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The east-west migration of trees during the Eemian Interglacial registered on isopollen maps of Poland

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ABSTRACT

The directions of the post-Wartanian (post-Saalian) migration of some thermophilous trees and shrubs into the territory of Poland was reconstructed on the basis of isopollen maps, prepared for the Eemian Interglacial based on the palynological data from 187 Polish pollen profiles. Isopollen maps clearly demonstrated, that all thermophilous trees, which appeared in this area in the early Eemian (*Quercus*, *Ulmus*, *Fraxinus*), migrated from the east or north-east. Also *Tilia* and *Alnus*, which arrived in the area of Poland in the middle part of the Eemian Interglacial migrated from the east. *Picea*, which colonized the territory of Poland twice: first at the very early stage of the interglacial, and then in the younger Eemian, migrated from the east and north-east. Only *Corylus*, *Carpinus betulus* and *Abies alba* migrated from other directions (from the south, from the south-west and from the south-west, respectively). Domination of the western and south-western directions of migration routes clearly differentiates the Eemian Interglacial from the Holocene, during which the majority of trees and shrubs migrated into territory of Poland from the south, south-east, south-west and west, and only a few, such as *Ulmus* and *Picea*, also from the east and north-east. We assumed that the most probable reason of this difference was a presence of the Wartanian (Saalian) refugia of many trees, including thermophilous taxa, in the Eastern Europe (west Russia or Black See region). From those regions, together with the decay of the ice sheet, these trees migrated directly into Central Europe along the northern slopes of the Carpathians, or at first migrated to the north via regions which were beyond the maximum range of the Saalian, and from there to the west after the ice sheet melted in this part of Europe.

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1. Introduction

During glacial extremes, small populations of thermophilous trees and shrubs persisted in southern Europe (south of the Alps), while restricted boreal populations might have also survived farther north (van der Hammen et al., 1971; Huntley and Birks, 1983; Bennett et al., 1991). This has been challenged by the notion of northern cryptic glacial refugia of trees with disjunctive distributions that were well north of southern regions (e.g. Willis et al., 2000; Stewart and Lister, 2001; Willis and van Andel, 2004). Tzedakis et al. (2013) examined the evidence for these tree refugia in northern Europe during the most extreme conditions of the Last Glacial (Weichselian; Vistulian in Polish stratigraphy) and the maximum contraction of tree populations. Their review revealed the absence of temperate trees north of 45°N and a west-east asymmetry in boreal tree distribution, with a treeless Western Europe north of 46°N, while restricted boreal populations persisted in Eastern Europe up to 49°N, and higher latitudes east of the Fennoscandian ice-sheet.

Even less than about the location of the Weichselian refugia of European trees is known about their occurrence during the older glaciations, including the Saalian (Wartanian in Polish stratigraphy). Genetic data are lacking, and very scarce palynological records on the presence of trees during this glaciation come exclusively from the long sequences of maar site in southern Italy (e.g. Allen and Huntley, 2009) and in Greece (e.g. Tzedakis, 1993, 2003; Tzedakis et al., 2003). Therefore, information on the directions of the postglacial colonization of Europe by trees during the Eemian Interglacial can be very valuable for the reconstruction of locations of the Saalian tree refugia in Europe. Poland, located on the intersection of potential migration routes running from south to north and from east and south-east to west (and in the opposite direction), seems to be a relevant area for this type of study.

Thanks to pollen analysis, the vegetation changes during the Eemian Interglacial in Poland are very well documented (Mamakowa, 1989, 2003). Today there are almost 400 palynologically documented sites of this interglacial in our country (Kupryjanowicz et al., 2017). Even a preliminary review of the pollen data from the Polish sites pointed to a significant regional differentiation of vegetation in Poland in almost all periods of the Eemian Interglacial. It depended on the physiographic features of terrain and above all the order, rate and directions of migration of particular plant species. The isopollen maps are the best illustration of this kind of process. Isopolles are the synchronous lines that determine the area of the same pollen percentage of a particular plant taxon. They connect the points (sites) on the map that have the same amount of pollen at the same time. The term isopolles was introduced by Szafer (1935). Later, this synthetic way of the pollen data presenting was used and developed both in Europe (Sauramo, 1940; Firbas, 1949; Bertsch, 1953; Donner, 1963; Moe, 1970; Birks et al., 1975; Birks and Saarnisto, 1975; Huntley and Birks, 1983; Ralska-Jasiewiczowa, 1983) and in America (Davis, 1976; Bernabo and Webb, 1977; Davis and Webb, 1975; Webb et al., 1987). In recent years the role of the isopollen method has significantly increased due to the development of databases, specialized software and numerical methods. The isopollen maps began to be created with various types of computer software (e.g. Huntley, 1988, 1990a, b; Hoek, 1997a, b; Ralska-Jasiewiczowa et al., 2004a; Nalepka, 2005; Pokorny et al., 2006; Obidowicz et al., 2013a) and often converted into paleovegetation maps (e.g. Bradshaw and Holmquist, 1999; Lindbladh et al., 2000).

The Eemian isopollen maps created by us are the first synthetic comparison of information on the over-regional changes of vegetation in Poland during the Eemian Interglacial. This is also the first such complex study of the Eemian Interglacial in Europe. Our major aim was to: (1) reconstruct the directions of migration for major European trees and shrubs into the territory of Poland during the Eemian Interglacial, (2) compare their spread during the Eemian Interglacial and Holocene, and (3) use these data to locate potential Saalian refugia of studied taxa.

2. Material and methods

2.1. Sites used for drawing the isopollen maps

Based on Mamakowa's studies (Mamakowa, 1989, 2003) and original works from 2003 to 2014 we created a complete list of almost 400 Eemian sites in Poland, which are documented palynologically (Kupryjanowicz et al., 2017). We found that studies of the Polish Eemian sites are very diverse. Almost half of them are elaborated only with very low resolution and they are not included in our database. To the database exclusively comprised pollen data from 187 sites, where a complete pollen record was registered at least for one phase of the Eemian Interglacial. Their locations are shown in Fig. 1. To view a list of them and references see Appendix.

2.2. Palynostratigraphy of the Eemian Interglacial in Poland

Due to the lack of determination of the absolute age of the Eemian lacustrine and mire sediments, the horizons for which we drew isopollen maps are not time horizons, but they are biostratigraphical horizons, i.e. pollen horizons. They were determined on the basis of a detailed regional palynostratigraphy of the Eemian Interglacial elaborated specially for this project (Fig. 2). It is based on the division developed by Mamakowa (1989), in which seven regional pollen assemblage zones (E1 to E7 R PAZs) were distinguished in the Eemian succession of vegetation. Mamakowa's division is similar to other European regional palynostratigraphies (e.g. Andersen, 1961, 1966, 1975; Menke and Tynni, 1984), and this enables the correlation of regional pollen zones from the whole of Europe. However, the resolution of Mamakowa's palynostratigrahy is too low for the needs of our study. Therefore we have developed for the purposes of this study, a more detailed palynostratigraphy (Fig. 2). We divided each Mamakowa regional pollen zone into 2–4 subzones. A total of 24 regional pollen subzones were distinguished within the Eemian Interglacial and one each for the Late Wartanian (Saalian) and for the beginning of the Early Vistulian (Weichselian). Brief characteristics of distinguished regional pollen zones and subzones are shown in Table 1.

2.3. Construction of isopollen maps

Data necessary for isopollen maps of the Eemian Interglacial, are stored in the POLPAL system (Walanus and Nalepka, 1999; Nalepka and Walanus, 2003; see also web page http://adamwalanus.pl/Polpal.html). Most of the pollen tables that make up the Eemian database contains raw data, i.e. pollen counts. Several tables contain percentages, because they were available only in such a form. More than a dozen tables contain raw data, which were created by digitizing diagrams available in the literature or in other archives. These tables contain the data only for selected pollen spectra.

The pollen horizons, for which isopollen maps were constructed, are identified with only the single pollen spectra, selected within single pollen zones or subzones (Table 1). So Eemian pollen horizons are not the same as PAZ, or PASZ as defined by Birks (1986). In particular pollen profiles from one to 22 pollen horizons were distinguished (Fig. 3).

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