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Response of terrestrial and lake environments in NE Poland to Preboreal cold oscillations (PBO)

Magdalena Fiłoc [a,*], Mirosława Kupryjanowicz [a], Monika Rzodkiewicz [b], Magdalena Suchora [c]

[a] Department of Paleobotany, Institute of Biology, University of Białystok, Ciołkowskiego 1J, 15-425 Białystok, Poland
[b] Department of Quaternary Geology and Paleogeography, Institute of Geoecology and Geoinformation, Adam Mickiewicz University, Dzięgielowa 27, 61-680 Poznań, Poland
[c] Department of Hydrobiology, University of Life Sciences in Lublin, Dobrzańskiego 37, 20-262 Lublin, Poland

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ABSTRACT

The multi-proxy data (pollen, diatoms, Cladocera, ^{14}C) from the sediments of Lake Suchar Wielki representing the period ca. 11,600–9800 cal. BP have allowed the reconstruction of the influence of Preboreal cold oscillations on terrestrial and aquatic environments in NE Poland. The reconstructed changes in plant, cladoceran and diatom communities indicated an occurrence of four short-lasting negative climate events during the Preboreal period. The first three of them occurred in the early Preboreal (ca. 11,300–11,150, 11,100–11,000 and 10,900–10,850 cal. BP) and they were separated by short, warmer intervals. The obtained palynological data indicated that these events did not result in the transformations of the pine-birch forests strongly dominant in that period, but were only manifested by changes in the pollen production by the trees forming woodstands. In the lake during these coolings, cold-water Cladocera species developed, and the abundance of aquatic organisms decreased. Water level in the lake during two older early-Preboreal cold events increased significantly, and remained low during the last event. In the late Preboreal a fourth cooling took place. The cold peak was relatively short (ca. 10,300–10,200 cal. BP), but was preceded by a ca. 300-year-long period when conditions for plants were unfavourable. The drop in temperature was accompanied by a decrease in the humidity of the climate and a decrease in the water level in the lake. Again, the abundance of cold-water species increased. The acreage covered by pine decreased, and a temporary spreading of birch occurred. This last cold event in the Preboreal was followed by a relatively stable warm phase at the end of this chronozone. The recorded climate changes in NE Poland during the Preboreal correspond fairly well with those reported for other regions of Europe and the whole Northern Hemisphere.

1. Introduction

The temporary cooling at the beginning of the Holocene was first described by van Geel and Kolstrup as early as 1978. However, it was not until data from the Greenland ice core (GRIP) were available that a reconstruction of a more complete picture of this cooling, called the Preboreal oscillation (PBO), was possible, as well as the dating of this event to ca. 11,400–11,250 cal. BP (Kapsner et al., 1995; Björck et al., 1996; van der Plicht et al., 2004). The probable causes of the PBO were changes in the activity of the sun (Bond et al., 2001; Fleitmann et al., 2003; Hu et al., 2003; Gupta et al., 2005; Wang et al., 2005; Viau et al., 2006) and the influx of meltwater from Lake Agassiz (e.g. Fisher et al., 2002; Teller et al., 2002) and from Scandinavian ice sheets (Björck et al., 1997; Husum and Hald, 2002; Aharon, 2003; Nesje et al., 2004) to the North Atlantic, which resulted in disturbances of thermohaline circulation (e.g. Paul and Schulz, 2002; Renssen et al., 2002, 2006; Schulz et al., 2007). The PBO can also be linked to the drop in the atmospheric concentration of methane and greenhouse gases (Brook et al., 2000), as well as with stronger winds and weak rainfall in the Atlantic Ocean region (Hughen et al., 1996). This all suggests the global nature of this event.

* Corresponding author.
E-mail addresses: mfiloc@op.pl (M. Fiłoc), m.kupryjanowicz@uwb.edu.pl (M. Kupryjanowicz).

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The PBO is reflected in many terrestrial pollen records from North-Western Europe, Iceland and Greenland, in which it was dated similarly as in the Greenland ice core to ca. 11,300–11,150 cal. BP (Björck et al., 1996, 1997). At that time the Early Holocene expansion of birch forests was interrupted in Western Europe by a temporary spread of open grassland vegetation. This period is named the Rammelbeek Phase, and it is one of the best-described climate changes in our continent (e.g. van der Plicht et al., 2004; Bohncke and Hoek, 2007; Bos et al., 2007). Beyond palynological data, numerous other palaeoecological records from the Northern Hemisphere also indicate climate fluctuations at the beginning of the Preboreal period. The chironomid data from Lake Sils and Lake Silvaplana in the Central Alps present a temperature drop of 2 °C, dated to 11,450–11,350 cal. BP (Ilyashuk et al., 2009). In the chironomid record from Lake Brazi in the Romanian Carpathian Mountains, a decline in temperature by ca. 0.7 °C was noted between 11,480 and 11,390 cal. BP (Tóth et al., 2012). In Lake Lykkjuvøtn on the Faroe Islands the Preboreal cold event was dated to ca.11,200–11,120 cal. BP (Jessen et al., 2008), in Lake Torfadalsvatn in Iceland to ca. 11,200 cal. BP, and in Lake N14 in Greenland to ca. 11,075–11,000 cal. BP (Andresen et al., 2007). The occurrence of the cold oscillation at the beginning of the Preboreal is confirmed by records of water level rises in European lakes dated to ca. 11,250–11,050 cal. BP (e.g. Magny, 2001, 2004).

In north-eastern Poland, as a record of the PBO, the maximal spread of *Betula* registered at several sites studied by pollen analysis is described (e.g. Lake Miłkowskie – Wacnik, 2009; the Biebrza Upper Basin – Klerk et al., 2006; paleolake in Budzewo – Kołaczek et al., 2013). Also a short-term decrease in the $\delta\ ^{18}O$ Ostracoda record from Lake Hańcza between ca. 11,400 and 11,200 cal. BP is correlated with this cooling of the climate (Lauterbach et al., 2011).

A comparison of data on the PBO from the Netherlands (van Geel et al., 1981; Björck et al., 1997; van der Plicht et al., 2004; Bos et al., 2007), Switzerland (Ilyashuk et al., 2009), Germany (Bos, 2001), Poland (Ralska-Jasiewiczowa et al., 2003; Klerk et al., 2006; Wacnik, 2009; Laterbach et al., 2011; Kulesza et al., 2012; Kołaczek et al., 2013) and Lithuania (Stančikaitė et al., 2008, 2009) indicates that the cooling was not synchronized in Europe.

Sudden warming took place after the PBO, reaching 4 ± 1.5 °C. It is dated to 11,270 cal. BP in a GISP2 Greenland ice core (Kobashi et al., 2008). In north-western Europe rapid improvement of the climatic conditions was dated to ca. 11,125 cal. BP (Bos et al., 2007; Magny et al., 2007). This favoured the expansion of *Corylus avellana* (Giesecke et al., 2011). A reconstruction of water temperature based on the Mg/Ca concentration in planktonic foraminifers from the Andfjorden record, north Norway, shows an increase in temperature ca. 11,000 cal. BP by ca. 1 °C (Aagaard-Sørensen et al., 2011).

The next cold period took place in southern Greenland between 11,000 and 10,800 cal. BP. Two returns to more arid and colder conditions appeared in ca. 10,975–10,900 and 10,860–10,800 cal. BP, which were registered in Lake N14, and three cold episodes, appearing between 11,100 and 10,800 cal. BP were recorded in Lake Lykkjuvøtnon on the Faroe Islands (Andresen et al., 2007). During this period the water flow from Lake Agassiz to the North Atlantic continued; it began ca. 11,335 cal. BP and lasted until 10,750 cal. BP (Nesje et al., 2004).

The subsequent Preboreal cold period occurred after ca. 10,700 cal. BP. It was probably associated with a long-lasting influx of melt water from Lake Agassiz to the North Atlantic between 10,500 and 10,200 cal. BP (Nesje et al., 2004), or with three shorter influxes in 10,600, 10,400 and 10,300 cal. BP (Teller, 2001; Teller et al., 2002). Similarly dated (at ca. 10,600, 10,450 and 10,300 cal. BP) three cold events also occurred in the records from the Faroe Islands (Jessen et al., 2008). Three short-lasting changes in vegetation were registered in ca. 10,700, 10,500 and 10,300 cal. BP also in a profile from Lake Flåfattjønna, which could be a reflection of those climate oscillations in Norway (Paus, 2010). In the Alps, temperature drops of 0.8 °C (Heiri and Lotter, 2003) or even 1 °C (Larocque-Tobler et al., 2010) occurred in ca. 10,700–10,500 and 10,700–10,300 cal. BP, respectively. In the record from Lake N14 in Greenland, cooling in ca. 10,600 cal. BP was marked (Andresen et al., 2007). The short-term cooling in the eastern Carpathian Mountains was described between 10,350 and 10,100 cal. BP (Feurdean et al., 2008), and in the southern Carpathians a temperature drop of 1 °C occurred between 10,350 and 10,190 cal. BP (Tóth et al., 2012). The cooling also took place in Russia ca. 10,200–10,000 cal. BP, which was expressed by a marked reduction in vegetation cover (Subetto et al., 2002). All of these events were recorded at similar times in the whole of Europe, from the west to the east (Fig. 2). The reconstruction of water temperature from the Andfjorden record, north Norway, shows an increase in temperature after ca.10,000 cal. BP by ca. 1 °C (Aagaard-Sørensen et al., 2011).

Despite the large amount of data on coolings during the Preboreal period, the issue is still not well recognized, and requires new paleoecological data that will allow for better interpretation. In this article we present our research on Preboreal climate fluctuations registered in the multi-proxy record from a small dystrophic lake in NE Poland, located in the transitional zone between oceanic and continental climates (Woś, 1995). Due to this specific location, this region is an interesting area for palaeoecological study. We discuss the implications of Preboreal climate oscillations for the terrestrial and aquatic environmental changes in this part of Europe. This will result in a better understanding of the complexity of these changes and their connection with similar changes registered in records from other regions of Europe.

2. The study area

Lake Suchar Wielki (8.9 ha, 9.6 m max. depth, 54°01′41″ N, 23°03′21″ E) is located in Wigry National Park (WNP), few kilometres to the west of Lake Wigry, the biggest lake in this park. In the physical-geographical division it is assigned to the mesoregion of the East Suwałki Lake District, which is part of the Lithuanian Lake District. The climate of this area is temperate transitional with a tendency toward continentality, and it is characterized by the lowest temperatures in the lowland part of the country and the greatest number of days with average temperatures below 1 °C (Kondracki, 1994). The relief of the area was modelled by the Vistula (Weichselian) Glaciation (Ber, 2000). A number of kames, eskers, and frontal moraine heights occur in the northern and middle parts of WNP, while the southern part of the park comprises an extensive sandur with a strongly transformed primary glacial relief (Ber, 2009).

The forests of WNP constitute the northern part of the Augustów Primeval Forest, which covers almost 1150 km^2 and is one of the largest forest complexes in Poland. The severe climate of north-eastern Poland results in the occurrence of forest communities of a boreal character (Sokołowski, 1999). Numerous northern species forming these communities occur here at the limit of their ecological tolerance (Szafer and Zarzycki, 1977).

3. Methods

3.1. Coring

Drilling in a deep spot of Lake Suchar Wielki (Fig. 1) was carried out using Więckowski's probe with a length of 110 cm and a diameter of 5 cm. A core of bottom sediments with a thickness of 9.60 m was collected in winter 2009 from the ice surface of the lake.