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# Palaeoenvironmental and climate changes recorded in the lacustrine sediments of the Eemian Interglacial (MIS 5e) in the Radom Plain (Central Poland)

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ABSTRACT

The Radom Plain is a region with numerous fossil palaeolakes that formed a palaeolakeland. Lacustrine sediments of thickness varying from 0.5 to 18 m were encountered in numerous boreholes. Pollen analyses of the sediments filling the palaeolakes have proven that their sedimentation began after the retreat of the Saalian ice-sheet (MIS 6), continued during the Eemian Interglacial (MIS 5e), and terminated at the beginning of the Weichselian Glaciation (MIS 5d). Climate and palaeoenvironmental changes have been recorded in different deposits: muds, peats and gyttja. Local factors, such as reservoir depth, and geological conditions have influenced the type of the accumulated sediments. Eemian sites occur in two geomorphological positions: in small depressions on the glacial plateau and in small valleys in oxbow palaeolakes. Eemian lakes were formed from the melting of dead-ice blocks. 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 Glaciation. In many sites, a record of a complete Eemian succession is present, whereas in others it is fragmentary. Comparison of pollen data between the Radom region and other localities in Poland shows local and regional differences in the development of forest communities in the Eemian. In the Eemian sequences of the Radom Plain, a considerable contribution of *Tilia*, *Picea* and *Abies* pollen is distinct in the forest communities, often higher than in other Eemian sites of Central Poland. The particularly high percentage of *Tilia* (exceeding 30%), *Picea* (up to 67%) and *Abies* (30%) pollen are recorded in the Babin site. This phenomenon may indicate favourable environmental and climate conditions, facilitating further propagation of these trees. In the pollen record from the Babin site, three distinct abrupt/cool climate oscillations have been noted, with the oldest one recorded in the Saalian Glaciation. The two younger oscillations have been distinguished at the very beginning and at the very end of the Last Interglacial, respectively. Eemian sites from the Radom Plain are important for the reconstruction of palaeoenvironmental and palaeoclimate changes in the Eemian Interglacial in Poland and Europe.



## 1. Introduction

Deposition of sediments with the record of environmental and climate changes during the last interglacial (Eemian Interglacial, MIS 5e) (Mangerud, 1989) took place in various accumulation basins such as lakes, seas and oceans, volcanic craters and in various facies of fluvial and peat sediments. However, the reconstruction of environmental and climate changes of this interglacial is most precise based on data obtained from terrestrial sediments (Zagwijn, 1961, 1989, 1996; Andersen, 1966; Wijmstra and Smit, 1976; Beaulieu and Reille, 1984, 1992; Grüger, 1989; Litt, 1994; Mamakowa, 1989; Turner, 2002; Borisova, 2005; Velichko et al., 1991; Tzedakis et al., 2003; Seiriene and Kondratiene, 2005; Velichko et al., 2005; Brewer et al., 2008; Novenko et al., 2008; Boettger et al., 2009; Mirosław-Grabowska, 2009; Mirosław-Grabowska et al., 2015; Kupryjanowicz et al., 2016), and to a lesser degree – marine sediments (Seidenkrantz and Knudsen, 1997; Sánchez Goñi et al., 1999, Seidenkrantz et al., 2000; Head et al., 2005; Marks et al., 2013; Otvos, 2015). Based on pollen data, changes in vegetation indicate a specific trend in the vegetation succession, at first with the very high contribution of

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*Quercus*, followed by *Corylus*in forest communities, preceding the development of multispecies forests with *Carpinus*, *Tilia*, *Acer* andwith gradually entering *Picea* and *Abies*. The beginning and end of the interglacial is recorded in the development of pine-birch forests, in which trees with higher climatic requirements, such as *Ulmus* and *Fraxinus*, appeared and disappeared.

High resolution palinological investigations of terrestrial sediments, coupled with other investigations, including studies of marine (McManus et al., 1993; Seidenkrantz and Knudsen, 1997) and ice cores (Grootes et al., 1993; Jouzel et al., 1996), have allowed for a detailed reconstruction of climate changes during this interglacial. Although climate changes in Western and Central Europe had a larger amplitude than in Southern Europe, numerous pollen data have indicated that the climate of the Eemian Interglacial was stable and did not reveal larger fluctuations (Guiot et al., 1989, Zagwijn, 1996; Aalbersberg and Litt, 1998; Kühl and Litt, 2003; Klotz et al., 2004).

The record from high resolution pollen sequences has indicated the presence of short-term cool or arid climatic oscillationsin the oldest interglacial (Cheddadi et al., 1998; Sánchez Goñi et al., 2005; Müller et al., 2005; Sirocko et al., 2005; Seelos and Sirocko, 2007; Karabanov et al., 2000). Controversial results obtained from the Bispingen profile (Field et al., 1994) have pointed to a strong cooling during the *Carpinus* phase, not recorded in other profiles from Europe that were investigated using numerical methods (Guiot et al., 1989; Litt et al., 1996; Kühl and Litt, 2003; Klotz et al., 2004). A cold event at the termination of the Eemian Interglacial has also been observed in many long pollen sequences from Poland (Kupryjanowicz et al., 2016). The occurrence of climate oscillations during the interglacial obtained from pollen data has been supplemented with data from marine (McManus et al., 1993; Seidenkrantz and Knudsen, 1997) and ice cores (Greenland Ice-core Project (GRIP) Members, 1993; Grootes et al., 1993; Jouzel et al., 1996; North Greenland Ice Project members, 2004, The North Greenland Eemian Ice Drilling-NEEM (Community Members, 2012), indicating the instability of Eemian climate.

The majority of sites in Poland with lake sediments from the Eemian Interglacial (MIS 5e, Martinson et al., 1987) occur in a parallel belt in the central and eastern part of the country, between the maximal range of the last main phase of the Weichselian Glaciation (Kupryjanowicz, 2008; Kupryjanowicz et al., 2016; Marks, 2011, 2012) and the maximal range of the Saalian Glaciation (MIS-6; Cohen and Gibbard, 2010), particularly the Wartanian Stadial (Bruj and Roman, 2007; Lindner and Marks, 2012). The northern range of this occurrence is marked by the 51°30′ northern meridian, and the southern – by the 53°30′ northern meridian. Apart from this belt, sites with lake sediments are rather rare. In northern Poland, lake sediments are covered by a thick complex of glacial deposits from the Weichselian Glaciation (Marks, 2012), whereas in the south they have been removed by processes of erosion. Eemian lakelands continue to the west in Germany, where they have been recognized to the south of the maximal range of the Weichselian Glaciation (Menke, 1982; Caspers et al., 2002; Börner et al., 2015), as well as in the Netherlands (Bosch et al., 2000). Similarly as in Poland, these lakelands are dominated by small palaeobasins resulting from the melting of dead ice blocks after the Saalian Glaciation (MIS 6). Relatively numerous palaeobasins with sediments from the Eemian Interglacial occur also in Belarus, Lithuania, Ukraine and Russia (Marciniak et al., 2007; Pavlovskaya, 2000; Satkūnas et al., 1998; Satkūnas and Grigienė, 2012; Lozhkin and Anderson, 1991; Borisova, 2005).

Therefore, one of the aims of this paper, beside the reconstruction of the palaeoenvironment in the study area by the correlation of pollen and sedimentological data, is estimation of climate changes and documentation of short-term climatic events.

## 2. Study area and geological setting

The investigated area (Radom Plain) is located in the southern zone with sites demonstrating Eemian sediments (Fig. 1) (Kucharska, 2009; Żarski, 2014; Żarski et al., 2010, 2015) and thus is a part of the huge palaeolakeland.

The Radom Plain occurs in the transitional zone between the influence of continental and oceanic climates. The mean annual temperature for this zone exceeds 7.5 °C (Okołowicz and Martyn, 1984; Chrzanowski, 1991). So far, the state of knowledge on the palaeoclimate and palaeoenvironment of the Radom Plain area during the Eemian Interglacial was not satisfactory. The discovery of over a dozen sites with sediments of this age during the preparation of the Detailed Geological Maps of Poland (Złonkiewicz, 2001; Kucharska, 2009; Żarski, 2014) has contributed to pollen analysis in selected sites, which enabled recognizing the floral, palaeoclimate and palaeoenvironmental changes of the Radom Plain in the Eemian Interglacial, and presenting the specific climate of the region in the studied interval.

The study area is located within the Radom Plain (Kondracki, 2001), located in the southern part of the Mazovian Lowland. From the south, the Radom Plain borders with the foreland of the Holy Cross Mountains, which are part of the Małopolska Upland. The ground surface is generally located at 160–180 m a.s.l. The glacial plateau of the Radom Plain is cut by valleys of small rivers, which are tributaries of the Vistula River. The surface is generally covered by glacial tills, in places by fluvioglacial sands of the Saalian Glaciation (MIS 6) (Kucharska, 2009; Żarski, 2014), the ice-sheet of which was the last to cover the study area. Large parts of the area are covered by eolian sands and dunes, formed at the end of the Weichselian Glaciation. River valleys are filled with sands, gravel and muds of the Weichselian Glaciation, and by Holocene peats, muds and sands (Kucharska, 2009; Żarski, 2014). Sites with lacustrine and biogenic sediments of the Eemian Interglacial are present in the Radom Plain in two geomorphological positions: on the plateau and in the valleys. The plateau sites are located in small depressions, usually landlocked, on a post-glacial plateau built of glacial tills (Żarski, 2014). The valley sites are situated in contemporary valleys of small streams that incise the post-glacial plateau.

Preparation of subsequent sheets of the Detailed Geological Map of Poland has induced pollen studies in several sites that are briefly described below. Based on pollen data, the Saalian/Eemian and Eemian/Weichselian boundaries have been distinguished in the sections (Krupiński, 2007a, 2007b, 2008, 2009).

### 2.1. Plateau sites

**Łuczynów** (λ – 21°40′18.5″, φ – 51°23′26.3″- WGS 84, h – 168 m a.s.l), **Nowy Zamość** (λ – 21°44′1.8″, φ – 51°21′8.4″, h – 165 m a.s.l.) and **Florianów(** λ – 21°44′46.7″, φ – 51°23′43.8″, h – 170 m a.s.l.) are located in landlocked depressions near Zwoleń vicinity (Fig. 1). Length and width of these depressions reach about 60–150 m. The lithological column for these boreholes is presented in the compilation (Fig. 2). The boreholes terminated in glacial tills of the Saalian Glaciation (MIS 6). The tills are covered by diluvial-slope sands (Łuczynów, Nowy Zamość) or ice-dammed muds (Florianów) overlain by Eeemian lake muds, peats and gyttjas. The biogenic series reaches a thickness of: 4.10 m, 4.15 m and 3.90 m. Above the interglacial sediments occur muds (Nowy Zamość, Florianów), diluvial sands (Łuczynów) of the Weichselian Glaciation and Holocene peats or humus horizon (Fig. 2).

### 2.2. Valley sites

**Policzna** (λ – 21°37′20.9″, φ – 51°26′31.3″, h – 163 m a.s.l.),

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