THE HISTORY OF VEGETATION OF THE EEMIAN INTERGLACIAL IN THE GREAT POLISH LOWLAND

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ABSTRACT

The subject of this paper is the history of vegetation in the Eemian Interglacial in southern Great Poland determined in the course of palaeobotanical research. Pollen analysis was conducted for lacustrine deposits from two localities (Grudzielec near Kalisz and Lechitów near Góra). The obtained pollen diagrams show diagnostic features of the Eemian. The succession of vegetation in both studied localities is characterised by three distinctive phases: protocretaceous with dominant pine-birch and birch-pine forest and communities of mixed pine-oak and oak forest, mesocosmic with predominant hazel and well developed hornbeam-lime forest, and a telocretaceous one with widespread fir-spruce and pine forest. Moreover, the vegetation succession in top sections of the studied profiles was recognised as typical of the Early Vistulian. The presence of taxa with higher climatic requirements enabled the assessment of palaeoclimatic conditions in the Eemian climatic optimum of southern Great Poland. The development of vegetation in the Eemian Interglacial corresponds with the changes recorded in the nearby localities of Great Polish Lowland and other regions of Poland, as well as those of neighbouring countries. Some minor differences between the studied profiles result from different geographical location of the localities and various genesis of sedimentation basins.

KEY WORDS: pollen analysis, Eemian Interglacial, vegetation history, palaeoclimate, Great Polish Lowland.

INTRODUCTION

As a result of drilling for the Detailed Geological Map of Poland in the scale of 1:50 000 by the State Geological Enterprise Proxima S.A. from Wrocław and Geological Enterprise from Warsaw (works in Łódź), in 1994 new localities of biogenic deposits were discovered near Góra (Lechitów) and Kalisz (Grudzielec).

The palynological expertise, preliminary results of the pollen analysis from Lechitów published by the author, as well as the assessment of the age of Lechitów sediments (Malkiewicz 1998) had not given a complete stratigraphic and floristic picture of the studied sediments. Likewise, the palynological analysis of lacustrine sediments from Grudzielec was fragmentary and comprised only 7 samples (Kuszel and Sadowska 1994). Hence, these preliminary results encouraged the author to start the detailed palynological analysis of the mentioned deposits. This study aimed to help filling the gap in our knowledge on the palaeogeography and palaeoecology of the Eemian Interglacial in the Great Polish Lowland.

Morphology of the Great Polish Lowland

The Great Polish Lowland is one of the most extensive natural geographical regions of Poland. It is situated in the western part of the Polish Lowland, and comprises areas between the Warta–Noteć Valley in the north and the Trzebnica Hills in the south. Its western border is demarcated by the valleys of the Odra and Nysa Łużycka Rivers, the north-eastern border by the Vistula River Valley, and the south-eastern one by the margins of the Łódź Upland (Krygowski 1961) (Fig. 1).

The morphology of the Great Polish Lowland is associated with the processes of the Middle Polish and Vistulian Glaciations. Two separate macroregions are distinguished within the area (Kondracki 1994). The northern part of the Great Polish Lowland, with early glacial sculpture associated with the Vistulian Glaciation, is called Great Polish Lakeland. The southern part, of the Great Polish Lowland, is characterised by an old glacial sculpture resulting from the Middle Polish Glaciation. The boundary between the two regions goes along the line Zielona Góra, Leszno, Poznań.

Despite numerous, long-lasting studies of the Quaternary deposits of Great Polish Lowland (Krygowski 1961; Kozarski 1981; Stankowski and Krzyszowski 1991 and others), the stratigraphic documentation of this area is still unsatisfactory. Among relatively well studied and palaeobotanically documented sediments there are deposits of the terminal warm section of the Pleistocene – the Eemian Interglacial. A total of 160 sites of the Eemian have been de-
scribed so far in Poland. The 30 localities of the Eemian floras are situated within the Great Polish Lowland (Fig. 1, Table 1). The floras of middle and northern Great Poland have been relatively well studied (Środoń 1956; Janczyk-Kopikowa 1965, 1972; Noryśkiewicz 1978, 1999; Winter 1994; KuszeI 1997; Tobolski 1991; Stankowski et al. 1999), whereas the data from its southern part are scarce. Only a profile from Kalisz (Tolpa 1952) has a complete palaeobotanical documentation. Two other sites: Zębców (Borówek-Dłużakowa 1978) and the near Domaslów (Rotticki and Tobolski 1965) have been described in the form of an expert’s profile from Raki near Zmigród (KuszeI 1980) represents only an older part of the interglacial. The sites presented in this paper are situated in the southern Great Polish Lowland. The results extend the current knowledge on the history of vegetation of the Eemian Interglacial in this part of Great Poland.

Position of the studied localities

Lechitów is situated ca. 20 km west of Rawicz, in the Głogów Proglacial Stream Valley (Fig. 1). The geology and geomorphology of this locality has been included in a sheet description by Wąsosz (Chachaj 1994). The subject of pollen analysis was a section of sediments between 28.00 and 49.75 m a.s.l. The detailed description of the lithological profile has been presented by Malkiewicz (1998).

Grudzielec is situated ca. 27 km west of Kalisz, on Kalisz Plateau, and ca. 80 km north-east of Lechitów along a straight line (Fig. 1). The studied profile comprises 3.45 m thick peats and loams at the depth of 2.55-6.00 m a.s.l.

The sediments were deposited in a small hollow situated in a deep subglacial channel.

MATERIAL AND METHODS

In the course of this study a total of 249 samples were subjected to palynological examination (186 samples from Lechitów and 63 from Grudzielec). The samples of a volume of ca. 10 cm³ were collected from borehole cores at every 10 (Lechitów) or 5 cm (Grudzielec).

Methods of preparation of the material for the pollen analysis depended on the type of sediments in the particular samples. Peat deposits were boiled in KOH, while samples with considerable content of mineral material, such as loams and silty deposits, were treated with concentrated hydrofluoric acid for 24 hours. Subsequently the material was macerated using the Erdtman’s acetylation (1952). Sporomorphs were identified and counted using a light microscope. For identification of pollen grains and spores papers by Erdtman et al. (1961), Moore et al. (1991), Reille (1992, 1995) were used, as well as the data from The Palynological Card Index of Polish Plants (Sadowska et al. 1994-2001). Pollen spectra were counted on at least two slides; only in samples with low concentration of sporomorphs 3-4 slides were examined. In all analysed samples sporomorphs were well preserved and did not contain any damaged or unidentifiable grains. Likewise, the samples did not contain Tertiary taxa. On average a total of 600-1000 sporomorphs was found in each sample.

The results of pollen analysis are presented in two percentage pollen diagrams (Figs 2, 3). The calculations for the Lechitów profile are based on the total of 100% (AP + NAP), which includes trees, shrubs and dwarf shrubs (AP), herbaceous plants (NAP) together with aquatic, marshy and spore plants. As in material from Grudzielec Polyto-
TABLE 1. List of sites of the Eemian Interglacial floras in the Great Polish Lowland.

<table>
<thead>
<tr>
<th>Locality</th>
<th>Author and year</th>
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<tbody>
<tr>
<td>Szeląg</td>
<td>Srodon 1956</td>
</tr>
<tr>
<td>Rusinów</td>
<td>Stark et al. 1932</td>
</tr>
<tr>
<td>Winiary</td>
<td>Golab and Urbania 1938; pollen analysis Bąkowski</td>
</tr>
<tr>
<td>Kalisz</td>
<td>Tolpa 1952</td>
</tr>
<tr>
<td>Kaliska</td>
<td>Janczyk-Kopikowa 1965</td>
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<tr>
<td>Domasławów</td>
<td>Rotnicki, Tobolski 1965</td>
</tr>
<tr>
<td>Łaski Lubuskie</td>
<td>Janczyk-Kopikowa 1972; Skompski 1975</td>
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<tr>
<td>Przyłużne</td>
<td>Klatkowa 1990</td>
</tr>
<tr>
<td>Raszewy near Zerków</td>
<td>Rotnicki 1975; pollen analysis Tobolski</td>
</tr>
<tr>
<td>Raki near Zmigród</td>
<td>Kuszell 1980</td>
</tr>
<tr>
<td>Swarzędz</td>
<td>Kunkel and Tobolski 1977</td>
</tr>
<tr>
<td>Żębów</td>
<td>Bordowska-Dłużakowa 1978</td>
</tr>
<tr>
<td>Nakiło on the River Notec</td>
<td>Noryskiewicz 1978</td>
</tr>
<tr>
<td>Joźwin/84/76</td>
<td>Tobolski 1991</td>
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<tr>
<td>Kaziernik</td>
<td>Tobolski 1991</td>
</tr>
<tr>
<td>Włodawistów</td>
<td>Tobolski 1980, 1991</td>
</tr>
<tr>
<td>Raczków</td>
<td>Załoba and Jastrzębska-Manelka 1990b</td>
</tr>
<tr>
<td>Zagajew</td>
<td>Załoba and Jastrzębska-Manelka 1990b</td>
</tr>
<tr>
<td>Mątew</td>
<td>Klatkowa 1980</td>
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<tr>
<td>Ursów</td>
<td>Klatkowa and Załoba 1991</td>
</tr>
<tr>
<td>Emitnów</td>
<td>Klatkowa and Załoba 1991</td>
</tr>
<tr>
<td>Zbytki 1, 2</td>
<td>Kuszel 1997</td>
</tr>
<tr>
<td>Kopaszewko</td>
<td>Kuszel 1997</td>
</tr>
<tr>
<td>Rogaczewko</td>
<td>Kuszel 1997</td>
</tr>
<tr>
<td>Ziółkowo</td>
<td>Winter 1994</td>
</tr>
<tr>
<td>Bogdanowko</td>
<td>Winter 1994</td>
</tr>
<tr>
<td>Krzyżówki</td>
<td>Noryskiewicz 1999</td>
</tr>
<tr>
<td>Mikorzyn</td>
<td>Sińskowski, Bluszcz and Nita 1999</td>
</tr>
<tr>
<td>Lechitów</td>
<td>Malikiewicz 1998, this paper</td>
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<tr>
<td>Grudzielec</td>
<td>This paper</td>
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</table>

(† palynological expertise)

diacae were over-represented; water, swamp and spore plants were excluded from the basic sum. The ratio of trees, shrubs and dwarf shrubs to herbaceous plants is shown in pollen diagrams. Subsequently, curves for all the identified taxa are drawn. In each diagram local pollen assemblage zones are distinguished. They are numbered from the bottom towards the top of the profile, and marked with the first letter of the locality name.

Deposits from Grudzielec were additionally subjected to macroscopic examination. The material of the volume 50-100 cm³ was derived from the same core, from which samples for pollen analysis were collected. Sediments of the particular samples were kept in water for 48 hours, then boiled with 10% KOH. Afterwards, the material was washed using double 0.5 mm and 0.1 mm mesh sieves. Both fractions of the material were searched under binocular microscope for plant macroremains, which were subsequently identified using keys and detailed carpological papers (Nilsson and Hjelmqvist 1967 and others).

RESULTS AND DISCUSSION

History of terrestrial vegetation

Although both localities differ in terms of sediment thickness (small at Grudzielec, and over 21 m at Lechitów), both diagrams represent the complete pollen succession of the Eemian, including protocretaceous, mesocratic and telocratic phases (Iversen 1958; Dzięciołowski and Tobolski 1982; Birks 1986). It is characterised by the development of forest communities, starting from boreal pine and pine-birch forest, through deciduous forest, where trees and shrubs spread in the following order: Ulmus, Quercus-Fraxinus, Cori, Alnus, Tilia, Taxus and Carpinus (Fig. 4).

The characteristic trait of the section of thermophilous deciduous forest are also the very high values of Cori, reaching 65.0% at Grudzielec and 63.0% at Lechitów. The younger part of the interglacial is characterised by coniferous forest with Picea and Abies, followed by re-spread of Pinus in its final part. These features enable the correlation between the studied interglacial sediments and the Eemian deposits from the classic locality at the River Eem near Amersfoort in Holland (Zagwijn 1961) and numerous Polish sites of this age (Niklewski 1968; Noryskiewicz 1978; Kuszel 1980, 1997; Krupinski 1988; Mamakowa 1988, 1989; Tobolski 1991).

In the obtained diagrams, local pollen assemblage zones are distinguished. The diagram from Lechitów comprises 16 local zones, whereas the Grudzielec diagram – 9 zones. The local zones have been correlated with the regional pollen zones of the Eemian Interglacial distinguished for Poland (Mamakowa 1989) and for the Konin region (Tobolski 1991) (Table 2).

The protocretaceous phase is characterised by pollen spectra from regional pollen zones E1 and E2 (Mamakowa 1989).

![Fig. 4. Average percentages of trees in the pollen zones of Eemian Interglacial in investigated localities.](image-url)
TABLE 2. Table of correlation of local pollen assemblage zones at investigated localities with biostratigraphy elaborated for Poland and the Konin Region.

<table>
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<tbody>
<tr>
<td>V1</td>
<td>Gramineae–Artemisia–Betula nana</td>
<td>Artemisia–NAP</td>
<td>G-9 NAP–Betula–Pinus</td>
<td>L-16 NAP–Pinus</td>
</tr>
<tr>
<td>V2</td>
<td>Pinus</td>
<td>Pinus</td>
<td>G-8 Pinus–NAP</td>
<td>L-15 Pinus</td>
</tr>
<tr>
<td>V3</td>
<td>Picea–Abies–Alnus</td>
<td>Picea–Abies</td>
<td>G-6 Picea–Abies–Alnus</td>
<td>L-13 Abies–Picea–Carpinus II</td>
</tr>
<tr>
<td>V4</td>
<td>Carpinus–Corylus–Alnus</td>
<td>Carpinus</td>
<td>G-5 Carpinus–Corylus–Alnus</td>
<td>L-10 Carpinus–Corylus–Alnus II</td>
</tr>
<tr>
<td>V5</td>
<td>Corylus–Quercus–Tilia</td>
<td>Corylus</td>
<td>G-4 Corylus–Quercus–Tilia</td>
<td>L-5 Corylus–Tilia–Carpinus</td>
</tr>
<tr>
<td>V6</td>
<td>Quercus–Fraxinus–Ulmus</td>
<td>Quercus</td>
<td>G-3 Quercus–Fraxinus–Ulmus</td>
<td>L-3 Quercus–Fraxinus–Ulmus</td>
</tr>
<tr>
<td>V8</td>
<td>Pinus–Betula</td>
<td>Betula</td>
<td>G-1 Pinus–Betula</td>
<td>L-1 Pinus–Betula</td>
</tr>
</tbody>
</table>

In southern Great Poland its initial part (zone E1) is characterised by the dominance of pine-birch and birch-pine forest (Figs 2, 3). These communities were dispersed in various habitats, from poor sandy and outwash areas to richer habitats in river valleys. The continuous curves of Salix and Alnus may suggest the development of willow thickets associated with the close vicinity of a river or a stream, similar to the present-day Salici-Populetum (R. Tx. 1931) Meijer Drees 1936, or Salicetum pentandra-cinerae (Almq. 1929) Pass. 1961. The relatively low percentage of Alnus may indicate that the alder probably did not form forest communities, such as alder carrs or riverside carrs. It most likely occurred only as an admixture in willow communities.

Pollen grains of Salix, Hippophae rhamnoides and spores of Selaginella selaginoides, found in the oldest part of this zone in Grudzielec, confirm the occurrence of shrub communities. The proportion of herbaceous plants, which does not exceed 10.6% in this zone, indicates the small importance of herb communities, which occurred mainly in open and sunlit areas with low density of forest stands.

In the younger part of the protocoric phase (zone E2) the pine invaded all accessible habitats. On poor sandy soils it formed pine forest with the admixture of birch, which probably resembled the present-day fresh pine forest Vaccinio myrtilli-Pinetum Kobendza 1930. On richer soils, pine forest appeared with bigger proportion of oak and birch, and the admixture of hazel in the undergrowth. Also communities of humid and fertile habitats and riparian forest were of greater importance. The maximum share of Ulmus and the higher curve of Fraxinus indicate the development of communities resembling elm-ash riverside carrs, probably in type of the present-day Fraxino-Ulmetum campestris association (R. Tx. Ap. Lohm. 1952) Oberd. 1955. The dominant trees of these forest were elm and ash, with some admixture of alder and spruce. The continuous presence of Salix pollen, and the occurrence of Alnus suggest that in wetter habitats, in the vicinity of a lake or in river valleys, willow and alder thickets were possibly present.

The zone E2 is characterised by the absolute though low-percentage curve of elm (Mamakowa 1989). In the Grudzielec profile the culmination of Ulmus (4.7%) occurs at the end of the protocoric phase, whereas at Lechitów maximum values of Ulmus (6.3%) appear at the beginning of mesocoric phase, before the highest values of oak. The absolute culmination of Ulmus in the Eemian Interglacial could occur much later, even in the middle section of this interglacial (zone E5). This phenomenon was recorded in several profiles of Great Poland, such as Zbytki 2 (Kuszell 1997), Kalisz (Topola 1952) and Jóźwia 84 (Tobolski 1991), as well as in other parts of Poland (Krupiński 1992; Klatkowa 1990; Klatkowa and Balwiern 1990; Klatkowa and Winter 1990 and others). A maximum proportion of the elm in forest communities of various sections of the mesocoric phase has been observed also in some profiles from Germany (Seifert 1990; Litt 1994). In both the present profiles the content of elm was the highest, as compared with the values found in other localities of Great Poland, where they range from 1.8 to 4.0% (Topola 1952; Mamakowa 1989) (Fig. 5). The proportion of Ulmus at Grudzielec is similar to that found at Kalisz (4.0%) (Topola 1952) and Imbramowice (Mamakowa 1989). The Lechitów profile is the first Eemian locality in the Great Polish Lowland, where the elm values exceed 6.0%. High percentage values of Ulmus at Imbramowice, compared with other sites of Poland, have been explained by the south-western migration of this taxon (Mamakowa 1989). Such a large share of the elm at Lechitów, as well as the substantial proportions of this tree at Jaworzyna Śląska (3.0%) and Wolów (3.2%) (Kuszell 1980) support the probable direction of migration of the elm from the south-west.

At the beginning of the mesocoric phase (zone E3) the pine-birch forest was still quite important in forest commu-
Fig. 5. Maximum pollen values of Ulmus in Eemian sites in the Great Polish Lowland.

nities. This is especially clear in the diagram from Lechitów. At Grudzielec we observe a rapid development of mixed and oak forest (Fig. 3). Pine-oak forest of the Eemian resembled most likely the modern forest communities of the alliance Quercetum, or communities similar to the present-day Quercetum Kozłowska 1925 em. Matuszkiewicz et Polakowska 1955, Apart from main components of this forest, birch and lime were also relatively frequent. Hazel was the dominant species of the shrub-layer. Forest communities of that time were comparatively light with Ericaceae and Poaceae spreading in their herb layer. Maximum shares of Quercus suggest the development of forest similar to the present-day light oak forest Potentillo-Quercetum (Libbert 1933) Knapp 1942, that occurred only in south-exposed areas. They mostly overlapped southern slopes of moraine hills. Such communities were dominated by oak, with some admixture of pine. In this forest, like in mixed coniferous forest, tree crowns were faintly dense, which allowed the development of the undergrowth and herb layer. The dominant of the shrub layer was hazel, sometimes accompanied by birch. The southern exposure of oak forest communities enabled the development of more thermophilous plants, such as Ilex aquifolium, Hedera helix or Viscum album.

The maximum percentage values of Fraxinus and Ulmus suggest that communities of riverside forest played still an important role in the vegetation cover of the studied area. An increase in the ash values could be associated not only with the development of communities resembling the present-day elm-ash riverside carrs, but also the association Carici remotae-Fraxinetum Koch 1926, whose present localities are reported from the Great Polish Lowland. Besides, Ulmus and Fraxinus, Alnus, Salix and Hedera could occur in this forest. In moist habitats, near rivers and around the studied sedimentation basins alder thickets with some admixture of the spruce developed.

An absolute culmination of Corylus in the middle part of the mesocratic phase (zone E4) indicates that in this time this shrub was most widespread. The period is characterised by an intensive development of thermophilous deciduous forest. Undoubtedly, a part of hazel pollen comes from the undergrowth of oak-pine forest. As oak forest are light, and their leaves develop in late spring, the hazel had favourable conditions for flowering and dispersal in these communities. However, such high contents of hazel pollen in the climatic optimum of the Eemian were probably associated with the development of distinct hazel thickets or even forest. According to Mamakowa (1989) they could resemble the present-day association Peucedano-Corcyretum Kozł. 1925 em. Medw.-Korn. 1952, though at present is of a relic character due to excessive damage by man. The contemporary hazel communities could have ideal conditions for their development in dry and warm habitats facing south. The important components of these communities, besides the dominating hazel, were probably oak, elm, hornbeam and pine. They most likely had the form of shrubs (like in modern warm thickets of Peucedano-Corcyretum).

Apart from communities that had already existed, the formation of new multispecies deciduous forest and mixed forest developed. Predominating were hornbeam-lime and oak-hornbeam communities characterized by a large share of Tilia and the increasing role of Carpinus. A new species, Taxus baccata, appeared in forest communities. Due to its wide ecological tolerance it occurred probably as a shrub, displacing the hazel from the undergrowth, or a tree. However, Taxus did not play an important role in forest communities of southern Great Poland. The shares of Taxus in the studied profiles are low and range 0.0-0.1%. Similarly its values were found in other localities of the Great Polish Lowland (Srodoń 1956; Borówko-Dłużakow 1978; Tobolski 1991; Klatkowa and Zaloba 1991; Kuszell 1997), Taxus was especially abundant at sites of Lower Silesia: Imbramowice – 11.8% (Mamakowa 1989), Jaworzyna Śląska 1.1%, Wola – 4.6%, and Zofiówka – 7.8% (Kuszell 1980, 1997). High percentage values of the yew in south-western Poland correspond with the content of this species in West-European localities, e.g. in Lower Lusatia (Erd 1973) and north-western Germany (Behre 1962, 1970; Menke 1967; Müller 1974). Yew came most probably to south-western Poland from the west of Europe. Climatic conditions at this new site turned out to be the most favourable for its development (Mamakowa 1989).

The profiles from Grudzielec and Lechitów represent the so-called „late lime” sites, included to variant A by Mamakowa (1989). They are characterised by a maximum share of lime coming after the culmination of Corylus and before the highest values of Carpinus (Figs 2, 3). Maximum values of lime in both the studied profiles are similar, and amount to 12.5% and 13.5% at Grudzielec and Lechitów, respectively. Even values as high as 5-8% indicate the large importance of the species in communities of deciduous forest (Mamakowa 1989). The examination of the Eemian pollen diagrams from Great Poland (Tolpa 1952; Tobolski 1991; Kuszell 1997) and south-western Poland (Kuszell 1997; Mamakowa 1989) reveals the average values of lime ranging 5-10%. The distribution of profiles, in which features of „early lime” and „late lime” could be distinguished, suggests the geographical variability of this zone (Mamakowa 1989). Characteristics of „late lime” occur most often in diagrams from localities of western and south-western Po-
land. Similar features are typical of most German profiles (Erd 1973; Seifert 1990; Litt 1994). In the undergrowth of various types of communities of deciduous forest, Hedera, Viscum and Hex were also common.

An increase in the share of Alnus and the permanent occurrence of Ulmus and Fraxinus may indicate that besides the existing Riverside elm-ash carrs in the type of Fraxino-Ulmetum campestris (R. Tx. Ap. Lohm. 1952) Oberd. 1955 and Riverside ash carrs similar to Carici remotae-Fraxinetum Koch 1926, ash-alder forest appeared. It might resemble the present-day Circaeo-Alnetum Oberd. 1953. Most likely these communities invaded the habitats of Riverside elm-ash carrs, or shallow and drying out peripheral parts of the lake. On the other hand, peatbog and swampy areas overgrown by alder carr communities, may be similar to the present association Carici elongatae-Alnetum (Koch 1926) R. Tx. et Bodeaux 1955. The dominants of these communities were alder, with the admixture of ash, birch and spruce.

The terminal section of the mesoscenic phase (zone E5) represents a strong expansion of Carpinus betulus, a tree species of a wide edaphic tolerance. This resulted in the reconstruction of the existing forest communities. Mixed oak forest, sometimes with a considerable admixture of Carpinus, still occurred, though their distribution was probably strongly limited. Likewise, the hazel communities were still present. However, the most widespread type of community became dry-ground forest. The present-day hornbeam forest belong to climax communities occurring in a wide range of habitats, on different soil types (in terms of fertility), and in various water conditions. They form numerous subcommunities, variants and facies. Also in the Eemian Interglacial dry-ground forest could develop, the physiometry of which depended on habitat conditions. On relatively dry, mesotrophic substrata dry-ground forest occurred, of which the main components, apart from the hornbeam, were probably oak and pine. Lime and maple could appear in smaller quantities. On fresh eutrophic soils communities of typical dry-ground forest were present. In this forest, hornbeam was accompanied by numerous deciduous trees, such as oak, lime, maple, elm, ash. On moist, fertile soils another type of dry-ground forest developed, similar to riverside carrs, with alder, elm and ash as dominants. The main component of the undergrowth of all the mentioned dry-ground types of forest was hazel, though Hedera, Viscum, Hex, Buxus, Vitis and Taxus were also present. In phytosociological aspect, dry-ground forest of the Eemian of Great Poland was probably similar to Galio-Carpinetum Oberd. 1957. and Tilio-Carpinetum Traczky 1962, the two associations of dry-ground forest occurring nowadays in Poland. Although the distribution of the latter community is at present limited to areas east of the Lower Vistula River and the line Konin–Krotoszyn–Wrocław, it could have been much more widespread in Eemian in the eastern part of Great Poland. The Eemian dry-ground forest near Lechitów were probably similar to Galio-Carpinetum, the present-day type of dry-ground forest occurring in western Poland. This hypothesis may be supported by the presence of pollen grains of Galium (Rubiaceae). Galium sylvaticum is one of the characteristic species of the association Galio-Carpinetum.

A new component of dry-ground stands in the studied area was the beech. At Grudzielec only one pollen grain of Fagus sylvaticus was found, while at Lechitów as many as 23. In central and northern Europe, Fagus sylvaticus is considered a characteristic tree of the Holocene, whereas in the interglacial sediments it is rare, and only single pollen grains of this species are found (Srodoń 1984, 1985). In Poland Fagus has been reported from 26 sites of the Eemian Interglacial (Kuszell 1997). Considering the whole number of Polish localities of the Eemian (around 160), it seems that this genus did not play an important role in forest communities of that time. Frenzel (1968) suggested that Fagus could survive the South and Middle Polish glaciations in mountain refuges of the Near East. The distance between the refuges of this tree and the Central European mountain ranges was too long, and the time of the Masovian and Eemian Interglacials too short for tree to became widespread in the forest of the Eemian Europe.

The communities of wetlands and swampy habitats were still of great importance, especially in the vicinity of Lechitów. Apart from the riverside elm-ash and ash carrs also alder carrs appeared, probably in type of the modern Carici elongatae-Alnetum (Koch 1926) R. Tx. et Bodeaux 1955.

The telocenic phase (zones E6 and E7) is characterised by a large share of conifers. Apart from still existing communities of dry-ground forest, communities of coniferous forest became more widespread. At the beginning the dominant species was Abies alba accompanied by pine and spruce. In poorer habitats most probably forest with Picea was more common. However, the subsequent expansion of the pine led to its dominance in coniferous stands, and to the disappearance of taxa of higher thermal requirements. Maximum values of Abies alba at Lechitów amount to 17.5%, and correspond with the numbers found in localities closer to the Sudety Mountains, such as Jaworzyna Śląska, Wólów and Kubryk (Kuszell 1980, 1997). The fir values at Grudzielec reach 30%, like in Kalisz (Tokpa 1952) and Ustków (Klatkowa and Zakoba 1991). The present geographical distribution of Abies alba is restricted to submontane areas and uplands of southern Poland, with the centre in the Carpathians. Forest with the fir may be encountered also in the South Polish Upland and Roztocze. In the Eemian Interglacial communities with fir forest may have been much more widespread, as compared to their present distribution.

The high values of Alnus suggest that swampy alder forest of Carici elongatae-Alnetum type, with a relatively large share of the spruce, was still important. The continuous presence of Ulmus and Fraxinus may be associated with the riverside elm-ash and ash carrs. However, they occurred only in the vicinity of Lechitów, probably in the Barycz Valley.

In the terminal section of the Eemian Interglacial (zone E7), in areas surrounding the studied localities, pine forest with some admixture of birch started to dominate. At Grudzielec it comprised also the larch.

The expansion of pine forest and the recession of other forest communities was accompanied by the occurrence of various communities of open habitats. The presence of Salix, Juniperus and Hippophaë indicates the formation of shrub communities, whereas the Chenopodiaceae, Artemisia, Rumex acetosella, Helianthemum and Caryophyllaceae – the development of steppe-like and grassland communities. Profiles representing a complete pollen succession of the Eemian Interglacial only rarely include sediments of the
Early Vistulian. Within Great Polish Lowland deposits of the Early Vistulian were recorded only at 9 sites: Kalisz (Tolpa 1952); Kaliska (Janczyk-Kopikowa 1965); Rak (Kuszell 1980); Jóźwin 84 and 76, Kazimierz and Władysław (Tobolski 1991); Ustków (Klatkowa and Ząbka 1991) and Mikorzyn (Stankowski et al. 1999). Profiles from Grudzielec and Lechitów make this list longer.

The Early Vistulian in the Lechitów profile is represented by only one sample, which indicates the decrease in Pinus content (below 40%), and the increase in NAP values to over 50%. From among other trees, only Betula and Pinus survived, although their shares are very low. Such a pollen picture suggests that pine forest was very sparse or occurred only in patches, with sporadically occurring birch trees. The presence of Salix and Hippophae in this sample could indicate the formation of shrub communities (Fig. 2). A rise in values of Poaceae and Artemisia, as well as the presence of Caryophyllaceae, Chenopodiaceae and Helianthemum could suggest the increasing role of xeromorphic communities.

In the Grudzielec profile sedimentary strata of the Early Vistulian were found at the depth of 3.12-2.55 m. They represent an open birch forest or its patches with admixture of pine and larch. The importance of larch increases in the upper part of the zone. Open areas were covered by the vegetation of shrub tundra with willows and probably shrub birches, juniper, sea buckthorn and grasses (Fig. 3). It seems that xeromorphic communities were also widespread, especially in the younger part of this period, as evidenced by the increasing share of Artemisia. Like at Lechitów, Pinus, that survived the Eemian Interglacial, is present in small quantities. An increasing importance of wet, peaty meadows may be concluded from the high values of Cyperaceae, continuous though low values of Sphagnum and the presence of Ranunculus, Ranunculus acetosella type, Polygonum bistorta, Saxifraga officinalis or Plantago media type. The frequent occurrence of Apiaceae, Asteraceae, Chenopodiaceae and Brassicaceae probably indicates the important role of nitrophilous communities.

From among the mentioned sites of the Early Vistulian, found in the area of Great Polish Lowland, only Kalisz II (Tolpa 1952; Mamakowa 1989) and Ustków (Klatkowa and Złobka 1991) have the vegetation picture similar to that found at Grudzielec. Other sites, like the neighbouring Władysławów, Kazimierz and Jóźwin, represent the steppe vegetation with conspicuous continental features (Tobolski 1991). In the profile from Mikorzyn (Stankowski et al. 1999) another important component of plant communities was the pine. A different composition of vegetation communities has also the first pollen zone of the Early Vistulian from Zgierz-Rudunki (Jastrzębska-Mamelka 1985). It represents shrub tundra with an important share of juniper, dwarf birch and shrub willows. The vegetation picture of the Early Vistulian found in the Lechitów profile can be compared only with Imbramowice (Mamakowa 1989), where open pine forest, or its patches, with rare tree birches and the larch occurred.

Characteristics of aquatic and marsh vegetation

To obtain a more detailed information on the vegetation and palaeoecological conditions of the studied water bodies, the analysis of plant macroremains was applied (Table 3).

Since the beginning of the interglacial (zone E1) till the middle part of the mesocratic phase (zone E4) quiet and warm lakes of a considerable depth occurred at the studied sites. In their deeper parts several plant taxa, such as Myriophyllum spicatum, Nuphar, Potamogeton, Ceratophyllum demersum and Najas sp., occurred, whereas in shallower places Nymphea alba was present. The margins of lakes were covered by communities of rushes with Sparganium, Typha latifolia, Poaceae, Carex rostrata, Carex fusca and other sedges.

The spore-pollen picture of the upper part of the mesocratic (zone E5) and telocratic phases (zones E6 and E7) indicates that the sedimentation basin became shallow and partly overgrown. At Grudzielec large quantities of Polygonaceae s.l. (over 70%), numerous fragments of brown mosses of the genus Drepanoclados and fruits of Carex sp. were found. Dryopteris filix-mas could be a representative of ferns. The genus, like Drepanoclados, occurs in abundance on marshy and peat bog lake margins, and its thick floating mats impede the development of water vegetation. The scarcity of other aquatic plants in the studied samples indicates that the Grudzielec lake basin was of similar edaphic conditions. Apart from single pollen grains of Myriophyllum spicatum and Potamogeton, which could survive in small water bodies, no other taxa of aquatic plants have been found. The abundance of ferns made also difficult the development of reed swamps and other lakeside communities. At Lechitów the process of shallowing of the lake was much slower. The presence of aquatic plants, such as Myriophyllum, Nuphar, Potamogeton or Sagittaria indicates a considerable depth of the basin, at least in its central part. However, marginal parts of the basin were overgrowing intensely, as suggested by the presence of Stratiotes aloides, Nymphaea alba, Sparganium, Typha latifolia, numerous sedges and ferns.

### TABLE 3. Plant macroremains in the Grudzielec profile (F - fruit, L - leaf).

<table>
<thead>
<tr>
<th>Number of samples</th>
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<td><strong>Depth (m)</strong></td>
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<td>5.85-5.75</td>
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<td>5.60-5.50</td>
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<td>4.85-4.65</td>
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<td>4.60-4.30</td>
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<td>4.25-4.00</td>
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<td>3.95-3.90</td>
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<td>3.65-3.45</td>
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**Notes:**
- **F** - fruit
- **L** - leaf

The presented palaeobotanical material not only provides the information on plant cover, but also enables the estima-
tion of palaeoclimatic changes. Alterations of climatic conditions have an overwhelming impact on physico-geographical conditions, and hence the direction and rate of changes in the plant cover and animal world.

Numerous earlier palaeobotanical papers on the Eemian indicated that its climate was stable and oscillated from a cool one in its early part, through warm in its climatic optimum, to become again boreal at the decline of the Inter- glacial (Frenzel 1968; Mamakowa 1989; Mojski 1993; Taylor et al. 1993; Litt et al. 1996; Kuszell 1997 and others). In recent years the climate of the Eemian has been a subject of vigorous debate, which produced numerous palaeoecological and palaeoecological papers discussing the instability of the climate of this late warm section of Pleistocene (Anklín et al. 1993; Field et al. 1994; Thouveny et al. 1994; Seidenkrantz et al. 1995; Kukla, Mc Manus et al. 1997; Cheddadi et al. 1998).

The obtained palaeobotanical material enables to draw conclusions on the climate of the Eemian Interglacial in the southern part of the Great Polish Lowland.

The early section of the protocaric phase is characterised by a cool and dry climate. The evidence for this comes from the high values of herbaceous plants, and the occurrence of xeromorphic communities with heliophytes. The subsequent improvement of climate was associated with a gradual expansion of deciduous trees. The presence of fruits of Ceratophyllum demersum and Najas sp. in the Grudzięcic profile, and the occurrence of Fraxinus in forest communities of both the profiles indicate warm summers and mild winters (Tobolski 1991). The appearance of Typha latifolia enables the assessment of an average temperature of July at about 14-15°C for this part of the Eemian, while the presence of Selaginella selaginoides indicates that the mean temperature of July did not exceed 17°C (Tobolski 1991; Kuszell 1997).

In the mesocaric phase the climate was markedly warmer. This is suggested by the appearance of taxa with higher thermal requirements, such as: Viscum, Hedera helix, Ilex aquifolium, Buxus, Vitis vinifera and Taxus baccata. The presence of flowering Hedera is associated with fairly high summer temperatures and the temperature of the coldest month, not dropping below -1.5°C (Iversen 1944). The appearance of the Viscum, whose northern limit of continuous range is associated with the July isotherm of 17°C, suggests also that summer temperatures were high (Iversen 1944; Tobolski 1991). The presence of Ilex aquifolium and Taxus baccata indicates that winters could be even warmer than suggested by the presence of Hedera helix (Iversen 1944). The fruiting Ilex aquifolium in Rusinowo and Bramowice allow to assume the average temperatures of January around 0°C in south-western Poland. Nowadays it does not occur in Polish natural forest communities. Its present distribution is associated with western, central and southern parts of Europe and the north of Africa. Taxus baccata develops best in a climate characterised by a high air humidity, mild winters and warm (not hot) summers. It is most abundant in central and western Europe, north Africa, Asia Minor and the Caucasus. In Poland the yew reaches its western distribution limit. Taxus baccata grows in single island-like localities, predominantly in the west and north of the country. It may be concluded that the climate of the Eemian in its climatic optimum was warm and oceanic. The average temperature of July could be 20-22°C, and in January exceeded 0°C. Also the rapid it expansion of the hazel indicates that the climate gradually became more oceanic (Zagwijn 1961; Mamakowa 1989; Tobolski 1991; Litt 1994; Kuszell 1997). In the last section of the mesocaric phase the climate was still warm and humid, similar to that in the interglacial optimum. The recorded Hedera and Viscum suggest high temperatures of the warmest and the coldest month (Iversen 1944). The appearance of Ligustrum and Jasminum in forest communities provides evidence for mild winters, as both genera are frost-sensitive. The continuous occurrence of Taxus baccata signals good habitat conditions and more pronounced oceanic influence. At Lechitów additionally the pollen of Buxus was found. Buxus sempervirens is classified as an atlantic-mediterranean species. At present the best conditions for the species development are in western and southern Europe, north-western Africa and Asia Minor. The species has limited habitat requirements, though it is sensitive to frost and extremely drought-resistant. Buxus pollen is rarely found in the Eemian sediments; in Poland it has been reported from 15 localities of the Eemian (Noryśkiewicz 1978; Krupiński 1978, 1986, 1988; Kuszell 1980, 1997; Dąbrowski et al. 1987; Janczyk-Kopikowa 1991; Granošzewski 1993; Kru- piński and Morawski 1993; Malkiewicz 1998). The occurrence of Buxus and Ilex aquifolium in the Eemian Interglacial suggests that the climate of this period was warm, winters mild, and air humidity high.

The telocaric phase represents the Eemian section, when climate became cooler and moister. The spread of the fir and spruce in this time suggests the increased air humidity. According to Mamakowa (1989) the expansion of the spruce and fir reflects climatic conditions similar to those found at present in the lower sub-alpine forest zone. Only the survival of Hedera helix till the end of this period proves that mean temperatures of January did not fall below -4.0 to -5.0°C (Mamakowa 1989). The terminal part of the interglacial is characterised by a complete disappearance of trees and bushes with higher thermal requirements, the lack of indicator plants of a warm climate and widespread pine forest. All this allows to estimate the climate of this period of the Eemian as boreal.

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LITERATURE CITED


MAMAKOWA K. 1989. Late Middle Polish glaciation, Eemian and Early Wistulian vegetation at Imbramowice near Wroclaw and the pollen stratigraphy of this part of the Pleistocene in Poland. Acta Palaeobot. 29 (1): 11-176.


ROTNICKI K. 1975. Stratigraphic evidences of the survival of Riss gla citectonic structures and forms in the marginal zone of the maximum extent of the last glaciation. Questiones Geogra- phicae, 2: 113-137.

ROTNICKI K., TOBOLSKI K. 1965. Pseudo morfotyzi wielo bo wów z lodem szczelinowym i stanowisko tundry w peryglacialnym basenie sedymencylcznym ostatniego zlodowacenia w Kepnie. (Pseudomorphoses on the fissure ice polygons and the locality of tundra in the periglacial sedimentary basin of the last glacialation at Kepno (South Great Poland)). Bad. Fizjogr. nad Polską Zach. 15: 93-146 (in Polish with En- glish summary).


HISTORIA ROŚLINNOŚCI INTERGLACJALU EEMSKIEGO
NA OBSzarZE NIZINY WIELKOPOLSKIEJ

STRESZCZENIE

Tematem pracy jest historia roślinności w interglacjale eemskim w południowej Wielkopolsce przedstawiona na podstawie badań paleobotanicznych. Analizie pyłkowej poddano osady jeziorne z dwóch stanowisk: Gruzdzielec koło Kalisza i Lechitów koło Góry.

Uzyskane diagramy pyłkowe wykazują cechy diagnostyczne dla interglacjalu eemskiego. Sukcesja roślinności w badanych stanowiskach charakteryzuje się wyraźnie wykształconymi fazami: protokratyczną, w której panują lasy sosnowo-brzozowe i brzozowo-sosnowe oraz zbiorowiska lasów mieszańcowych sosnowo-dębowych i dębowych, mezokratyczną z dominującą leszczyną i dobrze wykształconymi lasami grabowo-lipowymi oraz telokratyczną, w której panują lasy jodłowo-świerkowe i sosnowe. Ponadto w stropowych odcinkach badanych profilów stwierdzono sukcesje roślinności typową dla początku wczesnego vistulianu. Występowanie taksjonów o wyższych wymaganiach klimatycznych pozwoliło ocenić warunki paleoklimatyczne południowej Wielkopolski.

Rozwój roślinności w interglacjale eemskim wykazuje podobieństwo do zmian roślinności, jakie obserwowano w sąsiednich stanowiskach z obszaru Niziny Wielkopolskiej, a także z innych rejonów Polski i krajów sąsiednich. W opracowanychprofilach zaobserwowano nieznaczne różnice, które wynikają z odmiennego położenia geograficznego stanowisk i innej genezy zbiorników sedimentacyjnych.

SŁOWA KLUCZOWE: analiza pyłkowa, interglacja eemskiego, historia roślinności, paleoklimat, Nizina Wielkopolska.