Acta Palaeobotanica 64(1), 1–19, 2024
https://doi.org/10.35535/acpa-2024-0001

e-ISSN 2082-0259
ISSN 0001-6594

A differentiated palynological record of the Eemian interglacial in two palaeolakes Niesadna and Parysów from the Garwolin Plain (Central Poland)

ALEKSANDRA BOBER[1*], IRENA AGNIESZKA PIDEK[1], MARCIN ŻARSKI[2] and PAULINA HAŁAS[1]

[1] Maria Curie-Skłodowska University, Institute of Earth and Environmental Sciences, Al. Kraśnicka 2d, 20-718 Lublin, Poland; e-mails: ab.aleksandrabober@gmail.com, ORCID: 0000-0002-8315-0877; irena.pidek@mail.umcs.pl, ORCID: 0000-0002-1979-4897; paulina.halas@mail.umcs.pl, ORCID: 0009-0001-0993-6660

[2] The Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warszawa, Poland; e-mail: mzar@pgi.gov.pl, ORCID: 0000-0002-0699-6561

Received 25 July 2023; accepted for publication 14 December 2023

ABSTRACT. Two neighbouring Eemian (MIS 5e) palaeolakes, discovered during works on reambulation of the Garwolin sheet of the Detailed Geological Map of Poland (scale 1: 50 000), revealed differences in the palynological record of the succession of the Eemian interglacial. In the profile of Parysów WH-125, a very pronounced hiatus in the transition from the mesocratic to the telocreatic period, i.e. from the hornbeam to the spruce-fir zone, is visible. In the pollen diagram of Niesadna, the maximum percentages reached by *Quercus*, *Corylus* and *Carpinus* are very low, although this is undoubtedly an Eemian succession. The reasons for this should be sought in the presence of several sedimentary gaps probably caused by the different geological and geomorphological conditions of the Niesadna palaeolake located on a slope as opposed to the Parysów palaeolake, which was formed by the melting of a block of dead ice in the process of deglaciation of the area during the late Saalian (MIS 6). An additional rationale for the hypothesis of extremely unfavourable conditions for undisturbed sedimentation in Niesadna palaeolake is its geological-geomorphological situation that caused admixtures of mineral material in the organic sediment, including sand intercalations, indicating that erosion was taking place. The two developed pollen successions were presented against other published data on the Eemian interglacial in the Garwolin Plain, with particular emphasis on the continuity of the Eemian succession. The palynological results showed that the Parysów WH-125 profile joins several other profiles lacking representation of the upper part of the hornbeam zone and sometimes also the lower part of the spruce-fir zone (e.g. Żabieniec, Jagodne). On the other hand, the presence of distinct sedimentary gaps in the oak, hazel, and hornbeam zone, as is the case in the Niesadna profile, has not been recorded in any of the profiles in the Garwolin Plain examined to date. The Eemian pollen succession in the studied Niesadna and Parysów palaeolakes is presented against the broader background of the course of this interglacial in the European Lowlands.

KEYWORDS: Central Poland, palynology, palaeolake, Garwolin Plain, Eemian interglacial

INTRODUCTION

The Eemian interglacial, correlated with Marine Isotope Stage 5e (MIS 5e) according to the stratigraphic scheme of Cohen and Gibbard (2019), has been discussed in numerous palynological studies from Poland, of which over 180 have produced isopollen maps for major plant taxa (Kupryjanowicz et al., 2018). Retreat of the ice sheet in the late Saalian (MIS 6) and

* Corresponding author

Publisher: W. Szafer Institute of Botany, Polish Academy of Sciences

glacial deposits shaped the landscape of Central Poland where an extended lake district developed (Bruj and Roman, 2007; Roman et al., 2021). In the Radom Plain Żarski et al. (2018) found Eemian sites that occur in two geomorphological positions: in small depressions on the glacial plateau and in small valleys in oxbow palaeolakes. Fossil lakes were formed from the melting of dead-ice blocks. The mentioned authors (Żarski et al., 2017) conclude that pollen data obtained from the palaeolake sediments document climate and vegetation changes characteristic of the late glacial period, the Eemian interglacial, and the beginning of the Weichselian (=Vistulian) Glaciation. In many sites, a record of a complete Eemian succession is present, whereas in others, it is fragmentary.

The Garwolin Plain has been, so far, very poorly recognized in terms of organogenic deposits of the last interglacial period. Multiproxy studies of lake sediments of the Eemian carried out in the Garwolin Plain area provided, in recent years, a lot of new data related to the presence of the fossil Eemian Lakeland in Central Poland. These palaeolakes were discovered during fieldwork on the Garwolin sheet of the Detailed Geological Map of Poland at a scale of 1:50 000 (Żarski, 2020). So far, profiles of different thicknesses of Eemian organogenic sediments have been documented, e.g. Kozłów (Pidek et al., 2021; Suchora et al., 2022), Struga (Zalat et al., 2021; Bober et al., 2023), Wola Starogrodzka PWS-1 and PWS-2 (Kupryjanowicz et al., 2023) reaching over 5 metres, as well as those where the thickness of Eemian sediments did not exceed 3.5 metres, e.g. Żabieniec (Pidek et al., 2022), Jagodne (Bober et al., 2021) and Wola Starogrodzka G-122 (Kupryjanowicz et al., 2021). The palynostratigraphy of all diagrams is adopted from the study according to Mamakowa (1989), which distinguishes Regional Pollen Assemblage Zones (R PAZs) from E1 to E7. In turn, it was refined based on the study of subzones by Kupryjanowicz and Granoszewski (2018). The temporal range of the record in the investigated palaeolakes includes the Eemian interglacial period and thus sometimes the end of the preceding glaciation (late Saalian) correlated with MIS 6 (Cohen and Gibbard, 2019). Examples are the palynological diagrams of Struga G-120 (Bober et al., 2023) and Wola Starogrodzka G-122 (Kupryjanowicz et al., 2021). In the case of profiles Żabieniec Ża-19 (Pidek et al., 2023) and Jagodne (Bober et al., 2021), a thicker series of early Vistulian peat layers was discovered above a series of Eemian sediments. Sedimentary gaps seem to be a distinct problem in the fossil lake record. They have been found in several Eemian profiles in the study area (Pidek et al., 2021; Bober et al., 2023; Kultys et al., 2023b). In particular, the hiatus is mostly present in the section covering the decline of the E5 R PAZ zone and the beginning of the E6 R PAZ zone. In the last interglacial profiles from north-eastern Poland Kupryjanowicz (2008) found several profiles with sedimentary gaps in the deposits covering the same time span. In one case, the Słup site in the Garwolin Plain, the record was found to be absent in the E3 R PAZ zone, after which the record continues again in the E4 R PAZ (Kultys et al., 2023b).

Questions regarding the continuity of the Eemian succession record and possible climatic oscillations within the last interglacial period have long attracted the interest of Quaternary researchers (Cheddadi et al., 1998; Shackleton et al., 2002; Velichko et al., 2005; Brauer et al., 2007; Brewer et al., 2008; Lauterbach et al., 2012). These problems are still unresolved (Govin et al., 2015), therefore each successive palynological diagram contributes to our knowledge of climate stability of the Eemian and thus allows us to understand natural climate variability in the interglacial, in which humans did not influence climatic phenomena. It is noteworthy that close to our study area there are Eemian palaeolakes with a complete record of pollen succession and those in which this record contains numerous sedimentary breaks. Examples of such contiguous interglacial lakes with different records are also found in the studied region (see Kozłów: Suchora et al., 2022 and Żabieniec: Kultys et al., 2023a; Pidek et al., 2022). Thus, the compilation of multiple profiles over a small area helps to distinguish which changes in the pollen diagram are related to local environmental conditions (e.g. substrate relief, hydrology of the area), and which are due to supra-regional climate change in Europe during the Eemian.

The present study brings data on two new profiles from the Garwolin Plain. These are the Niesadna G-267 and Parysów WH-125 profiles (Fig. 1). Our aim was to trace the completeness

Figure 1. Location of the Niesadna and Parysów sites in the Garwolin Plain (regional division according to Solon et al., 2018)

of these records in the light of the sedimentary gaps found in several profiles from the Garwolin Plain. Most of these gaps appear in the E5 R PAZ or at the transition from E5 to E6 R PAZ (e.g. Jagodne: Bober et al., 2021; Żabieniec: Kultys et al., 2023a, b; Pidek et al. 2022; Puznówka: Pidek et al., 2022) analogous to what Kupryjanowicz (2008) suggested in records from NE Poland. In addition, the nature of pollen spectra representing the late Saalian in the Garwolin Plain has been well recognized in recent years (Kupryjanowicz et al., 2021). The aforementioned work made it possible to distinguish stadial-interstadial fluctuations within the late Saalian section in the diagram from the Wola Starogrodzka site. Both the issues of sedimentary gaps and the record from the late Saalian will allow to shed new light on the problem of climate oscillations and environmental changes influenced by them.

The results are interpreted against the background of the Eemian succession in the neighbouring sites, to verify to what extent the pollen successions recorded in the sediments of the Niesadna and Parysów palaeolakes are complete and can join the well-recognized sites of the Eemian interglacial in the studied region.

STUDY AREA AND MATERIAL

The Niesadna (51°59′8.6″N, 21°35′56.7″E) and Parysów (51°58′51.3″N, 21°40′39.4″E) sites are located within the Garwolin Plain in Central Poland (Fig. 1). The genesis of both palaeolakes is probably related to the melting of a block of dead ice in the late Saalian glacial till. The first recognition of interglacial succession in the Niesadna profile is given by Kulikowska (2018) in a master's thesis. An in-depth palynological study was undertaken in 2019 by Aleksandra Bober.

Material for palynological research was collected from the Niesadna G-267 and Parysów WH-125 cores. Profile Niesadna G-267 was taken with a GEOPROBE core drill, drilling

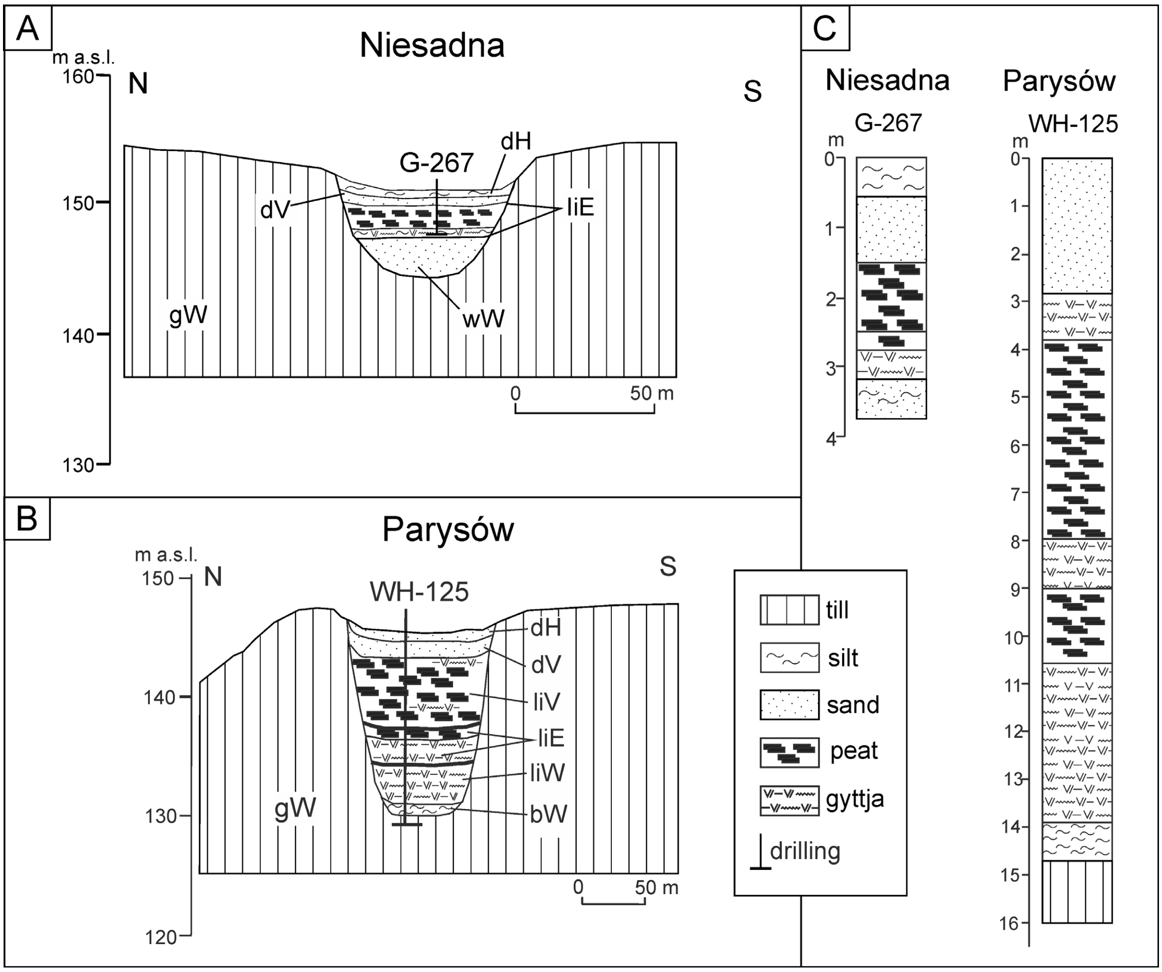

Figure 2. **A**. Geological cross-section of the Niesadna G-267; **B**. Geological cross-section of the Parysów WH-125; **C**. Lithostratigraphic profile of the Niesadna G-267 core and of the Parysów WH-125 core

Table 1. Description of sediment of the G-267 core

Depth [m]	Sediment characteristics
0.00–0.52	silt, dark grey
0.52–1.44	sand, fine-grained, beige
1.44–2.50	peat, dark brown
2.50–3.12	gyttja, dark
3.12–3.15	sand, fine-grained
3.15–3.55	silt, light grey
3.55–3.60	sand, medium-grained

Table 2. Description of sediment of the WH-125 core

Depth [m]	Sediment characteristics
0.00–0.40	sand, various grained
0.40–2.83	sand, fine grained
2.83–3.80	peaty gyttja
3.80–4.50	peat, sedge/moss low decomposed
4.50–7.60	peaty gyttja, well decomposed
7.60–7.80	peat low decomposed
7.80–7.96	peaty shale
7.96–9.00	gyttja
9.00–10.75	peat low decomposed
10.75–11.30	peaty gyttja
11.30–13.90	gyttja
13.90–14.70	silt
14.70–16.00	till

was done to a depth of 3.60 m, and a series of Eemian sediments were recognised between 1.46 and 2.78 m (Fig. 2A and 2C; Table 1). Profile Parysów WH-125 was taken with a WH drilling rig method, drilling was done to a depth of 12.70 m, a series of Eemian sediments were recognised between 9.65 and 12.70 m (Fig. 2B and 2C; Table 2).

METHODS

To identify the pollen succession, we used 40 samples from the series for palynological analysis from the Niesadna core and 28 samples from the Parysów WH-125 core. Laboratory processing of the samples for pollen analysis followed the standard procedure (Berglund and Ralska-Jasiewiczowa, 1986). After decalcification in 10% HCl and boiling in 3.5% KOH, the mineral fraction was removed using 40% hydrofluoric acid (for 24 hours). The samples were then macerated based on Erdtman's acetolysis.

Pollen spectra were calculated from at least two slides until 700–1000 pollen grains had been counted. The total pollen sum, including trees and shrubs (AP) and dwarf shrubs and herbaceous terrestrial plants

(NAP) was taken as 100%. The percentage shares of pollen of aquatic plants, spores, redeposited sporomorphs and colonies of algae of the genera *Pediastrum*, *Botryococcus* and *Tetraëdron* were calculated according to the basic sum (AP + NAP = 100%), including calculated taxon to this sum. The results of palynological analyses are shown in tables. Percentages of AP, NAP, and taxa excluded from the total pollen sum were calculated in the POLPAL software (Nalepka and Walanus, 2003) and pollen diagrams were plotted using TiliaIT software (Grimm, 2015). Each palynological diagram has been divided into Local Pollen Assemblage Zones (L PAZs) according to criteria by West (1970) and Janczyk-Kopikowa (1991). L PAZs have been assigned to Regional Pollen Assemblage Zones (R PAZs), according to Mamakowa (1989).

RESULTS AND VEGETATION HISTORY

Vegetat ion development at the Niesadna site (G-267 profile) was reconstructed based on the pollen diagram (Fig. 3) and characteristics of pollen spectra (Table 3).

Vegetation development at the Parysów site (WH-125 profile) was reconstructed based on the pollen diagram (Fig. 4) and characteristics of pollen spectra (Table 4).

As can be seen from the presented palynological diagrams (Figs 3, 4) the palaeoenvironment at Niesadna reaches with its palaeobotanical record to the Late Saalian / Eemian transition, while in the Parysów profile WH-125 the record starts from the E2 R PAZ of the Eemian interglacial.

The interpretation of the vegetation history will be presented on the basis of palynostratigraphic zones and the characteristic guiding features of the Eemian succession, which Mamakowa (1989) included: the order of encroachment of *Pinus-Betula-Ulmus*, *Quercus*, *Corylus-Alnus*, *Tilia*, *Carpinus* trees and the very high proportion of *Corylus* in the climatic optimum of more than 50%.

LATE SAALIAN/EARLY EEMIAN TRANSITION

In the G-267 1 L PAZ zone in the Niesadna profile a significant percentage of NAP was recorded (above 12%), dominated mainly by *Artemisia*, Poaceae and Cyperaceae indicating the open nature of the plant communities, among which steppe-tundra communities with perennials, grasses and representatives of Amaranthaceae were present. The significant proportion of *Pinus sylvestris* t. pollen recorded in the palynological diagram may in this situation suggest that part of the pine pollen originates from long-distance transport, which is very efficient in open late glacial landscapes (Granoszewski, 2003; Fiłoc et al., 2018; Nita et al., 2018). The presence of *Myriophyllum spicatum*, *Ceratophyllum* hairs, as well as trichosclereids and pollen of Nymphaeaceae may suggest the existence of an eutrophic water body with stagnant or low-flow water, not very deep, on the surface of which a community with *Nuphar* and other representatives of this family developed during the summer. The rushes surrounding the lake included *Phragmites australis* t. and *Typha latifolia*. The presence of *Filipendula* (? *F. ulmaria*), *Comarum palustre* and large proportions of Cyperaceae and Musci indicate a boggy area in the lake vicinity.

PROTOCRATIC PERIOD OF EEMIAN INTERGLACIAL (E1-E2 R PAZ)

In zone G-267 2 L PAZ (corresponding to E1 R PAZ), the high proportions of *Pinus sylvestris* t. and *Betula* indicate the development of pioneer boreal birch forests with a significant proportion of pine trees that have spread over a larger area. In addition, the determination of pine stomata in palynological preparations also testifies to the presence of this tree in situ in the close vicinity of the lake. A threshold limit of ~50% of *Pinus* pollen in pollen spectra is considered a marker of pine forest development. The threshold was defined based on published data on modern and fossil pollen spectra reflecting the presence of pine forest (see Lisitsyna et al., 2012 and discussion therein) and represents the upper limit of values presented by Lisitsyna et al. (2012). This value agrees with earlier findings of Hicks (2001) in Finland and reflects the existence of boreal pine communities. Defining of pine dominated communities is useful in terms of climate interpretations as the occurrence of these communities is limited by the mean July temperature of +12°C (Zagwijn, 1989).

This approach to pine pollen data was also used by Pidek and Poska (2013) when interpreting forest development during the Cromerian complex in the fossil record of Łuków in eastern Poland. The authors determined parts of early and late interglacial that reflect development of boreal pine forests basing on 50% threshold limit of *Pinus* pollen. Simultaneously the pollen values of *Artemisia* drop below 5% at the transition between the late glacial

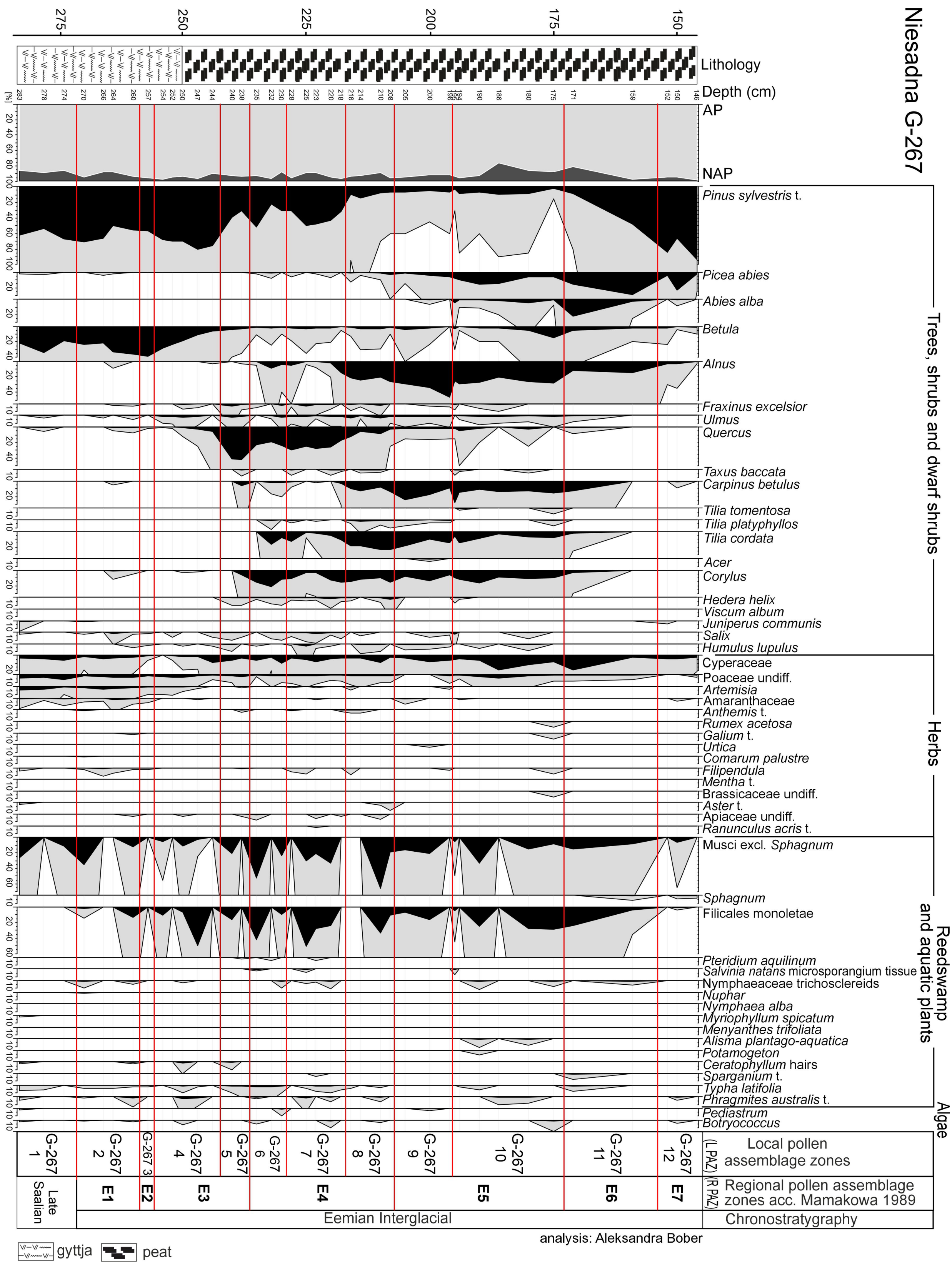

Figure 3. Pollen diagram of the Niesadna G-267 core profile

period and the E1 R PAZ. Such values are typical of Central Poland in this period (Kołaczek et al., 2018). The presence of a continuous curve of *Salix*, *Ulmus* and *Quercus* is noteworthy, indicating the occurrence of these trees in the landscape. Granoszewski (2003) is of the opinion that at the beginning of the Eemian interglacial, riparian communities developed in river valleys. These rich communities included not only elm and willow, but also oak.

Table 3. Description of the Local Pollen Assemblage Zones (L PAZs) of Niesadna G-267

L PAZ number and name	Sample section	Description
G-267 1 NAP-*Pinus*	2.78–2.70	Low frequency of sporomorphs. The percentage of *Pinus sylvestris* t. pollen is up to 66% and that of *Betula* pollen is up to 34%. Maximum proportion of *Juniperus* communis is 1.4%, single pollen grains of *Salix*, *Picea abies*, *Quercus* and *Ulmus* are present. There was a significant proportion of NAPs, up to 15%, mainly *Artemisia* (4.5%), Poaceae undiff. (6%) and Cyperaceae (6%). Among the pollen of rush plants are *Phragmites australis* t. and *Typha latifolia*. Aquatic vegetation is represented by *Myriophyllum spicatum* and *Ceratophyllum* hairs. Musci spores are present in a significant proportion (~26.5%), *Pediastrum* and *Botryococcus* cenobia are also present. The upper limit of the zone was determined based on a significant increase in the percentage of *Pinus sylvestris* t., *Betula* and a simultaneous decrease in NAP.
G-267 2 *Pinus-Betula*	2.66–2.60	High proportion of sporomorphs. Increase of *Pinus sylvestris* t. to 70.5% and *Betula* to 36%. The percentage of *Salix* is ~1.6%. The beginning of the continuous curve of *Quercus*. *Ulmus* and *Fraxinus excelsior* occur as single pollen grains, *Alnus*, *Carpinus betulus* and *Corylus* similarly. Single grains of *Humulus lupulus* pollen were also noted. The proportion of NAPs is high, 12%, mainly *Artemisia* (4%), Poaceae undiff. (3.5%), Cyperaceae (4.5%) and Amaranthaceae (1.8%). *Filipendula* has a continuous low percentage curve with 1%. The pollen of rush plants is represented by *Comarum palustre* and *Phragmites australis* t., and a continuous low percentage curve of *Typha latifolia* is also present. Aquatic vegetation is represented by *Nuphar* pollen, Nymphaeaceae trichosclereids and *Ceratophyllum* hairs. An increase in the percentage of Filicales monolete spores to 13.5% and a further increase in Musci to about 35% can be observed. *Botryococcus* cenobia are still present. The upper limit of the zone was determined based on a significant decrease in NAP and an increase in *Betula*.
G-267 3 *Betula-Pinus*	2.57	The percentage of *Pinus sylvestris* t. pollen drops to 56%, the maximum value of *Betula* is 39%. *Quercus* has a continuous low-percentage curve of. The share of NAP drops to 4.2% including: *Artemisia*, Poaceae undiff., Cyperaceae, Amaranthaceae and Apiaceae. Single pollen grains of *Humulus lupulus* and *Filipendula* are noted. The rush plants are represented by *Typha latifolia* pollen. The upper limit of the zone was determined based on the increase of *Pinus sylvestris* t. and the decrease of *Betula* and the further decrease of NAP.
G-267 4 *Pinus-Quercus*	2.54–2.44	*Pinus sylvestris* t. increases to 80% and *Betula* decreases to 6.5%. *Quercus* increases to 6%. *Ulmus* and *Fraxinus excelsior* have continuous low-percentage curves. Single pollen grains of *Alnus*, *Corylus*, *Humulus lupulus* and *Salix* are present. Low proportion of NAP is noted, mainly with *Artemisia*, Poaceae undiff. and Cyperaceae. Rush plants are represented by pollen of *Phragmites australis* t. and *Typha latifolia*. Aquatic vegetation is represented by Nymphaeaceae trichosclerides and *Ceratophyllum* hairs. The proportion of Filicales monolete and that of Musci are significant, up to 49% and 9.5%, respectively. *Botryococcus* cenobia are present. The upper limit of the zone was determined based on a significant increase in the percentage of *Quercus* and, at the same time, a significant decrease in the percentage of *Pinus sylvestris* t.
G-267 5 *Quercus*	2.40–2.38	A sharp increase in *Quercus* can be observed with 42%. Maximum share in the entire profile of *Fraxinus excelsior* is ~3%. *Ulmus* increases to 2% and *Corylus* to 6%. The share of *Pinus sylvestris* t. pollen drops to ~35%, *Betula* has a low share of 3.4%. *Carpinus betulus* and *Alnus* have continuous curves with 6% and 8%, respectively. *Hedera helix* and *Salix* also have continuous curves while *Taxus baccata* and *Humulus lupulus* appear as single pollen grains. *Artemisia*, Poaceae undiff. and Cyperaceae have shares of 0.2%, 2.6% and 4%, respectively. Other herbaceous vegetation is less than 1% including *Anthemis* t. and *Filipendula*. Rush vegetation is represented by *Typha latifolia* pollen. Aquatic vegetation is represented by *Ceratophyllum* hairs. The proportion of Filicales monolete spores drops to 13.5% and Musci varies up to 20%. Single spores of *Pteridium aquilinum* were also recorded. The upper limit of the zone was determined based on the decline of *Quercus*, the growth of *Corylus*, and the appearance and growth of *Tilia cordata*.
G-267 6 *Corylus*	2.35–2.28	The maximum proportion of *Corylus* in the entire profile is 21.5%. An increase of *Alnus* to 9% and a decrease of *Quercus* below 30% can be observed, the share of *Fraxinus excelsior* and that of *Ulmus* are similarly ~2%. A continuous curve in the percentage of *Tilia cordata* can be seen with 16.5% and single pollen grains of *Tilia platyphyllos* can be found. The continuous low-percentage curve of *Hedera helix* continues. Continuous low-percentage curves of *Picea abies* and *Carpinus betulus* appear. The pollen values of *Pinus sylvestris* t. are at a constant level of ~33%, while *Betula* has a low share with 2.3%. There are single pollen grains of *Taxus baccata* and *Humulus lupulus*. The share of NAP is 7.7%, mainly Poaceae undiff. and Cyperaceae. Rush vegetation is represented by pollen of *Phragmites australis* t. and *Typha latifolia*. Aquatic vegetation is represented by the tissues of microsporangium *Salvinia* natans and trichosclereids Nymphaeaceae. The proportion of Filicales monolete increases to 25.5% and that of Musci to 38.5%, sporadic spores of *Pteridium aquilinum* and single cenobia of *Pediastrum* and *Botryococcus* were recorded. The upper limit of the zone was determined based on a temporary decrease in the percentage of *Corylus*, *Tilia*, *Alnus* and an increase in *Pinus sylvestris* t.
G-267 7 *Pinus-Corylus-Tilia*	2.25–2.16	There is a high proportion of *Tilia* with 12% (*Tilia cordata* and *Tilia platyphyllos*). The pollen percentage of *Quercus* (28%), *Fraxinus excelsior* (2.9%) and *Corylus* (15.5%) has continuous curves. There are increasing proportions of *Alnus* up to 15%, *Carpinus betulus* up to 3% and *Hedera helix*. Single grains of *Taxus baccata* and *Salix* and *Humulus lupulus* are noted. The percentage of *Pinus sylvestris* t. is ~45%, while that of *Betula* is 3.5%. Among NAPs, mainly Cyperaceae (8.5%) and Poaceae undiff. (1.5%) occur. Rush vegetation is represented by *Phragmites australis* t., *Sparganium* t. and *Typha latifolia*. Aquatic vegetation is represented by Nymphaeaceae trichosclerides and *Salvinia natans* microsporangium tissues. There is a significant proportion of Filicales monolete spores of ~51% and Musci with ~35%. *Botryococcus* cenobia are present. The upper limit of the zone was determined based on a further decrease in *Corylus*, a decrease in *Pinus sylvestris* t. and an increase in *Alnus*.

Table 3. Continued

L PAZ number and name	Sample section	Description
G-267 8 *Ulmus-Carpinus-Alnus*	2.14–2.10	Maximum share of *Ulmus* is 3.5%. Increase in share of *Carpinus betulus* to 12.5% and *Alnus* to 24% and *Tilia* (total) to 24% can be observed. Decrease in *Quercus* to 9% and *Fraxinus excelsior* to ~1.6% are also observed. Continuous low-percentage curve of *Picea abies* and *Hedera helix* and single pollen grains of *Taxus baccata* and *Humulus lupulus* occur. Decrease in *Pinus sylvestris* t. to 7% can be seen. Among NAPs, Cyperaceae dominate (9%) Poaceae undiff., Apiaceae, *Aster* t. and *Anthemis* t. were also noted. Rush vegetation is represented by *Phragmites australis* t. and *Typha latifolia*. A decrease in Filicales monolete to 33% and an increase in Musci to 65% are observed. *Botryococcus* cenobia was noted. The upper limit of the zone was determined based on the growth of *Alnus* and *Carpinus betulus*.
G-267 9 *Alnus-Carpinus-Tilia*	2.08–1.96	Significant increase and culmination of *Tilia* at 25% (total), the maximum of *Alnus* at 46.5% are observed. *Carpinus betulus* increases to 24%, after a temporary decline the share of *Picea abies* also increases to ~6.5%. The proportion of *Pinus sylvestris* t. pollen decreases to 4.5% and that of *Betula* to 1%. Single pollen grains of *Abies alba*, *Hedera helix* and *Humulus lupulus* were recorded. Among NAPs, mainly Cyperaceae (8%) and *Artemisia*, Poaceae undiff., Amaranthaceae, *Aster* t., *Filipendula* and *Urtica* occur. A decrease in spores of Filicales monolete to 13.5% and Musci to 17.5% can be seen. *Pediastrum* cenobia are sporadic. The upper limit of the zone was determined based on the decrease of *Alnus* and the increase of *Carpinus betulus* and the beginning of a continuous low-percentage curve of *Abies alba*.
G-267 10 *Carpinus-Picea*	1.95–1.75	The increase and culmination of *Carpinus betulus* at ~27.5% and then its decrease and, at the same time, the increase of *Picea abies* to 14.5% and *Abies alba* to 4.5% are observed. The maximum share of *Salix* is 2.5%. The share of *Pinus sylvestris* t. pollen to 9% and an increase in *Betula* to 14.5%are observed at the end of the zone. Low share of *Corylus* (9%), *Quercus* (5%), *Ulmus* (1.2%) and *Fraxinus excelsior* (1%) is typical. Single pollen grains of *Taxus baccata*, *Hedera helix* and *Humulus lupulus* were recorded. The maximum proportion of NAP is ~24% with mainly Cyperaceae (19.5%), Poaceae undiff. (3.5%) and Amaranthaceae, *Galium* t., *Rumex acetosa* and *Filipendula*. Rush vegetation is represented by the pollen of *Phragmites australis* t. and *Typha latifolia*. Aquatic vegetation is represented by the pollen of *Alisma plantago-aquatica*, *Potamogeton*, microsporangium tissues of *Salvinia natans*, and trichosclereids of Nymphaeaceae. An increase in the proportion of spores of Filicales monolete to 27% and that of Musci to 26.5% can be observed. *Botryococcus* cenobia are sporadically present. The upper limit of the zone was determined based on the growth of *Picea* abies, *Abies alba* and *Pinus sylvestris* t. and on the decline of *Carpinus betulus*, *Corylus* and *Quercus*.
G-267 11 *Picea-Abies-Pinus*	1.71–1.59	Growth and culmination of *Abies alba* at ~22% and then the growth and culmination of *Picea abies* at ~29.5% are observed. *Pinus sylvestris* t. increases up to 48%, *Betula* has a low share up to 5% and those of *Alnus* and *Carpinus betulus* are 15% and 12%, respectively. Low share of *Tilia* (total) 2.5%, *Corylus* 2%, other trees such as *Quercus* and *Ulmus* less than 1% can be recorded. Share of NAP is ~20% mainly with Cyperaceae (18.5%) and Poaceae undiff. (1%). Rush vegetation is represented by *Sparganium* t. pollen and *Typha latifolia*. Aquatic vegetation is represented by Nymphaeaceae trichosclereides. There is a decrease in spores of Filicales monolete to 3% and those of Musci to 8%. The presence of *Sphagnum* spores was noted. The upper limit of the zone was determined based on the decrease in the percentage of deciduous trees and the increase in *Pinus sylvestris* t.
G-267 12 *Pinus*	1.52–1.46	Increase and culmination of pollen *Pinus sylvestris* t. at ~94%, low share of *Betula* up to 2.4% are observed. Still high share of *Picea abies* up to 23%, and, at the same time, low share of *Abies alba* up to 3% are recorded. *Carpinus betulus* and *Alnus* have low-percentage curves. Among NAP, mainly Cyperaceae, Poaceae undiff. and Amaranthaceae occur. The rush vegetation is represented by *Phragmites australis* t. The spores of Filicales monolete, *Sphagnum* and Musci have a share of 6% and *Botryococcus* cenobia were recorded.

High percentages of herbaceous pollen persist indicating still significant areas occupied by open communities. Among these, the continuous presence of *Filipendula* pollen documenting the spread of wet meadows is typical of early interglacial plant communities.

In the marginal zone of the Niesadna palaeolake, the composition of the reed swamp communities was similar to that of the previous zone, and representatives of the Nymphaeaceae family were still present among the aquatic plants.

The zones G-267 3 and WH-125 1 L PAZs correspond to E2 R PAZ. Its palynological record occurs in both pollen diagrams (Figs 3, 4). Characteristics of this regional zone are the high percentages of *Pinus sylvestris* t., still significant but receding shares of *Betula* and continuous percentage curves of *Quercus* and *Ulmus*. These features indicate the formation of riparian forests with elm, oak and ash in the river valleys, with birch and pine forests still dominating the landscape. It should be remembered that on the Garwolin Plain today, as well as during the Eemian interglacial period, the valleys of the Świder and Wilga – the right-bank tributaries of the Vistula – functioned. On the other hand, the Vistula valley itself forms the western border of the region. In the Niesadna pollen diagram the division into E1 and E2 was based it on our knowledge and experience with other pollen diagrams from the Garwolin Plain. These much better reflect

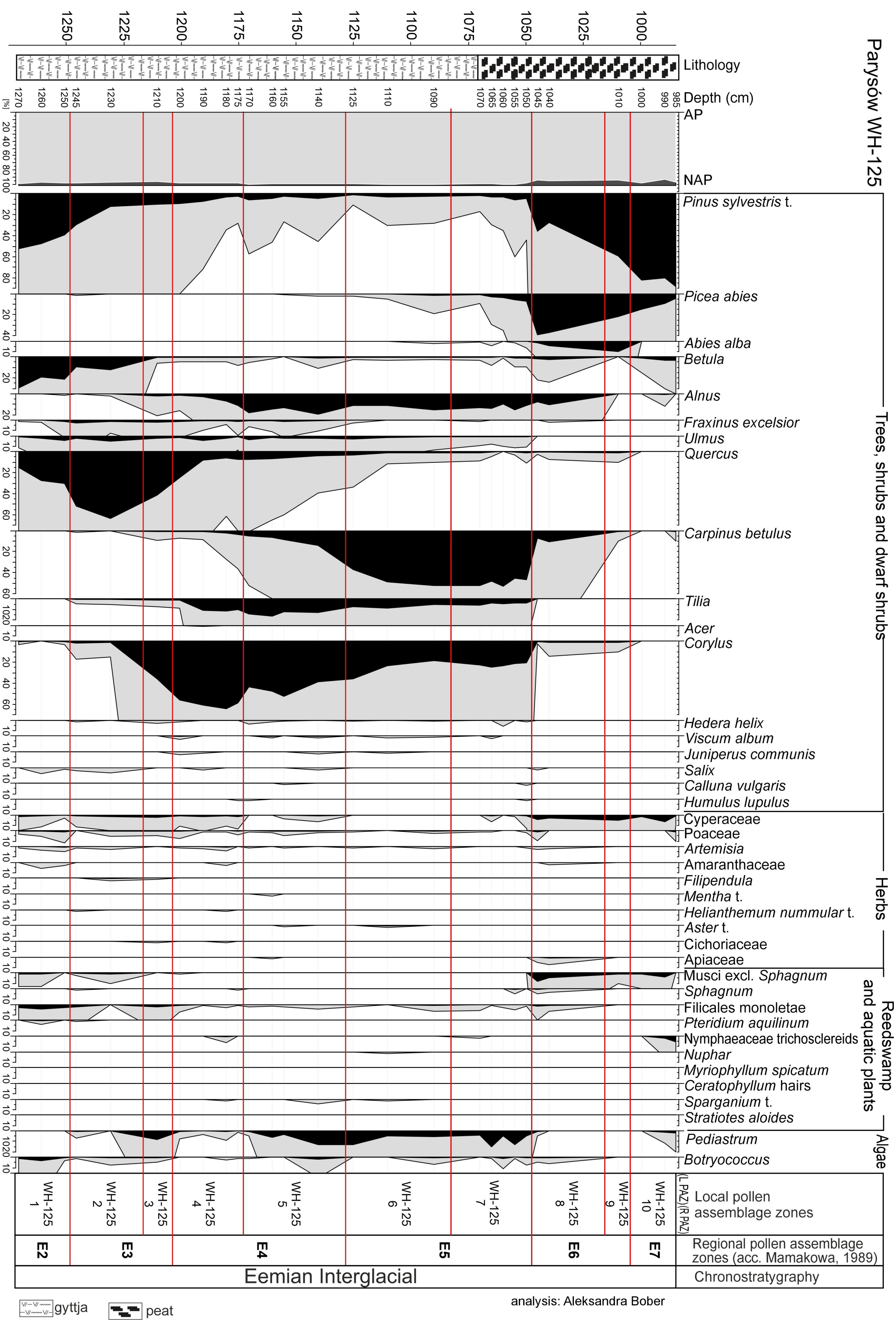

Figure 4. Percentage pollen diagram of the Parysów WH-125 core profile

Table 4. Characteristics of the local pollen assemblage zones (L PAZs) of Parysów WH-125

L PAZ number and name	Sample section	Description
WH-125 1 *Betula-Pinus-Ulmus*	12.70–12.50	High frequency of sporomorphs is typical. Share of *Pinus sylvestris* t. is up to 52.5%, culm of *Betula* occurs with 29.5% throughout the profile. High proportion of *Quercus* is recorded with ~30.5% and the proportion of *Ulmus* is ~4.6% and that of *Fraxinus* is ~1.6%. The beginning of a continuous curve of *Corylus* and *Alnus* can be observed. The presence of *Salix* (0.5%) was noted. Low proportion of NAP is observed mainly with *Artemisia*, Poaceae undiff., and Cyperaceae and Amaranthaceae. Spores of Filicales monolete (4.6%), *Pteridium aquilinum* (0.4%), and Musci (1.3%) were present. *Botryococcus cenobia* were recorded. The upper limit of the zone was determined based on the decrease of *Pinus sylvestris* t. and *Betula*, and the increase of *Quercus*.
WH-125 2 *Quercus*	12.45–12.30	Decline of *Pinus sylvestris* t. to 12% and *Betula* to 9.5% can be observed. Rapid increase and culmination of *Quercus* at 63.5%, followed by the culmination of *Ulmus* at 5% and *Fraxinus* at 2.9% are recorded. Low proportion of *Salix* is typical. Beginning of a low-percentage curve of *Corylus*, *Alnus* and *Tilia* can be seen. Single pollen grains of *Carpinus betulus* and the presence of *Hedera helix pollen* were noted. Low proportion of NAPs (2%) is observed, mainly with *Artemisia*, Poaceae undiff. and Cyperaceae totaling less than 2%. Sporadically also present are *Helianthemum nummularium* t. and *Filipendula*. Spores of Filicales monolete (2.3%), Musci (1%) and *Sphagnum* are present. *Pediastrum* and *Botryococcus cenobia* were recorded. The upper zone limit was determined based on the decline of *Quercus* and growth of *Corylus*, *Alnus*, *Tilia*, and a small growth of *Carpinus betulus.*
WH-125 3 *Quercus-Corylus*	12.10	Pollen share of *Pinus sylvestris* t. is ~10% and that of *Betula* is below 1%. Increase in the share of *Corylus* to 36% and a simultaneous decrease in *Quercus* to 41.5% are observed. Share of *Ulmus* and *Fraxinus* is 2.1% and 2.3%, respectively. Percentage of *Alnus* is 2.1%, that of *Tilia* and *Carpinus betulus* is below 1%. Single *Hedera helix* pollen grains were recorded. Among NAPs mainly Poaceae undiff., Cyperaceae, Cichoriaceae and *Filipendula* occur. Filicales monolete spores and a significant proportion of *Pediastrum*, ~8%, and *Botryococcus were* recorded. The upper limit of the zone was determined based on a further increase in *Corylus* and *Tilia* and a decrease in *Quercus* and *Pinus sylvestris* t.
WH-125 4 *Corylus*	12.00–11.75	The proportion of *Corylus* pollen increases and reaches a maximum of 64%. The share of *Alnus* increases to 11.5% and that of *Tilia* to 11.5%, and a slow increase of *Carpinus betulus* to 3.6% was also recorded. A further decline in *Pinus sylvestris* t. (2.8%), *Betula* (1%), *Quercus* (6.2%), *Ulmus* (1.4%) and *Fraxinus* (0.5%) can be seen. Single pollen grains of *Acer*, *Hedera helix*, *Viscum album*, and *Humulus lupulus* were recorded. Among NAPs, small proportions of *Artemisia*, Poaceae undiff., Cyperaceae, Amaranthaceae, *Helianthemum nummularium* t. and Cichoriaceae were recorded. Rush vegetation is represented by *Sparganium* t. Aquatic vegetation is represented by Nymphaeaceae trichosclerides. Spores of Filicales monolete, Musci and *Sphagnum* have been recorded. Notable is the decrease of *Pediastrum* to below 1%, *Botryococcus cenobia* are present. The upper zone limit was determined based on the growth of *Alnus*, *Tilia* and *Carpinus betulus*.
WH-125 5 *Corylus-Tilia-Alnus*	11.70–11.40	Maximums throughout the profile are 16% for *Tilia* and 19.5% for *Alnus*. *Corylus* has still high proportion, up to 40%, increase in the proportion of *Carpinus betulus* to up to 14.5% is observed. Beginning of a continuous curve of *Picea Abies* pollen share can be seen. *Pinus sylvestris* t., *Betula*, *Quercus*, *Ulmus* and *Fraxinus* show low-percentage curves. Single pollen grains of *Hedera helix* and *Viscum album* were recorded. Very low proportions of NAP were occasionally recorded with pollen grains of *Artemisia*, Poaceae undiff. and Cyperaceae, as well as Apiaceae, *Aster* t. and *Mentha* t. Rush vegetation is represented by pollen of *Sparganium* t. Spores of Filicales monolete and a re-increase of *Pediastrum* to 13.5% and *Botryococcus* to about 1.9% were recorded. The upper zone limit was determined based on the increase of *Carpinus betulus* and the decrease of *Tilia*, *Alnus and Corylus.*
WH-125 6 *Carpinus-Corylus-Alnus*	11.25–11.10	An increase in the proportion of *Carpinus betulus* to 48.5%, a gradual decrease in *Corylus to* 23.5%, *Alnus* to 11.5% and *Tilia* to 9% are observed. A low-percentage curve of *Picea Abies* is present. *Quercus*, *Ulmus* and *Fraxinus* are present in a very low proportion. Single seeds of *Hedera helix* and *Viscum album* were noted. Very low proportion of NAP is typical. Rush vegetation is represented by *Sparganium* t. Aquatic vegetation is represented by *Nuphar* pollen. There is a low proportion of Filicales monolete spores, numerous *Pediastrum* cenobia, with 13.5%, are present. The upper zone limit was determined based on the growth of *Carpinus betulus* and *Picea Abies*, and the decline of *Quercus*, *Ulmus* and *Fraxinus excelsior*.
WH-125 7 *Carpinus-Corylus*	10.90–10.50	Increase in the proportion of *Carpinus betulus* and its culmination throughout the profile with 53% can be recorded. Increase in the proportion of *Picea Abies* to around 7%, with a continuous curve of *Abies alba* appearing in the upper part of the zone are observed. *Corylus*, *Alnus* and *Tilia* are at constant values of 20%, 14% and 5%, respectively. Low proportions of *Quercus*, *Ulmus* and *Fraxinus excelsior* are typical. Single grains of *Hedera helix* and *Viscum album* were noted. Low proportion of NAP can be seen. Rush vegetation is represented by *Sparganium* t. Aquatic vegetation is represented by Nymphaeaceae trichosclerides. Spores of Filicales monolete and *Sphagnum* were recorded, as well as *Pediastrum* cenobia with 13.5% and *Botryococcus* with 1.1%. The upper limit of the zone was determined based on the rapid decline of *Carpinus betulus* and the rapid growth of *Picea abies* and *Abies alba*.
WH-125 8 *Pinus-Picea-Abies*	10.45–10.40	Rapid increase and culmination across the *Picea Abies* profile with 39% are observed. Increase in the percentage curve of *Abies alba* to 4.5% and a significant share of *Pinus sylvestris* t. to 35.5% are recorded. Share of *Alnus* at a constant zone of ~10.5%. At the same time, a further decrease in *Corylus* (1.5%), *Carpinus betulus* (7.5%), and *Quercus* and *Fraxinus* as single pollen grains can be observed. Among NAPs, mainly Cyperaceae *Artemisia*, Poaceae undiff. and Amaranthaceae and Apiaceae occur. Spores of Filicales monolete, *Sphagnum* and Musci and *Pediastrum* and *Botryococcus cenobia* were recorded. The upper limit of the zone was set by a further increase in *Pinus sylvestris* t. and *Abies alba*, and a decrease in the proportion of deciduous pollen.

Table 4. Continued

L PAZ number and name	Sample section	Description
WH-125 9 *Pinus-Abies-Picea*	10.10	Further increase in *Pinus sylvestris* t. pollen to 59.5% is observed. A culmination of *Abies alba* at ~10% with a still high proportion of *Picea Abies* with ~22% are recorded. Other tree taxa are present as single pollen grains. Among the NAPs, only Cyperaceae were recorded. Musci spores were also recorded. The upper limit of the zone was determined based on the further growth of *Pinus sylvestris* t., the significant proportion of *Picea Abies*, the disappearance of *Abies alba* and the percentage curves of deciduous trees.
WH-125 10 *Pinus*	10.00–9.85	Further growth of *Pinus sylvestris* t. and its culmination at 88.5% are recorded, the share of *Picea Abies* is significant with ~15%. The share of *Betula* is still low, up to 3.5%. Among the NAP mainly Poaceae undiff. and Cyperaceae occur. Aquatic vegetation is represented by Nymphaeaceae trichosclereids. Musci spores and *Pediastrum* cenobia were recorded.

the regional E2 zone (named *Pinus-Betula-Ulmus*), whose characteristics are a *Betula* or *Pinus* maximum, the appearance of *Ulmus* and *Quercus* and a decrease in the proportion of NAP (Kupryjanowicz and Granoszewski, 2018). The problem of establishment of this boundary is related to the lack of sediments representing the *Betula* maximum (usually around 70%) in Eemian pollen diagrams, as well as the relatively low sampling resolution in this section of the Niesadna diagram. It is noteworthy that there is a significant difference in the percentage share of *Quercus* pollen in both sites. In the case of profile G-267 it is a little over 10%, while in profile WH-125 it is ~40%. In Niesadna, at a short distance from the lake, there were shrubby willows and communities in the type of wet meadows with *Filipendula* (*F. ulmaria*?), *Galium*, *Comarum palustre* and *Rumex acetosa*, as well as *Humulus lupulus* and *Ranunculus acris*. The shores of the lake were overgrown by a reed belt with broad-leaved creeper and common reed, while hornwort (*Ceratophyllum*) occurred in the lake alongside representants of the Nymphaeaceae family. Near the lake, ferns (numerous spores of Filicales monolete) developed extensively alongside mosses. In the case of the Parysów water body, the species composition was poorer and only spores of Filicales monolete, *Pteridium aquilinum* and Musci were recorded.

MESOCRATIC PERIOD OF EEMIAN INTERGLACIAL (E3-E5 R PAZ)

Zones G-267 4–5 and WH-125 2–3 L PAZs document the oak phase (corresponding to E3 R PAZ). As in the previous zone, the significant difference in the percentage of *Quercus* pollen between the two pollen diagrams draws attention. Presumably, oak together with elm and ash formed ash-elm riparian forests in moist eutrophic habitats. In turn, the receding pine-birch communities were replaced by mixed pine-oak forests and then oak communities. At the same time, hazel appeared in forest clearings and at the edge of woodlands. The minimal proportion of herbaceous pollen, with the exception of Cyperaceae, indicates that all available habitats, apart from bogs, were occupied by forest communities. In the Niesadna pollen diagram (Fig. 3), oak reaches its maximum proportion of 42%, and in the Parysów diagram (Fig. 4) it is over 63%. Presumably, therefore, the Niesadna diagram contains a hiatus in this section.

During the oak phase, the presence of *Hedera helix* in the woods is notable, as well as communities with *Humulus lupulus*, Apiaceae and *Filipendula* around the lake in Niesadna. The rush gradually transformed into a reed with the dominance of a *Typhetum latifoliae* community type (see Matuszkiewicz, 1981). In addition to the spores of Filicales monolete, the sporadic presence of *Pteridium aquilinum* indicates the development of drier forest community types in the vicinity of the lake. In parallel with the high proportions of Filicales monolete and Musci spores, there is also a high proportion of Cyperaceae pollen. The characteristics of the sediment in the lithological profile suggest the transformation of the water body into a peatland.

At that time, the area around the Parysów was presumably overgrown by peat bogs with mosses and *Sphagnum*.

The dynamic process of hazel dispersal that is typical of the G-267 6–8 and WH-125 4–5 L PAZs zones (corresponding to E4 R PAZ) is best reflected in the Parysów pollen diagram, as the *Corylus* pollen maximum here reaches as much as 64%, while the maximum value of this taxon in the Niesadna pollen diagram reaches only 21.5%. The zone with a *Corylus* maximum above

50% is a characteristic feature of the E4 R PAZ in the Eemian succession. Thus, there is probably a hiatus in the profile from Niesadna associated with the absence of part of the hazel phase record. This lack of record may indicate dynamic changes in the natural environment. This hypothesis is supported by the admixture of fine sand in the sediment suggesting active erosional processes. After the maximum of *Corylus* at both sites, the proportion of lime increases in the diagram, indicating an increasing role of this tree in the communities. In the Niesadna diagram (Fig. 3), pollen of *Tilia cordata* t. and that of *Tilia platyphyllos* have been determined. The culmination of *Tilia* (summed by both taxa) occurs after the maximum of *Corylus* thus testifying that we are dealing with the so-called variant B1 (see Mamakowa, 1989). This variant is called "early lime with late culmination," as the lime enters the forest community simultaneously with the hazel and culminates just after the hazel maximum. B1 is a variant typical of the pollen succession of the Eemian interglacial in central Poland (op.cit). During the E4 R PAZ, the conversion of oak forests into *Tilio-Carpinetum* oak-hornbeam communities with a higher proportion of lime and with the first hornbeam trees probably occurred. In the riparian and oak-hornbeam communities, *Fraxinus* and *Ulmus* were present in addition to a high proportion of *Quercus*, and pollen of indicator taxa for warm and humid climates was also recorded in this zone. *Taxus baccata* appeared alongside *Hedera helix*. The presence of *Filipendula* (*F. ulmaria*?) and *Rumex acetosa* may still suggest the occurrence of rush and reedswamp communities at the outskirts and wet meadow-like communities in the surroundings of the Niesadna lake. At its edge there was a rush dominated by *Typha latifolia* with *Phragmithes australis* t. and *Sparganium* t. Of note were numerous spores of Musci and Filicales monolete. In the Parysów profile, among the taxa associated with wetland habitats, the presence of pollen of the climbers *Hedera helix* and *Humulus lupulus* is notable. The sparse pollen of *Aster* t. and *Mentha* t. indicates the presence of wet meadow type communities. The still high proportion of *Pediastrum* and the presence of *Sparganium* t. indicate a eutrophic, not very deep-water body.

The younger part of the climatic optimum represented by the zones G-267 9–10 and WH-125 6–7 L PAZs (corresponding to the E5 R PAZ), is characterised by the dominance of *Carpinus betulus*, the maximum of which in the Parysów diagram (Fig. 4) is as high as 53%. This number is in line with the characteristics of the Eemian succession, in which pollen percentages of this tree reach over 50% in the hornbeam phase. In the Niesadna diagram (Fig. 3), the values are again much lower (settling at 27.5%). However, what is particularly noteworthy in this diagram is the high percentage of alder pollen, over 45%, which may indicate that alder dominated the site at that time.

Thus, it is possible that the presence of alder may have caused the deposition of alder peat in the Niesadna palaeolake, which may explain the discontinuity of sedimentation and the disturbance in the pollen diagram. The proportion of alder in the Parysów diagram (Fig. 4) is lower, around 14%.

In the declining phase of the E5 R PAZ, the proportion of *Picea abies* increases significantly: Niesadna – 14.5% and Parysów – 7%. This presumably documents the encroachment of spruce into the alder community, perhaps as a natural stage of succession, and may also indicate environmental changes related to both temperature decline and soil conditions. In the reed zone of the Niesadna lake, *Phragmites australis* t. has a higher proportion and *Typha latifolia* a much lower proportion. Representatives of the Nymphaeaceae family and *Alisma plantago-aquatica* continued to occur on the surface of the reservoir. The presence of the latter species suggests significant eutrophication of the very shallow lake (see Kłosowski and Kłosowski, 2015). Water fern *Salvinia natans* also marks its presence at this time. These facts indicate a significant degree of overgrowth on the lake surface. An alternative interpretation is also possible due to the simultaneous appearance of *Salvinia natans* and the temporary decrease in the proportion of Filicales monolete and Musci in the sample from 1.95 m. This composition of the pollen spectrum may suggest a disturbance in the sediment and redeposition of *Salvinia natans* tissue from older sediments or a sedimentary break. At Parysów, the rush zone was composed of *Sparganium* t., and among the aquatic taxa, the *Pediastrum* algae are present, indicating the presence of a eutrophic lake. There is also an increase in the proportion of Filicales monolete spores. Moreover, towards the end of the zone *Sphagnum* and Musci spores also appear indicating the peat bog character of the reservoir.

TELOCRATIC PERIOD OF EEMIAN INTERGLACIAL (E6-E7 R PAZ)

In the G-267 11 and WH-125 8–9 L PAZs (corresponding to the E6 R PAZ), the proportion of the pollen of coniferous trees (*Picea abies*, *Abies alba*, *Pinus sylvestris* t.) strongly increases and at the same time the pollen of deciduous trees decreases or disappears completely. This indicates that the habitats of hornbeam forests were shrinking and were being replaced mainly by pine, fir and spruce. The maximum values of spruce testify to the wide spread of moist coniferous forests. Granoszewski (2003) indicates that these may have been fir-spruce and spruce communities, as spruce also encroached on alder habitats transforming them into alder-spruce forests and, in the next stage of succession, into swampy spruce forests. Gradually, as temperatures dropped, pine-spruce forests and pine swamp forests spread.

In the younger part of the zone in the Niesadna diagram, there is a decline in the rush communities (disappearance of *Typha latifolia* and *Sparganium* t. pollen) and a significant decrease in the proportion of Filicales monolete spores and a slight decrease in the Musci ones. *Sphagnum* spores also appear. This characteristic of the pollen spectrum suggests oligotrophisation of the habitat. Presumably there has been a complete overgrowth of the water body and disappearance of open water. The palaeolake at Parysów was probably completely overgrown from WH-125 8–9 L PAZs as evidenced by the disappearance of nymphaeids and the simultaneous increase in Musci and *Sphagnum* spores. At the same time, the proportions of Cyperaceae and *Alnus* declined, and a significant increase was recorded in *Picea abies* and *Abies alba*. This picture may suggest the encroachment of spruce on both overgrown bogs as a result of natural succession in the alder community. It is possible that fir was also an admixture in this wet environment.

The abrupt change in the pollen spectra of Parysów WH-125 diagram marks not only the dramatic changes in the forest composition but a considerable cooling as well. It is manifested by the occurrence of boreal forests with pine and spruce prevalence. This change is also visible in the Niesadna G-267 diagram. Simultaneously, transition from the lake deposits with *Pediastrum* and *Botryococcus* algae to sedge-moss peats is observable in the Parysów diagram, while in Niesadna this is manifested by the disappearance of reed-swamp plants such as *Typha latifolia*, *Sparganium* t. and Nymphaeaceae.

Zones G-267 12 and WH-125 10 L PAZs (corresponding to the E7 R PAZ) were dominated by pine pollen. *Pinus sylvestris* t. reaches its maximum at Niesadna with 94% and at Parysów with 88.5%. In addition to the significant proportion of pine, the proportion of spruce was still high (more than 20% in the Niesadna profile and 15% in the Parysów profile), indicating that pine forests with a significant admixture of spruce still persisted in the area.

During the pine phase at the end of the interglacial, the complete disappearance of Filicales monolete spores and minimal proportions of Musci, with the continued presence of *Sphagnum* (Niesadna) spores, suggest the continued development of a peat bog with sedges and mosses that was surrounded by a pine forest. It is possible that spruce was still present on the surface of the bog.

DISCUSSION

LATE SAALIAN/EEMIAN BOUNDARY

The boundary between the late Saalian and Eemian interglacial at the Niesadna site was placed on a decrease in NAP values and an increase in pollen values of *Pinus sylvestris* t., while at the same time a fairly high proportion of *Betula*. Relatively quickly, as a result of natural succession, these pioneer forests are replaced by mixed pine-birch forests, followed by trees from later stages of succession. This boundary has been similarly delineated in other pollen diagrams recording the late Saalian / Eemian transition within the Garwolin Plain, e.g. Struga (Bober et al., 2018, 2023; Zalat et al., 2021) and Wola Starogrodzka (Kupryjanowicz et al., 2021). Similarly, the boundary between late glacial communities and pioneer boreal birch forest communities was drawn by Mamakowa (1989), among others. In the pollen spectrum of profile G-267, the significant proportion of herbaceous vegetation, among which *Artemisia* (up to 4.5%), Cyperaceae (up to 6%)

and Poaceae (6%) play a major role, indicate the open character of the landscape with shrubs of *Juniperus communis* and *Salix*.

Unfortunately, the small thickness of the Late Saalian section in the Niesadna profile does not warrant distinguishing sections that could be correlated with the Zeifen interstadial and the Kattegat stadial, analogous to what Kupryjanowicz et al. (2021) did for the nearby Wola Starogrodzka G-122 profile.

However, based on the presence of *Ceratophyllum* hairs, we can conclude that summer temperature was not lower than 15°C. Granoszewski (2003) found *Ceratophyllum demersum* both in late Saalian/ Eemian transition and in the Brörup interstadial. He suggested that the presence of *Ceratophyllum demersum* fruits may indicate that the mean July temperature was not lower than 15°C, although the northernmost fruiting specimen of this species was reported by Wasylikowa (1964) and coincides with July temperature as low as ~12°C.

PRESENCE OF SEDIMENTATION GAPS

At the Parysów site, at the abrupt transition between the E5/E6 R PAZ zones, the percentage of thermophilous taxa decreases significantly, and there is a cooling and wetting of the climate; documented in pollen diagrams (Figs 3, 4) by the sharp increase in the pollen values of *Picea abies*, *Abies alba* and *Pinus sylvestris* t., as well as NAP and *Betula*. These changes are typical of the decline of the interglacial (Granoszewski, 2003). Besides, Kuneš et al. (2011) points to the fact that the podzolisation and acidification of soils at the end of the interglacial periods may have been caused by the expansion of spruce and pine. This shift towards a cooler climate in the pollen spectrum and the concomitant change in sediment – the transition of gyttja to peat – may suggest changes of a local character determined by regional climatic conditions. Analogous sedimentary breaks at the transition from E5 to E6 R PAZ, and sometimes even the absence of E6 R PAZ, were noted by Kupryjanowicz (2008) in Eemian profiles from northern Podlasie. Their reason could have been both a decrease in annual precipitation and a significant drop in groundwater levels. This can be the reason of abrupt changes observable in the pollen diagram of Parysów WH-125 at the E5/E6 R PAZs transition. A review of Eemian sites from Poland, e.g. Imbramowice (Mamakowa, 1989) and Rzecino (Winter et al., 2008; Niska and Mirosław-Grabowska, 2015) and in Europe, e.g. Hinterste Mühle (Börner et al., 2018), indicates that this phenomenon occurs in many sites but that there is no consistent pattern. Indeed, as in the Garwolin Plain, it happens that in sites close to each other, full Eemian succession is registered in the gyttja, i.e., the water body functioned throughout the interglacial (e.g. Kozłów: Suchora et al., 2022) next to palaeolakes that registered only a fragment of the climatic optimum and became shallow and overgrown much earlier (e.g. Słup: Kultys et al., 2023b, and Jagodne: Bober et al., 2021). Such a situation also occurred at the German site of Hinterste Mühle (Börner et al., 2018) where gyttja deposit was replaced by peat accumulation.

Interestingly, it is the deepest palaeolake in Żabieniec that, after being transformed into a peat bog, still functioned for a considerable period of the early Weichselian passing through phases of a more humidified transitional peat to an ombrotrophically fed peatland (Pidek et al., 2023). The thicker overlying peat series in the Parysów profile prompts the hypothesis that sediments of early Weichselian are also present here, which requires palynological investigations to be undertaken.

In the pollen diagram of Niesadna (Fig. 3), the maximum percentages reached by *Quercus*, *Corylus* and *Carpinus* are strikingly low, although the other features undoubtedly testify to the Eemian succession. The reasons for this should be sought in the presence of several sedimentary breaks probably caused by the geological and geomorphological situation of the Niesadna palaeolake located on a slope in contrast to the Parys palaeolake, which was formed by the melting of a block of dead ice in the depression during the late Saalian receding. An additional rationale for the hypothesis that the geological-geomorphological situation of the Eemian basin is extremely unfavourable for undisturbed sedimentation is the admixture of mineral material in the organic sediment, including sand, indicating that erosion is taking place. The presence of distinct sedimentary gaps in both the oak and hazel and hornbeam horizons, as found in the Niesadna profile, has not been recorded in any of the profiles developed to date in the Garwolin Plain.

EEMIAN POLLEN SUCCESSION IN THE STUDIED SITES IN COMPARISON WITH OTHER PROFILES OF PALAEOLAKES OF THE GARWOLIN PLAIN

The longest continuity of the record during the entire interglacial covering all seven R PAZs (E1–E7) according to Mamakowa (1989) was found in the Kozłów K2-19 and Struga St-19 profiles (Fig. 5). This record is in carbonate gyttja deposits. However, also in these two palaeolakes the formation of the E7 R PAZ zone is certainly incomplete. As Kupryjanowicz et al. (2016) point out, a very large number of pollen diagrams in the pine dominated E7 zone records a transient abrupt increase in NAP values and also *Betula*, which marks a short-term cooling within the pine phase. Unfortunately, this record is absent in K2-19 and St-19 and has, so far, not been found either in other pollen diagrams from the Garwolin Plain. Thus, we suppose that the E7 R PAZ is probably uncomplete in several investigated profiles.

Another issue that is related to sedimentation continuity is the type of organic sediment in which the palaeobotanical record is preserved. As a rule, the Eemian profiles developed from the Garwolin Plain contain gyttjas in the bottom and peat or transitional peats in the top part. The exceptions are the above-mentioned two profiles K2-19 and St-19. A different type of organic sediment is represented by Niesadna. Due to its location on a slope and the admixture of sand in the organic sediment, it seems that the water body was flowing, at least periodically. Such an interpretation would exclude the development of a typical alder carr, which is formed in the drainless depressions of the area.

In addition, Prager et al. (2012) point out that the presence of alder on sites in the past is generally manifested in palynological data by a sharp decline in pollen concentration, strong corrosion of sporomorphs, often very high proportions of Filicales monolete and/or *Thelypteris palustris* spores and characteristic non-pollen palynomorphs typical of peat developed in an alder carr (Prager et al., 2012). Alder pollen is often poorly preserved due to high microbial (Havinga, 1967, 1984; Dilly et al., 2001) and macrofungal (Grauwinkel, 1987) activity in the presence of oxygen and nutrients. Meanwhile, in the Niesadna profile, alder pollen, as well as that of other taxa were preserved in a very good condition, with no changes in their structure or corrosion noted. Hence, it can be concluded that the conditions for their preservation in the peat sediment were good and perhaps the high proportions of *Alnus* pollen are rather the result of proximity to an alder stand, but not directly on the peat bog at the site of the profile.

It is evident that at the Niesadna site the significant proportion of alder, over 40%, is exceptionally high in relation to other Eemian profiles not only in the Garwolin Plain, but

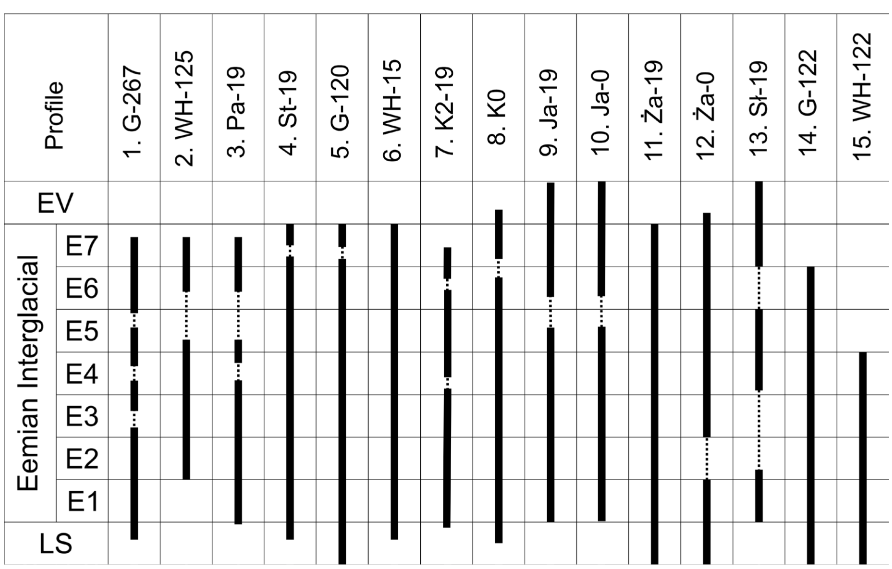

Figure 5. Representation of R PAZ in organogenic sediment profiles of the Eemian interglacial and late Saalian and early Vistulian from the Garwolin Plain. Designation of sites and profiles: **1**. Niesadna (this paper); **2**. Parysów WH-125 (this paper); **3**. Parysów Pa-19 (Bober et al., 2023); **4–6**. Struga (Bober et al., 2018, 2023; Zalat et al., 2021); **7**, **8**. Kozłów (Pidek et al., 2021; Suchora et al., 2022); **9**, **10**. Jagodne (Bober et al., 2021; Pidek et al., 2022); **11**, **12**. Żabieniec (Pidek et al., 2022); **13**. Słup Sł-19 (Kultys et al., 2023b); **14**, **15**. Wola Starogrodzka (Kupryjanowicz et al., 2021). The dashed line indicates sedimentation gaps interpreted from the pollen analysis results

also in Poland. A review of Eemian isopollen maps, which document the encroachment of alder and its maximum proportions during the interglacial period, indicates no more than 25% of *Alnus pollen* (Pidek et al., 2018).

Although *Alnus* produces a lot of pollen (Janssen, 1959) a study of modern pollen fall using Tauber traps conducted by Pidek (2007) in Roztocze (south-eastern Poland) shows a weak relationship between alder pollen deposition values and the proportion of alder in local plant communities. Alder pollen concentration probably represents local trees to a small extent and is largely dependent on regional vegetation. *Alnus* pollen mainly comes from large patches of alder communities growing in river valleys. Such valleys in the Eemian interglacial functioned not far from the Niesadna site, e.g. the extensive valley of the Vistula or the valleys of the Świder, Wilga and Struga rivers. It appears that upward transport of pollen from the valley area may be the most important factor controlling the spread of alder pollen (Pidek, 2007). The *Alnus* pollen season is also important, as alder trees begin to produce pollen as early as February, when most trees do not yet have leaves and alder pollen carried downwind does not encounter major obstacles.

Thus, the high proportion of alder pollen may be a local phenomenon in the Niesadna profile that is weakly related to the presence of extensive alder habitats.

CONCLUSIONS

The organogenic deposits of Niesadna and Parysów palaeolakes document the vegetation history of the Eemian interglacial, and the Niesadna profile additionally fragments the declining part of the late Saalian glaciation.

There are evident differences in the record of Eemian succession in the two sites, which is probably due to their geomorphological location. The Niesadna site is distinguished from other sites on the Garwolin Plain by a high record of alder. Its significant proportion is probably related to extensive alder patches in the valleys of nearby rivers. The lake sediment profile shows several sedimentary gaps probably resulting from the geomorphological position on the slope. The incomplete record of hornbeam and spruce pollen zones in the profile from Parysów indicates that these changes in the record of Eemian succession were mainly caused by regional environmental conditions including drier and colder climate and lowering of the ground water level.

Both profiles bring new facts to the knowledge of Eemian, while confirming drier and colder transition between E5 and E6 R PAZ and adding two new palaeolake records from the Garwolin Plain to the existing state of research.

ACKNOWLEDGEMENTS

The authors thank two Anonymous Reviewers for their valuable comments that helped to considerably improve the manuscript.

ADDITIONAL INFORMATION

CONFLICT OF INTEREST. The authors have declared that no competing interests exist.

ETHICAL STATEMENT. No ethical statement was reported.

FUNDING. The research was financed by the National Science Centre, Poland, project No. 2017/27/BST10/01905.

REFERENCES

Berglund, B.E., Ralska-Jasiewiczowa, M., 1986. Pollen analysis and pollen diagrams. In: Berglund, B.E., Ralska-Jasiewiczowa, M. (eds), Handbook of Holocene Palaeoecology and Palaeohydrology. J. Wiley & Sons Ltd., Chichester–Toronto, 455–484.

Bober, A., Pidek, I.A., Żarski, M., 2018. Late Saalian and Eemian Interglacial at the Struga site (Garwolin Plain, central Poland). Acta Palaeobotanica 58(2), 219–229. https://doi.org/10.2478/acpa-2018-0007

Bober, A., Brzozowicz, D., Drzymulska, D., Żarski, M., Suchora, M., 2021. Palaeobotanical record of the Eemian Interglacial succession at the Jagodne site (Garwolin Plain, central Poland). Geological Quarterly 65(2), 34. https://doi.org/10.7306/gq.1602

Bober, A., Drzymulska, D., Stachowicz-Rybka, R., Kończak, M., Żarski, M., 2023. High-resolution record of Late Saalian and Eemian palaeoenvironments: the case study of Struga and Parysów (central Poland). Geological Quarterly 67(3), 37. https://doi.org/10.7306/gq.1707

Börner, A., Hrynowiecka, A., Stachowicz-Rybka, R., Niska, M., Moskal-del Hoyo, M., Kuznetsov, V., Maksimov, F., Petrov, A., 2018. Palaeoecological investigations and 230Th/U dating of the Eemian Interglacial peat sequence from Neubrandenburg-Hinterste Mühle (Mecklenburg-Western

Pomerania, NE Germany). Quaternary International 467, 62–78. https://doi.org/10.1016/j.quaint.2017.04.003

Brauer, A., Allen, J.R.M., Mingram, J., Dulski, P., Wulf, S., Huntley, B., 2007. Evidence for last interglacial chronology and environmental change from Southern Europe. Proceedings of the National Academy of Sciences 104(2), 450–455. https://doi.org/10.1073/pnas.0603321104

Brewer, S., Guiot, J., Sánchez-Goñi, M.F., Klotz, S., 2008. The climate in Europe during the Eemian: a multi-method approach using pollen data. Quaternary Science Reviews 27(25), 2303–2315. https://doi.org/10.1016/j.quascirev.2008.08.029

Bruj, M., Krupinski, K., 2001. Biogeniczne osady jeziorne interglacjału eemskiego w Żeliszewie na Wysoczyźnie Siedleckiej. Przeglad Geologiczny 49(6), 538–543.

Bruj, M., Roman, M., 2007. Zasięg pojezierza z interglacjału eemskiego w Polsce a pozycja stratygraficzna ladolodów zlodowaceń środkowopolskich. Biuletyn Państwowego Instytutu Geologicznego 425, 29–36.

Cheddadi, R., Mamakowa, K., Guiot, J., De Beaulieu, J.-L., Reille, M., Andrieu, V., Granoszewski, W., Peyron, O., 1998. Was the climate of the Eemian stable? A quantitative climate reconstruction from seven European pollen records. Palaeogeography, Palaeoclimatology, Palaeoecology 143(1–3), 73–85. https://doi.org/10.1016/S0031-0182(98)00067-4

Cohen, K.M., Gibbard, P.L., 2019. Global chronostratigraphical correlation table for the last 2.7 million years. Quaternary International 500, 20–31. https://doi.org/10.1016/j.quaint.2019.03.009

Dilly, O., Bartsch, S., Rosenbrock, P., Buscot, F., Munch, J.C., 2001. Shifts in physiological capabilities of the microbiota during the decomposition of leaf litter in a black alder (*Alnus glutinosa* (Gaertn.) L.) forest. Soil Biology and Biochemistry 33(7–8), 921–930. https://doi.org/10.1016/S0038-0717(00)00239-X

Fiłoc, M., Kupryjanowicz, M., Nalepka, D., Balwierz, Z., Bińka, K., Granoszewski, W., Kołaczek, P., Majecka, A., Malkiewicz, M., Nita, M., Noryśkiewicz, B., Pidek, I.A., Walanus, A., Winter, H., 2018. Poaceae (Gramineae) – Grass family. In: Kupryjanowicz, M., Nalepka, D., Madeyska, E., Turner, C. (eds), Eemian History of Vegetation in Poland Based on Isopollen Maps. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences, 209–216.

Govin, A., Capron, E., Tzedakis, P.C., Verheyden, S., Ghaleb, B., Hillaire-Marcel, C., St-Onge, G., Stoner, J.S., Bassinot, F., Bazin, L., Blunier, T., Combourieu-Nebout, N., Ouahabi, A.E., Genty, D., Gersonde, R., Jimenez-Amat, P., Landais, A., Martrat, B., Masson-Delmotte, V., Parrenin, F., Seidenkrantz, M.-S., Veres, D., Waelbroeck, C., Zahn, R., 2015. Sequence of events from the onset to the demise of the Last Interglacial: Evaluating strengths and limitations of chronologies used in climatic archives. Quaternary Science Reviews 129, 1–36. https://doi.org/10.1016/j.quascirev.2015.09.018

Granoszewski, W., 2003. Late Pleistocene vegetation history and climatic changes at Horoszki Duże, eastern Poland: a paleobotanical study. Acta Palaeobotanica Suppl. 4, 1–95.

Grauwinkel, B., 1987. Beitrag zur Pilzflora des Erlenbruchwaldes – NSG Sodenmatt bei Bremen. Bremen: Veröffentlichungen aus dem Übersee-Museum Bremen A/8.

Grimm, E.C., 2015. TILIA Software.

Havinga, A.J., 1984. A 20-year experimental investigation into the differential corrosion susceptibility of pollen and spores in various soil types. Pollen et Spores 26, 541–558.

Havinga, A.J., 1967. Palynology and pollen preservation. Review of Palaeobotany and Palynology 2(1), 81–98. https://doi.org/10.1016/0034-6667(67)90138-8

Hicks, S., 2001. The use of annual arboreal pollen deposition values for delimiting tree-lines in the landscape and exploring models of pollen dispersal. Review of Palaeobotany and Palynology 117, 1–29. https://doi.org/10.1016/S0034-6667(01)00074-4

Janczyk-Kopikowa, Z., 1991. Problemy palinostratygrafii glacjalnego plejstocenu Polski z uwzględnieniem wyników analizy pyłkowej osadów interglacjalnych z Besiekierza (środkowa Polska) (summary: Problems of the palynostratigraphy of the pleistocene in Poland and the palynological analysis of interglacial deposits from Besiekierz (central Poland)). Annales UMCS 46(1 Suppl.), 1–26.

Janssen, C.R., 1959. *Alnus* as a disturbing Factor in Pollen Diagrams. Acta Botanica Neerlandica 8(1), 55–58. https://doi.org/10.1111/j.1438-8677.1959.tb00005.x

Kłosowski, S., Kłosowski, G., 2015. Rośliny wodne i bagienne. Flora Polski. Multico, 1–336.

Kołaczek, P., Kupryjanowicz, M., Nalepka, D., Balwierz, Z., Bińka, K., Fiłoc, M., Granoszewski, W., Majecka, A., Malkiewicz, M., Nita, M., Noryśkiewicz, B., Pidek, I.A., Walanus, A., Winter, H., 2018. *Artemisia* L. – Mugwort. In: Kupryjanowicz, M., Nalepka, D., Madeyska, E., Turner, C. (eds), Eemian History of Vegetation in Poland Based on Isopollen Maps. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences, 171–176.

Kulikowska, K., 2018. Rekonstrukcja krajobrazu w interglacjale eemskim na stanowisku Niesadna (Równia Garwolińska). Uniwersytet Marii Skłodowskiej-Curie w Lublinie, Lublin.

Kultys, K., Miroslaw-Grabowska, Zalat, A., Hrynowiecka, A., Łabęcka, K., Terpiłowski, S., Żarski, M., Pidek, I.A., 2023a. A palaeohydrological record of a complete Eemian series from Żabieniec Ża-19 (Garwolin Plain, Central Poland) with reference to palaeoclimate data. Acta Geologica Polonica 73(3), 355–378. https://doi.org/10.24425/agp.2023.145613

Kultys, K., Brzozowicz, D., Drzymulska, D., Szymanek, M., Mirosław-Grabowska, J., Pidek, I.A., Żarski, M., 2023b. Does the multi-proxy Eemian record from the Słup site (central Poland) indicate a more humid climate at the beginning of the hornbeam phase? Geological Quarterly 67(3), 24. https://doi.org/10.7306/gq.1694

Kuneš, P., Odgaard, B.V., Gaillard, M.-J., 2011. Soil phosphorus as a control of productivity and openness in temperate interglacial forest ecosystems. Journal of Biogeography 38(11), 2150–2164. https://doi.org/10.1111/j.1365-2699.2011.02557.x

Kupryjanowicz, M., 2008. Vegetation and climate of the Eemian and Early Vistulian lakeland in northern Podlasie. Acta Palaeobotanica 48(1), 1–130.

Kupryjanowicz, M., Granoszewski, W., 2018. Detailed palynostratigraphy of the eemian interglacial in Poland. In: Kupryjanowicz, M., Nalepka, D., Madeyska, E., Turner, C. (eds), Eemian History of Vegetation in Poland Based on Isopollen Maps. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences, 17–20.

Kupryjanowicz, M., Granoszewski, W., Nalepka, D., Pidek, I.A., Walanus, A., Balwierz, Z., Fiłoc, M., Kołaczek, P., Majecka, A., Malkiewicz, M., Nita, M., Noryśkiewicz, B., Winter, H., 2016. Instability of the environment at the end of the Eemian Interglacial as illustrated by isopollen maps of Poland. Geological Quarterly 60(1), 225–237. https://doi.org/10.7306/gq.1271

Kupryjanowicz, M., Nalepka, D., Pidek, I.A., Walanus, A., Balwierz, Z., Bińka, K., Fiłoc, M., Granoszewski, W., Kołaczek, P., Majecka, A., Malkiewicz, M., Nita, M., Noryśkiewicz, B., Winter, H., 2018. The east-west migration of trees during the Eemian Interglacial registered on isopollen maps of Poland. Quaternary International 467, 178–191. https://doi.org/10.1016/j.quaint.2017.08.034

Kupryjanowicz, M., Fiłoc, M., Drzymulska, D., Poska, A., Suchora, M., Żarski, M., Mroczek, P., 2021. Environmental changes of the stadial/interstadial type during the Late Saalian (MIS-6) – Multi-proxy record at the Wola Starogrodzka site, central Poland. Palaeogeography, Palaeoclimatology, Palaeoecology 572, 110420. https://doi.org/10.1016/j.palaeo.2021.110420

Kupryjanowicz, M., Fiłoc, M., Drzymulska, D., Żuk-Kępa, E., Żarski, M., 2023. Interglacjał eemski na stanowisku Wola Starogrodzka (Równina Garwolińska). In: Skurzyński, J., Jary, Z., Błaszkiewicz, M. (eds), Presented at the Streszczenia. XXVII Konferencja Stratygrafia Plejstocenu Polski „Późnoczwartorzędowe środowiska sedymentacyjne Pomorza Wschodniego. Stara Kiszewa, 132–134.

Lauterbach, S., Brauer, A., Litt, T., Schettler, G., 2012. Re-evaluation of the Bispingen palaeolake record – a revised chronology for the Eemian in Northern Germany. Geophysical Research Abstracts, EGU General Assembly 14.

Lisitsyna, O.V., Hicks, S., Huusko, A., 2012. Do moss samples, pollen traps and modern lake sediments all collect pollen in the same way? A comparison from the forest limit area of northernmost Europe. Vegetattion History Archaeobotany 21, 187–199. https://doi.org/10.1007/s00334-011-0335-x

Mamakowa, K., 1989. Late Middle Polish Glaciation, Eemian and Early Vistulian vegetation at Imbramowice near Wrocław and the pollen stratigraphy of this part of the Pleistocene in Poland. Acta Palaeobotanica 29, 1–176.

Matuszkiewicz, W., 1981. Przewodnik Do Oznaczania Zbiorowisk Roślinnych Polski. Warszawa, PWN, pp. 1–298.

Nalepka, D., Walanus, A., 2003. Data processing in pollen analysis. Acta Palaeobotanica 43(1), 125–134.

Niska, M., Mirosław-Grabowska, J., 2015. Eemian environmental changes recorded in lake deposits from Rzecino (NW Poland): Cladocera, isotopic and selected geochemical data. Journal of Paleolimnology 53(1), 89–105. https://doi.org/10.1007/s10933-014-9810-6

Nita, M., Kupryjanowicz, M., Nalepka, D., Balwierz, Z., Bińka, K., Fiłoc, M., Granoszewski, W., Kołaczek, P., Majecka, A., Malkiewicz, M., Noryśkiewicz, B., Pidek, I.A., Walanus, A., Winter, H., 2018. Sum of herb pollen (NAP). In: Kupryjanowicz, M., Nalepka, D., Madeyska, E., Turner, C. (eds), Eemian History of Vegetation in Poland Based on Isopollen Maps. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków, 225–227.

Pidek, I.A., 2007. Nine-year record of *Alnus* pollen deposition in the Roztocze region (SE Poland) with relation to vegetation data. Acta Agrobotanica 60(2), 57–64. https://doi.org/10.5586/aa.2007.031

Pidek, I.A., Poska, A., 2013. Pollen based quantitative climate reconstructions from the Middle Pleistocene sequences in Łuków and Zdany (E Poland): Species and modern analogues based approach. Review of Palaeobotany and Palynology 192, 65–78. https://doi.org/10.1016/j.revpalbo.2013.01.001

Pidek, I.A., Kupryjanowicz, M., Nalepka, D., Balwierz, Z., Bińka, K., Fiłoc, M., Granoszewski, W., Kołaczek, P., Majecka, A., Malkiewicz, M., Nita, M., Noryśkiewicz, B., Walanus, A., Winter, H., 2018. *Alnus* Mill. – Alder. In: Kupryjanowicz, M., Nalepka, D., Madeyska, E., Turner, C. (eds), Eemian History of Vegetation in Poland Based on Isopollen Maps. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences, 41–48.

Pidek, I.A., Zalat, A.A., Hrynowiecka, A., Żarski, M., 2021. A high-resolution pollen and diatom record of mid-to late-Eemian at Kozłów (Central Poland) reveals no drastic climate changes in the hornbeam phase of this interglacial. Quaternary International 583, 14–30. https://doi.org/10.1016/j.quaint.2021.02.032

Pidek, I.A., Poska, A., Hrynowiecka, A., Brzozowicz, D., Żarski, M., 2022. Two pollen-based methods of Eemian climate reconstruction employed in the study of the Żabieniec-Jagodne palaeolakes in central Poland. Quaternary International 632, 21–35. https://doi.org/10.1016/j.quaint.2021.09.014

Pidek, I.A., Hrynowiecka, A., Brzozowicz, D., Żarski, M., 2023. Palinostratygrafia Eemu i wczesnego Vistulianu w profilu Żabieniec Ża-19 (Równina Garwolińska). Presented at the Zlodowacenia i interglacjały w Polsce – stan obecny i perspektywy badań. Chęciny: Europejskie Centrum Edukacji Geologicznej, 54–55.

Prager, A., Theuerkauf, M., Couwenberg, J., Barthelmes, A., Aptroot, A., Joosten, H., 2012. Pollen and non-pollen palynomorphs as tools for identifying alder carr deposits: A surface sample study from NE-Germany. Review of Palaeobotany and Palynology 186, 38–57. https://doi.org/10.1016/j.revpalbo.2012.07.006

Roman, M., Mirosław-Grabowska, J., Niska, M., 2021. The Eemian Lakeland of the central Polish Plain: Environmental changes and palaeogeography. Palaeogeography, Palaeoclimatology, Palaeoecology 561, 110087. https://doi.org/10.1016/j.palaeo.2020.110087

Shackleton, N.J., Chapman, M., Sánchez-Goñi, M.F., Pailler, D., Lancelot, Y., 2002. The Classic Marine Isotope Substage 5e. Quaternary Research 58(1), 14–16. https://doi.org/10.1006/qres.2001.2312

Solon, J., Borzyszkowski, J., Bidłasik, M., Richling, A., Badora, K., Balon, J., Brzezińska-Wójcik, T., Chabudziński, Ł., Dobrowolski, R., Grzegorczyk, I., Jodłowski, M., Kistowski, M., Kot, R., Krąż, P., Lechnio, J., Macias, A., Majchrowska, A., Malinowska, E., Migoń, P., Myga-Piątek, U., Nita, J., Papińska, E., Rodzik, J., Strzyż, M., Terpiłowski, S., Ziaja, W., 2018. Physico-geographical mesoregions of Poland: Verification and adjustment of boundaries on the basis of contemporary spatial data. Geographia Polonica 91(2), 143–170. https://doi.org/10.7163/GPol.0115

Suchora, M., Kultys, K., Stachowicz-Rybka, R., Pidek, I.A., Hrynowiecka, A., Terpiłowski, S., Łabęcka, K., Żarski, M., 2022. Palaeoecological record of long Eemian series from Kozłów (Central Poland) with reference to palaeoclimatic and palaeohydrological interpretation. Quaternary International 632, 36–50. https://doi.org/10.1016/j.quaint.2022.02.022

Velichko, A.A., Novenko, E.Y., Pisareva, V.V., Zelikson, E.M., Boettger, T., Junge, F.W., 2005. Vegetation and climate changes during the Eemian interglacial in Central and Eastern Europe: comparative analysis of pollen data. Boreas 34(2), 207–219. https://doi.org/10.1111/j.1502-3885.2005.tb01016.x

Wasylikowa, K., 1964. Roślinność i klimat późnego glacjału w środkowej Polsce na podstawie badań w Witowie koło Łęczycy (summary: Vegetation and climate of the Late-Glacial in central Poland based on investigations made at Witów near Łęczyca). Biuletyn Peryglacjalny 13, 261–417.

West, R.G., 1970. Pollen zones in the Pleistocene of Great Britain and their correlation. New Phytologist 69, 1179–1183.

Winter, H., Dobracka, E., Ciszek, D. 2008. Multiproxy studies of Eemian and early vistulian sediments at Rzecino site (Łobez upland, western pomerania lakeland). Biuletyn Państwowego Instytutu Geologicznego 428, 93–110.

Zagwijn, W.H., 1996. An analysis of Eemian climate in western and central Europe. Quaternary Science Reviews 15, 451–469. https://doi.org/10.1016/0277-3791(96)00011-X

Zalat, A.A., Bober, A., Pidek, I.A., Żarski, M., 2021. Environmental and climate change during the Late Saalian–Eemian Interglacial at the Struga site (Central Poland): A diatom record against the background of palynostratigraphy. Review of Palaeobotany and Palynology 288, 104386. https://doi.org/10.1016/j.revpalbo.2021.104386

Żarski, M., 2020. Detailed Geological Map of Poland Scale 1: 50, 000 Garwolin Sheet (566).

Żarski, M., Winter, H., Kucharska, M., 2018. Palaeoenvironmental and climate changes recorded in the lacustrine sediments of the Eemian Interglacial (MIS 5e) in the Radom Plain (Central Poland). Quaternary International 467, 147–160. https://doi.org/10.1016/j.quaint.2016.12.001