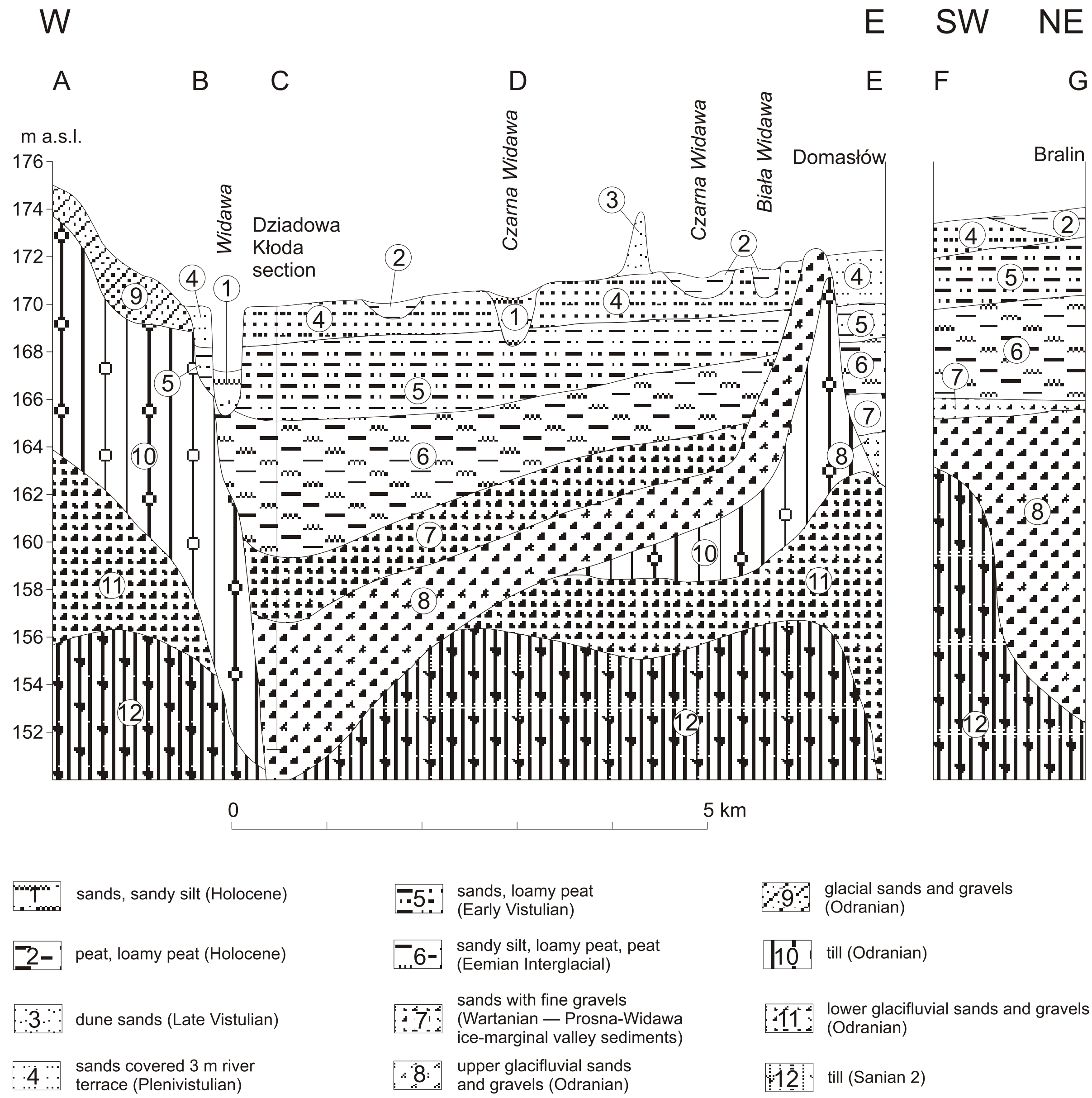

Fig. 4. Geological cross-sections through Widawa valley at Dziadowa Kłoda and along western part of the Prosna-Widawa ice-marginal valley (Chmal, 1988*a*; Winnicki, 2002)

cooling and continental conditions. The decreased contribution of *Sphagnum* further suggests a climatic deterioration (Mamakowa, 1989).

At the beginning of zone DK 2 *Betula* was undoubtedly the most important tree in the communities around the lake. The older part of this zone reflects the spreading and predominance of birch forests. In those communities, *Pinus* occurred, as well as *Larix* while *Picea* was also present locally during the Early Vistulian. The small but persistent values of *Betula nana* and *Juniperus* and the more numerous occurrence of *Artemisia* and Chenopodiaceae indicate an important role of shrub and herb communities in the older part of the zone. The survival of steppe-like communities, with a fairly diverse composition until the end of this zone suggests that the climate was still continental. The pollen of *Betula nana* seem to point to better climatic conditions and may serve as an argument for the cessation of continental influence in this zone (Tobolski, 1986). Presumably, the mean temperature of the warmest month in the older part of zone DK 2 was not lower than about 10° C and the presence of *Pinus* may even suggest temperatures reaching up to 12° C (Granoszewski, 2003). The more abundant occurrence of algae of the genus *Pediastrum* seems to be related to shallowing of the lake, and possibly indicates its eutrophication (Tołpa, 1961; Mamakowa, 1989).

In the younger part of zone DK 2, a gradual improvement of climatic conditions took place and sedimentation of organic deposits (silt with organic matter and peat) began. The vegetation shows initially a high proportion of birch which, however, was progressively displaced by pine. The lower proportion of herb vegetation at this time indicates an increasing density of forest

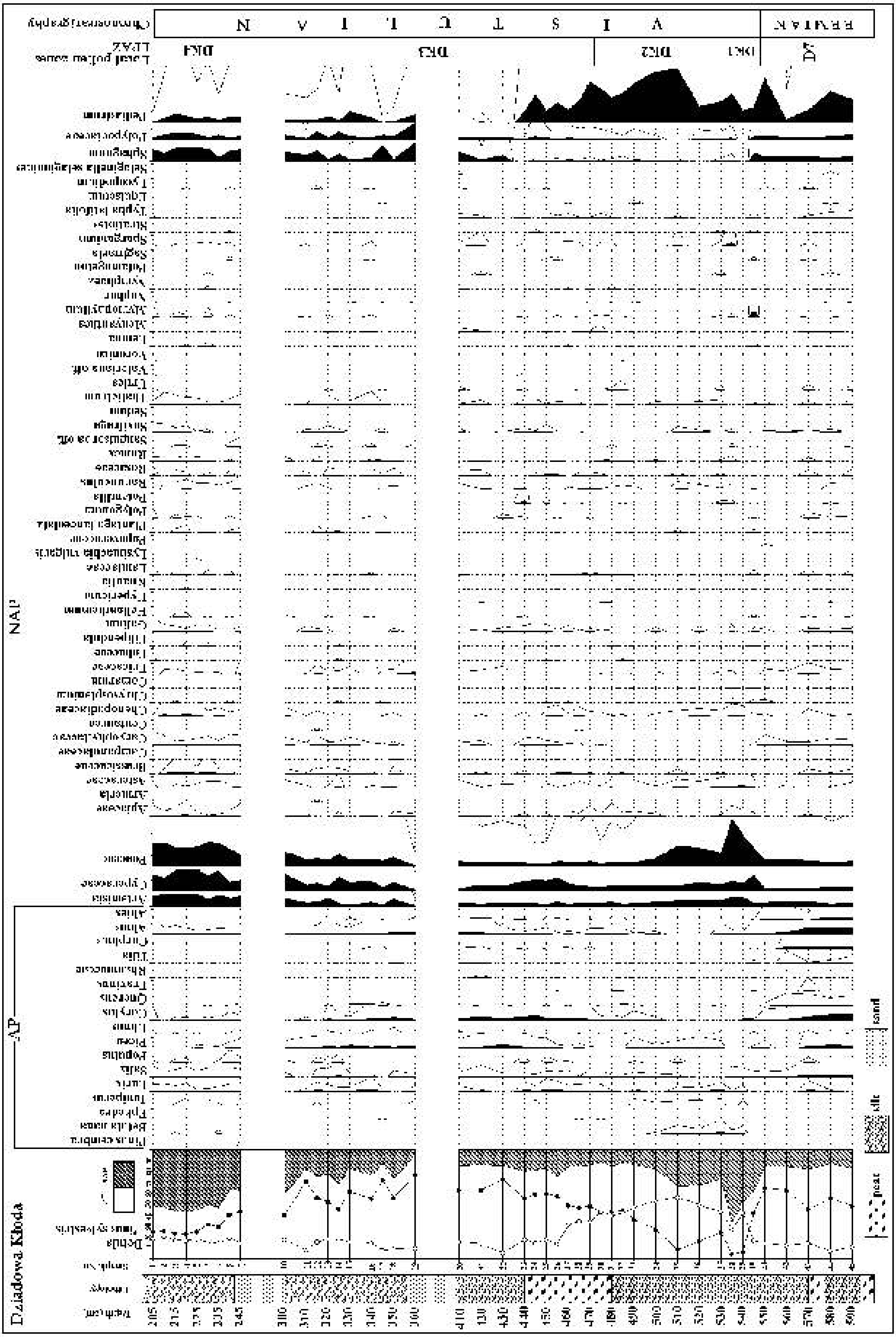

Fig. 5. Pollen diagram from Dziadowa Kłoda borehole section

communities. *Picea* and *Salix* appeared, and *Alnus* was present in wetter habitats in the region of Dziadowa Kłoda. A marked decrease in the proportion of *Sphagnum* spores suggests a change towards wetter conditions (Granoszewski, 2003).

At the end of zone DK 2, the lake shallowed rapidly as expressed by a change from lacustrine to swamp sedimentation. At that time the deposition of peat started (4.80–4.70 m), possibly due to slower water flow in the lake. The presence of *Typha latifolia*, *Sparganium* and *Myriophyllum* points to development of reed swamp and progressive lake shallowing. The vegetation in this phase indicates a boreal climate. *Typha latifolia* reflects an improvement of the climatic conditions, with a mean temperature in July of *ca*. 14°C (Tobolski, 1991; Aalbersberg and Litt, 1998).

At the beginning of zone DK 3, deposition of peat continued (4.70–4.40 m). At that time, birch forest was succeeded by pine forest with *Picea*, *Larix* and *Alnus*. Low percentages of herb pollen point to the considerable density of forests at Dziadowa Kłoda. The persistent occurrence of *Picea*, *Salix* and *Alnus* must here been associated with moist habitats. *Corylus*, *Ulmus*, *Quercus*, *Tilia* and *Abies* pollen appear sporadically. This may have come from lower parts of the Sudety Mountain and from their foreland, and their pollen may had been derived by long-distance transport. The continuous values of *Corylus* show that hazel perhaps occurred close to Dziadowa Kłoda until the end of the zone as at other sites in Poland (Kozarski *et al*., 1980; Mamakowa, 1986; Tobolski, 1986; Stankowski and Nita, 2004).

The participation of pollen of aquatic and swamp plants is low. The occurrence of *Typha latifolia*, *Sparganium* and *Myriophullum* may still be evidence of increased spreading of redswamp communities. Their development was undoubtedly influenced by the milder climatic conditions prevailiy then, and by a lowering of the water level and a rise in the organic matter content. The expansion of pine forest with a greater variety of trees indicates a boreal climate and the mean temperature of the warmest month was at least 14–15°C (Tobolski, 1991). At the end of this zone indications of an oceanic climate are more abundant Ericaceae pollen and *Sphagnum* spores (Tobolski, 1986).

In zone DK 3 heterogeneous deposits occur. The peat-bog was inundated and mineral sediments were washed in. The change from a peaty deposit to silt and sandy silt (4.40–4.10 m) reflects an increase in water level in the basin and a smaller participation of aquatic and swamp plants. The less frequent occurrence of *Pediastrum* is typical of a deep lake (Tołpa, 1961; Tomaszewicz, 1979; Granoszewski, 2003).

In the younger part of zone DK 3, the deposition of silt was interrupted by sandy sediments (4.10–3.60 m), devoid of pollen, possibly due to heavy rains and floods. Following this short interval, recorded at a depth of 3.60–3.00 m, a change in accumulation took place, from sands into more organogenic sediments (loamy silt). The pollen spectra from silt sediments adjoining the lower and upper sandy levels show a clear similarity. A change in accumulation and in plant compositions seem to reflect cooling of the final stage of this zone. This climatic feature during the younger part of the Early Vistulian Glaciation must have resulted in increased fluvial transport and intensified erosion and accumulation, as in other regions of Poland (Mamakowa and Środoń, 1977; Klatkowa, 1990).

At the boundary between zones DK 3 and DK 4, a change in deposition from sandy silt to sandy sediments (3.00–2.45 m) took place again. Above these deposits, sandy silt of zone DK 4 accumulated (2.45–2.05 m). Starting from the older part of this zone, symptoms of climatic continentality increase, as indicated by increasing frequencies of the steppe-like communities.

In zone DK 4 the forest communities were replaced by herbaceous plants. This is reflected this a successive rise in herbaceous pollen values with a high proportion of Cyperaceae, Poaceae and *Artemisia* and also of light-demanding herbs and shrubs. It may be supposed that these communities approximate to steppe meadows with stands of *Pinus sylvestris* and the presence of other trees and shrubs such as *Larix*, *Juniperus*, *Betula*, and *Salix*, characteristic of a cold climate. The tundra-like environment was also associated with *Betula nana*. It is notable that *Betula* indicates milder continental climate conditions in this zone (Tobolski 1986; Bińka and Nitychoruk, 1996).

The higher admixture of sand recorded in the younger part of this zone may have been caused by increased sand supply to the lake. Redeposition may have been responsible for the presence of rare pollen grains of thermophilous trees and shrubs in zone DK 4. The absence of forest in this zone indicates that the maximum mean temperature of the warmest month must have been little more than10°C, as olso inferred from coeval deposits in Eastern Germany (Aalbersberg and Litt, 1998). However the aquatic vegetation, with *Myriophyllum* present, suggests higher temperatures of about 13° to 15°C (Kolstrup, 1980).

CORRELATION OF LOCAL POLLEN ZONES FROM DZIADOWA KŁODA WITH REGIONAL POLLEN ZONES OF THE VISTULIAN GLACIATION

The local pollen assemblage zones (L PAZ), distinguished in the diagram from Dziadowa Kłoda, were correlated with the regional pollen zones (R PAZ). Table 1 presents the correlation of local zones (D 7, DK 1–DK 4) in the profile studied with the regional pollen assemblage zones of the Eemian Interglacial (E 7) and zones of the Early Vistulian (EV 1–EV 3), defined for Poland by Mamakowa (1986, 1989) and also with the divisions established for western Europe (Behre and Lade, 1986; Behre, 1989).

The upper limit of the Eemian Interglacial and Early Vistulian, determined by the youngest pollen spectrum of D 7 (L PAZ), corresponds with the criterion accepted in pollen stratigraphy for the transition of the Eemian into the Vistulian Glaciation (E 7), (Zagwijn, 1961; Mamakowa, 1989; Litt, 1994). Characteristic are the successive rise in the herb pollen values and the formation of more open communities with a fairly marked proportion of different heliophytes. At the decline of the Eemian Interglacial (E 7) moderately cool climatic conditions set in.

DK 1 L PAZ has been correlated with the Herning Stadial (EV 1). Climatic conditions became cooler in this stadial, as shown by the growth of herb and shrub communities and also by the hydrological changes in the lake basin studied. There were most probably only individual stands of birch in the area around Dziadowa Kłoda. In middle and southern Poland an open landscape with minor groups of trees and a mosaic of various communities (from wet shrub tundra similar to subalpine meadows and steppe — like communities; Mamakowa,1986) then predominated.

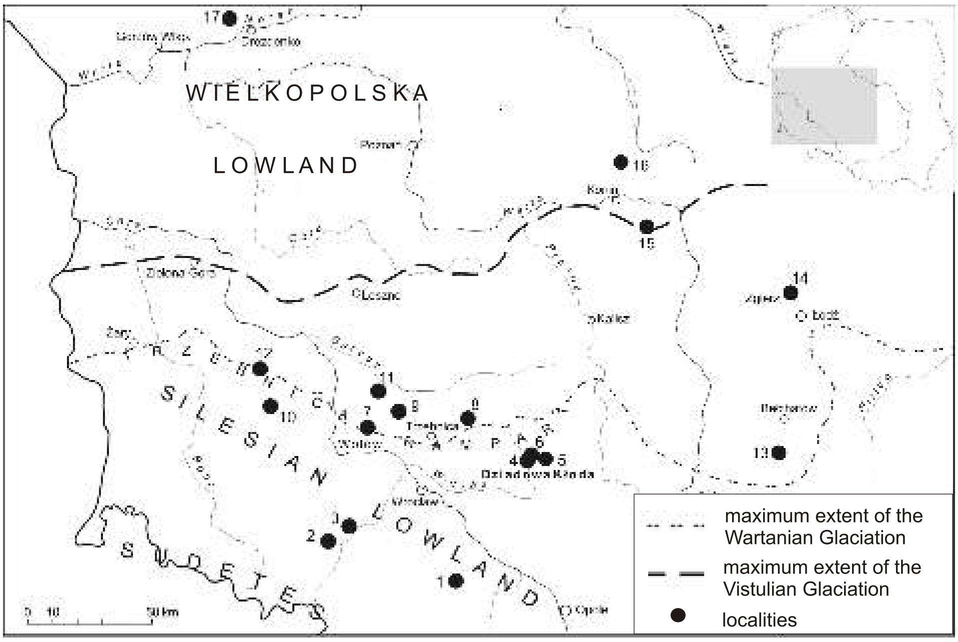

Fig. 6. Localities of the Eemian Interglacial, Eemian with Early Vistulian and Brörup Interstadial

Localities discussed in the paper: 1 — Jutrzyna (Kuszell, 1998), 2 — Jaworzyna Śląska (Dyjor and Kuszell, 1978; Kuszell, 1980), 3 — Imbramowice (Mamakowa, 1989), 4 — Dziadowa Kłoda (Kuszel, 1998), 5 — Domasłów (Rotnicki and Tobolski, 1965), 6 — Szklarka (Kuszell, 1998), 7 — Wołów (Kuszell, 1980), 8 — Kubryk (Kuszell, 1997), 9 — Raki (Dyjor and Kuszell, 1975; Kuszell, 1980), 10 — Szklary Dolne (Borówko-Dłużakowa, 1973), 11 — Lubiel (Krzyszkowski *et al*., 1994), 12 — Zofiówka (Kuszell, 1997), 13 — Kuców (Balwierz, 2003), 14 — Zgierz-Rudunki (Jastrzębska-Mamełka, 1985), 15 — Władysławów (Tobolski, 1991), 16 — Mikorzyn (Stankowski and Nita, 2004), 17 — Stare Kurowo k/Drezdenka (Kozarski *et al*., 1980)

Zones DK 2 and DK 3 represent an interstadial oscillation correlated with the Brörup Interstadial (EV 2). In the older part of this interval, dwarf birch and subsequently birch forest expanded, whereas in the younger part an expansion of pine forest occurred, with an admixture of *Picea* and *Alnus*, and maybe also *Corylus*. The vegetation of this period is indicative of boreal climate at Dziadowa Kłoda. During the Brörup Interstadial the mean temperature of the warmest month was between 15–16°C in Eastern Germany and Poland (Aalbersberg and Litt, 1998). In Horoszki Duże (Eastern Poland) the minimum July temperature must therefore have been at least 12 to 13°C, and maybe even 15°C (Granoszewski, 2003).

Zone DK 4 corresponds with the Rederstall Stadial (EV 3). In this period herbaceous communities dominated the area in the vicinity of Dziadowa Kłoda. These were probably plant communities including Poaceae, *Artemisia* and Chenopodiaceae of steppe-sward type (Tobolski, 1991). The expansion of open communities and the decreasing importance of forest points to a distinct deterioration in climate and an increase in continentality.

The age of the Early Vistulian has been confirmed by means of pollen analysis only in a few instances in southwestern Poland. Currently, the flora of the Eemian Interglacial in the Silesian Lowland is known from 12 localities (Fig. 6). Among them, a few that are valuable for extending our knowledge are profiles that provide a continuous record of the vegetational history of the Eemian and of the older part of the Vistulian. An Early Vistulian age of palaeolakes is confirmed at: Imbramowice (Mamakowa, 1989), Wołów and Raki near Żmigród (Dyjor and Kuszell, 1975; Kuszell, 1980), Zofiówka (Kuszell, 1997), and at Dziadowa Kłoda. From the Imbramowice and Zofiówka profiles the first oscillation of the Early Vistulian has been recorded. In the profile from Raki near

Table 1

Correlation of local pollen zones from Dziadowa Kłoda with regional pollen zones of the Eemian Interglacial and Early Vistulian

Local pollen zones (L PAZ) Dziadowa Kłoda	Regional pollen zones (R PAZ) Mamakowa 1989	Plant cover	Correlation	
–	EV 4	birch-pine forest	Odderade Interstadial	Early Vistulian
DK 4	EV 3	steppe with shrubs	Rederstall Stadial	
DK 3	EV 2	pine-forest	Brörup Interstadial	
DK 2		birch-pine forest		
DK 1	EV 1	steppe with shrubs	Herning Stadial	
D 7	E 7	pine forest	Eemian Interglacial	

Żmigród a few samples representing a 4 m-long section with high contents of pollen of herbaceous plants may be ascribed largely to the Early Vistulian.

In the Wołów I-72 profile a thicker succession representing a cool section, with a high proportion of *Pinus* and *Betula*, was ascertained (Kuszell, 1980). In the declining part of interglacial at the Early Vistulian, two cold oscillation can be distinguished, separated by an interstadial warming. This has been correlated with Amersfoort Interstadial. Mamakowa (1989) held a different opinion. In her opinion this profile belongs to the Eemian Interglacial: the whole sequence may possible be connected with E 7 (R PAZ) of the Eemian Interglacial and the very beginning of the first Vistulian stadial.

The profile from Dziadowa Kłoda is the first locality on the Silesian Lowland that reveals the first warm oscillation of the Early Vistulian Glaciation, developed in an uninterrupted profile that also includes the Eemian Interglacial. The pollen spectra from other localities reflect parts of the Early Vistulian Glaciation, in which diagnostic zones for the Brörup Interstadial are not recorded.

Localities of the Eemian Interglacial also with deposits of the Early Vistulian, located close to Dziadowa Kłoda (Fig. 6) in the Wielkopolska Lowland occur at Władysławów (Tobolski, 1986, 1991), Szklarka (Kuszell, 1998), Lechitów and Grudzielec (Malkiewicz, 2002), and Mikorzyn (Stankowski and Nita, 2004). Complete Eemian and Brörup Interstadial successions in this region are from Władysławów and Mikorzyn. The Early Vistulian in the Lechitów profile is represented by one sample, whereas at Grudzielec only the initial part of EV 1 is present. According to the Malkiewicz (2002) entire top section of the pollen diagram from Grudzielec records vegetation developed under cool climatic conditions of the Early Vistulian and this interval has not been referred to regional pollen zones. The profile from Szklarka containing the Eemian Interglacial and a thicker succession of Early Vistulian deposits are described based on the analysis of scattered samples only (Kuszell, 1998).

The diagram from Dziadowa Kłoda shows a distinct similarity with diagrams of the Brörup Interstadial from neighbouring regions of Poland. The succession in these profiles is characterized by a dominance of dwarf birch forest and subsequently of pine forest with spruce, larch, alder and perhaps hazel. This pattern of vegetation development can be found not only in distant regions of Poland but also in western Europe (Menke and Tynni, 1984; Behre and Lade, 1986; Behre, 1989; Litt, 1994).

In the vegetation succession from Dziadowa Kłoda no climatic oscillation was found between a birch zone (DK 2) and a pine zone (DK 3). As in the diagram from Dziadowa Kłoda, at Stary Kurów near Drezdenko (Kozarski *et al*., 1980) and at Władysławów (Tobolski, 1991), no cool climatic oscillation within the Brörup Interstadial was recorded. In the profile studied there are no traces of cooling expressed by a rise in herbaceous plant values in the upper part of the birch section of the Brörup Interstadial. A cold oscillation was recorded only in some diagrams from Poland. This climatic oscillation is visible in pollen diagrams from the localities in Eastern and Central Poland (Jastrzębska-Mamełka, 1985; Balwierz, 2003; Granoszewski, 2003; Stankowski and Nita, 2004). The birch zone of the Brörup Interstadial from these profiles corresponds to the Amersfoort Interstadial of the type locality in Holland (Zagwijn, 1961), while the pine zone can be correlated to the Brörup Interstadial at its type locality in Denmark (Andersen, 1961; Behre and Lade, 1986; Behre, 1989).

CONCLUSIONS

Zones DK 1 and DK 4 at Dziadowa Kłoda belong to the Early Vistulian Glaciation, representing woodless periods — stadials, whereas zones DK 2 and DK 3 document an interstadial plant succession (Table 1). The development of vegetation communities during the Brörup Interstadial at Dziadowa Kłoda does not record a cooling event between the birch and pine phases. This may result from a milder climatic conditions in the older part of the Brörup Interstadial in this part of the country.

Among localities with deposits of the Eemian Interglacial and of the Vistulian Glaciation in Poland, only a few include a full vegetational succession of the Early Vistulian: five sites in Central Poland and two localities in eastern regions.

Up to the present, in the Silesian Lowland no profile with a complete or almost complete flora of the Early Vistulian has been recorded. Until now, in that region of Poland the vegetation succession of the Brörup Interstadial has remained unknown. Dziadowa Kłoda is the first locality with lake and swamp deposits that provide a record of three climatic shifts above the Eemian, with a transition from moderately cool (E 7) to cool and continental climate (EV 1), subsequently to milder climatic conditions (EV 2), and again to a cool climate (EV 3). The different climatic conditions in the pollen zones find a distinct reflection in the vegetation composition. This indicates a transition from subarctic landscape of park tundra to forest communities of boreal climate, and then again to tundra vegetation. The presence of thermophilous trees and shrubs in the profile analysed may be due to redeposition during the cool climate, but it may be also that some of these persisted in southwestern Poland until the younger part of the Early Vistulian.

In the profile at Dziadowa Kłoda rapid changes of sedimention took place in the lake. Changes to minerogenic deposits are observed at the boundaries between the Eemian Interglacial and the Vistulian, in the younger part of the Brőrup Interstadial and also in the Rederstall stadial.

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