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Periodic lake-peatland shifts under the Eemian and Early Weichselian climate changes in Central Europe on the basis of multi-proxy studies

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ABSTRACT

Long-term palaeoecological sequences dated to the Eemian interglacial and Weichselian glaciation are crucial for understanding cyclic climate changes and ecosystem responses. This article presents a multi-proxy (palaeobotanical, zoological and geochemical) study considering variable aspects of the Eemian-Early Weichselian lake-mire succession in central Poland. The investigated sequence, collected from a former small kettle-hole, revealed many ecosystem alterations, i.e. warm stages led to the terrestrialisation of the lake, whereas stadial coolings to its reappearance. Hence, we examined whether: (i) the Eemian warming influenced the ecological succession of the lake, (ii) lakes which reappeared during the Herning and Rederstall stadial coolings developed alike and (iii) the beginning of peatland functioning (interglacial or interstadial) had an impact on further plant succession. The results show that thermal amelioration during the Eemian interglacial supported domination of *Tetraedron minimum* and *Pediastrum boryanum* var. *boryanum*, which contributed to the sedimentation of bituminous shales. The expansion of *Salvinia natans* in the final stage of lake existence (Middle Eemian) was probably a result of the mild climate characterised by the lack of late spring frosts. Algae, in contrast to Cladocera, revealed bipartition of the Herning and Rederstall stadials (older sections were colder, younger warmer). However, geochemical and isotopic data point to the very low productivity of the lakes during those stadials. The lake that existed during the Herning stadial revealed very low taxonomical diversity of Cladocera, whereas that during the Rederstall was characterised by relatively high diversity of this group. During the Late Eemian and Brørup interstadial, rich fens with some oligotrophic patches with *Sphagnum* sp. developed. This study revealed that small water bodies, due to their very local character and often uniqueness of palaeo-records, may be a very valuable source of information about climate and palaeoecology of different groups of organisms during the Eemian interglacial and the Weichselian glaciation.

1. Introduction

Glacial–interglacial cycles led to changes in distribution, cover and structure of lakes in the temperate and boreal areas of Northern Hemisphere. Each deglaciation caused the appearance of a new system of lakes, through basin development and delivery of water from permafrost degradation. Subsequent interglacial warming stimulated their eutrophication, further shallowing and finally, in several cases, transition into mires (Björk, 2010). Climate changes in the glacial–interglacial cycles that control transformations in vegetation cover follow the pattern from open communities, being configurations of tundra, cold steppe or parkland, through early woodland boreal forest until climax mixed deciduous, deciduous or coniferous forests, then another borealisation of forests and subsequent woodland opening, connected with climate cooling, to final reestablishment of open communities (Andersen, 1966). Changes in woodland-open land proportion and their structure in catchments influence lakes (Smol, 2002; Antoniades, 2013). The development of mires provides new habitats for woodlands preferring high water tables (Rydin and Jeglum, 2006), and therefore lake terrestrialisation affects forest structure. On the contrary, climate cooling events caused, in some cases, an increase in the water table and lake regenerations, and through the increased landscape openness cooling events indirectly contributed to the changes in mineral and organic matter deposited in lakes (Pawłowski, 2011; Stivrins et al., 2015; Kołaczek et al., 2015; Niska and Mirosław-Grabowska, 2015).

Eemian (syn. Ipswichian, Mikulinian, Sangamonian, MIS-5e) and Weichselian (syn. Vistulian, Würmian, Valdaian, Devensian, Wisconsin, MIS-5e–MIS-1) were the last full interglacial and glacial periods, respectively (Cohen and Gibbard, 2011), and sequences spanning both time intervals were registered in different areas of Europe (e.g. Jastrzębska-Mamełka, 1985; Granoszewski, 2003; Klotz et al., 2003; Helmens,

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2014). These archives enable insight into the long-term ecosystem transformations and vegetation dynamics under dramatic climate changes, which might be important for the construction of models predicting future climate changes (Kühl et al., 2007). Especially small size basins are sensitive for different subtle environmental shifts (cf. Seppä, 2007). Their record of rapid climate changes and their influence on vegetation in the surroundings of the site, as well as internal ecosystem dynamics, are more pronounced in comparison with large lakes. However, basins of relatively small surface and deep enough to provide the possibility for the accumulation of deposits spanning long-time series, especially in areas covered by the maximum extent of the Scandinavian ice-sheet or in its direct vicinity are very rare (Jastrzębska-Mamełka, 1985; Balwierz and Roman, 2002; Granoszewski, 2003; Bińka and Nitychoruk, 2011; Mirosław-Grabowska et al., 2015; Niska and Mirosław-Grabowska, 2015).

This article presents a palaeoecological study carried out on a small palaeolake/peatland (ca. 1–2 ha) in central Poland that recorded ca. 40 k years of the Eemian and Early Weichselian environmental changes (Kołaczek et al., 2012). This archive recorded one full-interglacial sequence (Eemian), one interstadial warming (Brørup) and two cold stadials (Herning and Rederstall). The main focus of our study was put on internal and external factors influencing the functioning of the lake-mire palaeoecosystem. The main aim of this study was the reconstruction of long-term functioning of this palaeoecosystem. The following research questions have been addressed: (i) how did the Eemian warming influence ecological succession and trophic conditions of a small lake? (ii) did the lakes that reappeared during stadial cooling periods (Kołaczek et al., 2012) develop in the same way? and (iii) did the time of mire development, i.e. interglacial optimum or interstadial warming, matter for further plant succession on this mire? As the main tool in our research, a multi-proxy analysis, including pollen, non-pollen palynomorphs (NPPs), plant macrofossils, subfossil Cladocera, and carbon, nitrogen content and their isotopic composition from organic matter, was applied.

2. Material and methods

2.1. Site setting and chronology of the profile

The study site (51°45′36″N, 18°36′08″E; 135 m a.s.l.; ca. 1–2 ha) is located in Ustków in central Poland within the Turek Upland, the part of the South Wielkopolska Lowland (Fig. 1). The upland, whose characteristic feature is the presence of numerous small closed depressions distinct in the present-day landscape of the southern part, developed as a morainic field during one of the recessional stages of the Saalian Glaciation (Warta stage) (Klatkowa and Załoba, 1991; Kondracki, 1998).

An 11 metre long profile from the Ustków site was collected in 1990 from the central part of the buried kettle-hole mire using a piston corer of Więckowski's type. The lithology and chronostratigraphy was published by Kołaczek et al. (2012). The profile spans the period between the Late Saalian and Early Eemian transition until the Rederstall stadial, which was evidenced from the palynological analysis. Unfortunately, each attempt of thermoluminescence dating of this profile failed to reveal reliable results (Kołaczek et al., 2012).

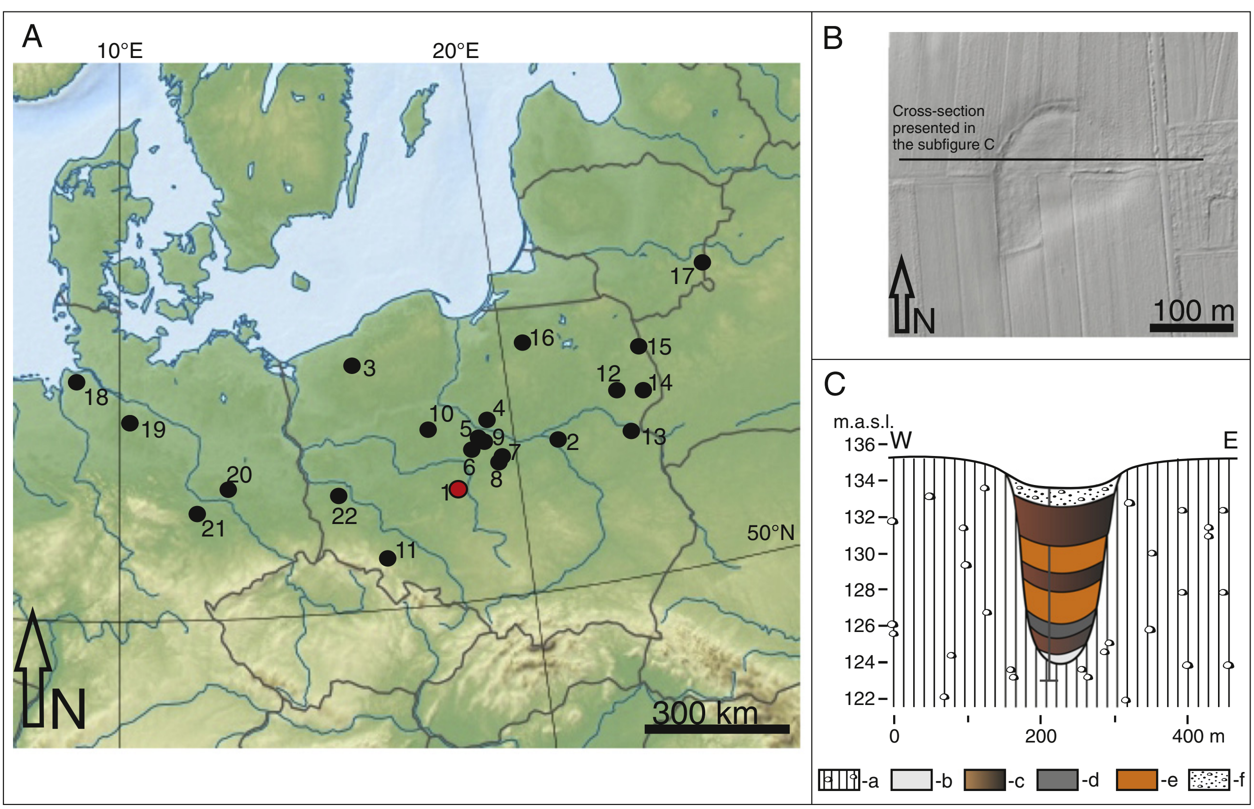

Fig. 1. The location of the Ustków site; A. in Central Europe; sites spanning the Eemian and/or Early Weichselian cited in the manuscript are marked by dots with numbers: 1 — Ustków (Kołaczek et al., 2012; this study), 2 — Warszawa-Wawrzyszew (Krupiński and Morawski, 1993), 3 — Rzecino (Niska and Mirosław-Grabowska, 2015), 4 — Studzieniec (Krupiński, 2005; Mirosław-Grabowska and Niska, 2007a), 5 — Kaliska (Mirosław-Grabowska and Niska, 2007b), 6 — Kubłowo (Roman and Balwierz, 2010), 7 —Besiekierz (Mirosław-Grabowska and Niska, 2005), 8 — Zgierz-Rudunki (Jastrzębska-Mamełka, 1985), 9 — Łanięta (Balwierz and Roman, 2002), 10 — Sławoszewek (Pawłowski, 2011), 11 — Imbramowice (Mamakowa, 1989), 12 — Czaple (Bińka and Nitychoruk, 2011), 13 — Horoszki Duże (Granoszewski, 2003); 14 — Solniki (Kupryjanowicz, 2008; Mirosław-Grabowska et al., 2015), 15 — Starowlany (Niska and Kołodziej, 2015), 16 — Niedzica (Bińka et al., 2011), 17 — Medininkai (Šeirienė et al., 2014), 18 — Oerel (Behre et al., 2005), 19 — Bispingen (Kühl and Litt, 2003), 20 — Gröbern (Boettger et al., 2000; Kühl and Litt, 2003), 21 — Neumark-Nord 2 (Bakels, 2012), 22 — Białowice (Kuszell et al., 2012); B. local topography of the Ustków site (LiDAR-derived topography map; http://www.geoportal.gov.pl/); C. cross-section of the kettle-hole from which the profile was collected (Kołaczek et al., 2012, corrected); a — glacial till, b — mineral loam, c — organic loam, d — bituminous shale, e — peat, f — various-grained sand with admixture of gravel.