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Lateglacial vegetation dynamics in the eastern Baltic region between 14,500 and 11,400 cal yr BP: A complete record since the Bølling (GI-1e) to the Holocene

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ABSTRACT

This paper discusses a complete record of vegetation history since the Bølling (GI-1e) warming (14,500 cal yr BP) up to the Holocene in Latvia. To date, this is the only complete record of such age in the eastern Baltic area and the northernmost area for which Bølling records are present. Combining pollen evidence, pollen accumulation rates (PAR) and plant macrofossil data, we assess the local and regional vegetation development, and we attempt to separate the true Lateglacial vegetation signal by removing the obviously redeposited thermophilous pollen; however, we remove not only their signal, we discuss the possibilities of separating the redeposition signal of the so-called “local Lateglacial trees”, pine and birch, by looking at their corrosion and degradation. The results show that the Bølling warming in the eastern Baltic area was a treeless tundra community consisting of the shrubs *Betula nana*, *Dryas octopetala* and *Salix polaris*. The Older Dryas cold spell is clearly recognised as a decline in the total concentration of plant macrofossils and PARs at between 14,200 and 13,500 cal yr BP. At 13,460 cal yr BP, the *B. nana* macrofossils disappear, and tree birch (*Betula* sect. *Albae*) appears, marking the start of tree birch forest. The presence of pine forest is confirmed by a variety of macrofossils, including bark, wood, needles and seeds, since 13,400 cal yr BP, at the same time at which pine stomata are found. The first identified pine stomata finds are associated with a *Pinus* PAR over 3000 grains cm^{-2} yr^{-1} and pine macrofossil finds with a *Pinus* PAR over 4000 grains cm^{-2} yr^{-1}. During the warmest period of the GI-1a (Allerød) at 13,000–12,700 cal yr BP, a pine forest with deciduous trees (birch – *Betula pendula* and aspen – *Populus tremula*) developed in the study area. The Younger Dryas (GS-1) cooling strongly affected the floral composition in eastern Latvia. The PAR of the tree taxa declined abruptly from a maximum value at 12,700 to below 1000 grains cm^{-2} yr^{-1} at 12,600 cal yr BP. The response time for the pine forest to collapse was 100 years according to the PAR data. Pine macrofossils disappear simultaneously with the pollen signal at 12,600 cal yr BP, yet occasional *Pinus* stomata are recorded throughout the Younger Dryas (GS-1). The landscape was treeless shrub tundra again, with *D. octopetala, S. polaris, B. nana* and *Juniperus* present. *Picea* is introduced in the region within the cold Younger Dryas and is represented by stomata (12,400–12,200 cal yr BP), needles, seeds and wood (since 12,050 cal yr BP up to the Holocene). The Pleistocene/Holocene boundary at 11,650 cal yr BP is marked by changes both in vegetation composition and sediment type. The organic rich gyttja accumulated instead of silts and clays, and the start of the Holocene warm period permitted forest re-expansion in eastern Latvia.

1. Introduction

Understanding the long-term dynamics of ecosystems is critical to predicting their response to future environmental changes. The postglacial environmental and climatic change with abrupt cooling, which interrupted the general warming trend as new land surfaced from under the ice cap of the last glaciation, has been studied for approximately a hundred years (Hartz and Milthers, 1901; Andersson, 1909; Hausen, 1913). These studies have revealed changes and rates of changes in Earth’s climatic system as well as locations of plant refugia, vegetation recolonisation routes and speeds (e.g., Bennett et al., 1991; Tarasov et al., 1999, 2000; Ravazzi, 2002; Ohlemüller et al., 2011). Palaeoecological records preserved in sedimentary deposits can provide unique insight into the nature of past ecosystems and the long-term plant population and plant community dynamics. Alongside the traditional Quaternary geological methods in investigating the glacial refugia and recolonisation, molecular tools (Taberlet et al., 1998; Sinclair et al., 1999;

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Hewitt, 2000; Petit et al., 2003; Cottrell et al., 2005) are applied to more precisely locate the plant refugia and regeneration from them. New evidence of Lateglacial (LG) habitat mammals, such as the woolly mammoth and the reindeer, moving together with the receding ice front and the open tundra strip, gives independent flora/community background to these areas (Ukkonen et al., 2006, 2011). The concept of treeless tundra in the eastern Baltic region fails to explain the rapidity of the LG and postglacial tree population dynamics of the region, showing that tree populations were present there at times (Heikkilä et al., 2009) and vanishing at others. Abrupt LG reversing climate change events occurred over the span of decades, such as in the Younger Dryas 12,850–11,650 cal yr BP (Lowe et al., 2008), when the cooling average summer temperatures dropped by approximately 3–4 °C, followed by a 7 °C warming in just 20–50 yr based on Greenland data (Dansgaard et al., 1989; Alley et al., 1993). Such reversals influenced the postglacial succession of flora and fauna (e.g., Litt and Stebich, 1999; Birks and Ammann, 2000; Lotter et al., 2000; Lõugas et al., 2002; Birks and Birks, 2004; Mortensen et al., 2011).

LG studies in the eastern Baltic area span over a century, focussing on ice-recession lines and chronology (Kalm, 2006). In recent years, new data on ice retreat were obtained with the help of varvochronology (Sandgren et al., 1997; Hang, 2003), new dating methods (Rinterknecht et al., 2006; 2008), palaeobotanical data (Saarse et al., 2009; Amon and Saarse, 2010; Amon et al., 2010, 2012; Kihno et al., 2011) and discussed in review papers (Raukas et al., 2004; Kalm et al., 2011).

This paper discusses a complete record of vegetation history since the Bølling warming (14,500 cal yr BP) up to the Holocene and is thus far the only record of this age in the eastern Baltic area and the northernmost area where Bølling records are available. We combine pollen evidence, pollen accumulation rate (PAR) and plant macrofossil data to assess the local and regional vegetation development. We attempt to separate the contemporary LG vegetation signal from the noise (caused by the reworked pollen from the older sediments) by removing (a) obviously redeposited thermophilous pollen and (b) corroded and degraded pollen of the so-called "local LG trees", such as pine and birch, which will perhaps help us to understand more precisely the LG vegetation in the eastern Baltic and elsewhere.

Fig. 1. Schematic relief map of the Baltic region showing the Lateglacial sites discussed in the text with the location of the Scandinavian Ice Sheet ice marginal zones as red lines (compiled from Kalm, 2006; Kalm et al., 2011). Ages of the ice marginal zones are from Saarnisto and Saarinen (2001), Saarse et al. (in press-a,in press-b), Amon and Saarse (2010), Kihno et al. (2011) and Kalm et al. (2011).

2. Study area

Lake Lielais Svētiņu (LS) is located in eastern Latvia, Rezekne district (56°45.5 N; 27°08.8 E), in the Lubana depression between the Latgale and Vidzeme uplands (Fig. 1). The area of the lake is 18.8 ha, the altitude is 96.2 m above sea level (a.s.l.), the mean depth is 2.9 m and the maximum depth is 4.9 m. The oblong brown-water humic water body belongs to the Daugava watershed area and has small inlets and outlets. The topography around the lake undulates, reaching up to approximately 100 m a.s.l., and the slope angle to lake shore is low. The highest estimated LG shoreline in the area is 108 m a.s.l. The Quaternary cover consists mainly of silts and clays of the Lubana basin, which have been greatly paludified in the Holocene. Forested areas (birch forest) and a few farms surround the lake today.

3. Material and methods

3.1. Coring and lithostratigraphy

The sediment was cored from lake ice using a 10-cm-diameter Russian corer in March 2009. The water depth below ice was 4 m. The sediment thickness reached 11.35 m of which the LG portion was the lowermost 3.75 m. In the present article, we used sample depths from the ice/water surface. Multiple parallel overlapping sediment cores were described in the field, photographed, carefully packed into 1 m plastic semi-tubes, wrapped in polyethylene film, labelled and transported to the laboratory for further analyses. The LG interval of the sediment core was analysed for the present study. The Holocene sediment was transported to Latvian University for additional analyses. The organic matter (OM) content of the sediment was determined by loss-on-ignition at 550 °C for 4 h (Heiri et al., 2001). The magnetic susceptibility (MS) was measured with a Bartington MS2E meter (Nowaczyk, 2001).

3.2. Chronology

Several samples containing material suitable for radiocarbon dating were selected and packed separately directly in the field, while most of the dating material was identified after sediment sieving in laboratory. Only terrestrial plant macrofossils were chosen as suitable material for radiocarbon dating, including twigs, bark, wood and seeds. The identified and cleaned specimens were sent to the Poznan Radiocarbon Laboratory, Poland. In total, 12 horizons were dated. The dates were calibrated, and an age–depth model was built with an OxCal 4.1 depositional model, including visible sedimentary boundaries (Reimer et al., 2004; Bronk Ramsey, 2008).