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Quantitative reconstruction of climate variability during the Eemian (Merkinė) and Weichselian (Nemunas) in Lithuania

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ABSTRACT

Little is known concerning climate changes in the Eastern Baltic region during the last interglacial–glacial cycle and in particular, climate changes during the Weichselian. In this study, a quantitative reconstruction of the mean January and July temperature for the Medininkai-117 site in Lithuania is presented. The reconstruction is based on pollen and plant macrofossils from this site, which reveal that the vegetation was characteristic of many northern Europe sites during the Eemian and Early Weichselian. Gradual evolution of the vegetation suggests that relatively uniform climate conditions existed during the Eemian. Our reconstructions support the view of a relatively stable Eemian, with short cooling phases of low amplitude. A strong increase in temperature was apparent during the beginning of the interglacial and decrease during the transition to the Weichselian. Reconstructed July temperatures of the Eemian interglacial were approximately 2 °C higher than today (18.5 °C; today: 16.2 °C) and were similar to today for January (−5.2 °C; today: −5.1 °C). July temperatures during the Early Weichselian were only ~2°C lower than during the Eemian, whereas the January temperatures gradually decreased. Winter temperatures were relatively high (above −10 °C) during the Early Weichselian.

Introduction

Investigations of the Eemian interglacial period are of special interest for paleoclimatologists, because it is the most recent complete warm period and presents vegetation and climate changes that are uninfluenced by human activity. Therefore, this interglaciation plays a substantial role in better understanding and modelling future climate changes during the current warm stage—the Holocene. The transition from the interglacial to the glacial period and several distinct climatic events characterize the Weichselian period.

During the last decades different views of the climatic conditions of the Eemian and Early Weichselian emerged. Generally, the Eemian interglacial has been considered a period of relatively stable climate (Boettger et al., 2000; De Beaulieu and Reille, 1989, 1992; Guiot et al., 1992; Mamakowa, 1989; Pons et al., 1992; Tzedakis, 1993). The identification of substantial climate fluctuations from the oxygen isotope data in GRIP ice -core records (Dansgaard et al., 1993) directed the discussion to possible climate instability (e.g., Cheddadi et al., 1998; Field et al., 1994; Rousseau et al., 2007; Seelos and Sirocko, 2007). The consensus currently focuses on the relatively stable nature of the Eemian climate and also on the presence of short and low -amplitude cooling intervals during this period (Müller et al., 2005). Discussion remains regarding 1) the presence of thermal-favoured episodes during the Early Eemian (Aalsbersberg and Litt, 1998; Cheddadi et al., 1998; Guiot, 1990; Kühl and Litt, 2003); 2) several thermal optimum periods (Klotz et al., 2003); 3) differences between present- day and Eemian climatic gradients over Europe (Aalsbersberg and Litt, 1998; Gebhardt et al., 2008, Kaspar et al., 2005; Velichko et al., 2008; Zagwijn, 1996); 4) whether the Eemian interglacial was, at least in some regions, warmer than present (Aalsbersberg and Litt, 1998; Gebhardt et al., 2008; Velichko et al., 2008); and 5) continentality during the Early Weichselian with relatively high summer temperatures (Henriksen et al., 2008; Kühl et al., 2007; Valiranta et al., 2009).

Therefore, new results of climate evolution during this period from new sites and localities are still significant and will expand our knowledge. Because climate reconstructions from the Eastern Baltic region are nearly absent the purpose of our investigation is to provide a detailed quantitative reconstruction of the climate development of the Eemian and Early Weichselian from pollen and plant macrofossils from the Medininkai-117 site in Lithuania and compare it to other reconstructions.

Eemian (Merkinė) interglaciation sediments are widespread in Lithuania and have been recorded from approximately 40 sections mostly concentrated in the southeastern part of the country. Sometimes their thickness reaches approximately 40–60 m in the sections, which are not covered by the sediments of the last (Weichselian, Nemunas) glaciation. Vegetation succession and paleoclimate fluctuations that are recorded in pollen and plant macrofossil diagrams during the last interglacial have been described in many papers and summarized by Kondratienė

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(1996). However, few attempts have been made to use numerical methods to obtain a more precise view of the climatic changes during this period. The first reconstruction, using probability theory proposed by Muratova et al. (1972), was performed by Kondratienė (1979) and based on pollen data. Climatic parameters were reconstructed only for the Eemian climatic optimum using data that were obtained from four sections. The reconstruction showed that the highest temperatures occurred during the beginning of the climatic optimum (M_{3a} zone), a decrease in temperature occurred during the M_{3b} zone and a repeated increase occurred at the end of climatic optimum (M_{3c} zone). During the last decade, the same method was used to process the pollen data of 34 Eemian sediment sections (Kondratienė and Šeirienė, 2000; Šeirienė and Kondratienė, 2005) and more detailed climate reconstructions were performed. The results obtained were similar to the previous ones. The methods appeared to be unsuitable for reconstructing the climate of treeless landscapes because it was impossible to obtain reliable parameters for the beginning and end of the interglacial and for the Weichselian glaciation. Other limitations of this method are that the growth probabilities were calculated only for a limited number of trees and only to the genus level. We know that the temperature and precipitation requirements of various species within the genus can be very different. In contrast, plant macro fossils can often be determined to species level and are more locally distributed; hence they can add important information about paleoclimate conditions (Birks and Birks, 2000).

Consequently, our recent study includes plant macro fossils and pollen and assesses climatic fluctuations by transferring the botanical data into quantitative climate information in a probabilistic manner which uses presence and quantifies uncertainty. For this approach, the Medininkai-117 section – one of the most complete late Pleistocene sediment sequences in Lithuania covering the time interval of the Eemian (Merkinė) interglacial to the Early-Middle Weichselian (Nemunas) – was chosen. The section was analysed for pollen and also plant macrofossil.

Study site and data

Study site

The Medininkai-117 borehole is in eastern Lithuania, 30 km south-east of Vilnius and 2.4 km north-west of Medininkai, in the central part of the Medininkai highland at 54°3′N and 25°7′E (Fig. 1). The modern January temperature at this site is −5.1 °C and the modern July temperature is 16.2 °C, with annual precipitation 675 mm. The site is a small paleolacustrine kettlehole filled with sediments. It is in the area outside the maximum limit of the Late Weichselian ice- sheet advance and presents a continuous sediment record spanning the entire Eemian (Merkinė) interglacial, Weichselian (Nemunas) glaciation and Holocene. Continuous sedimentation during these periods allows reconstructions

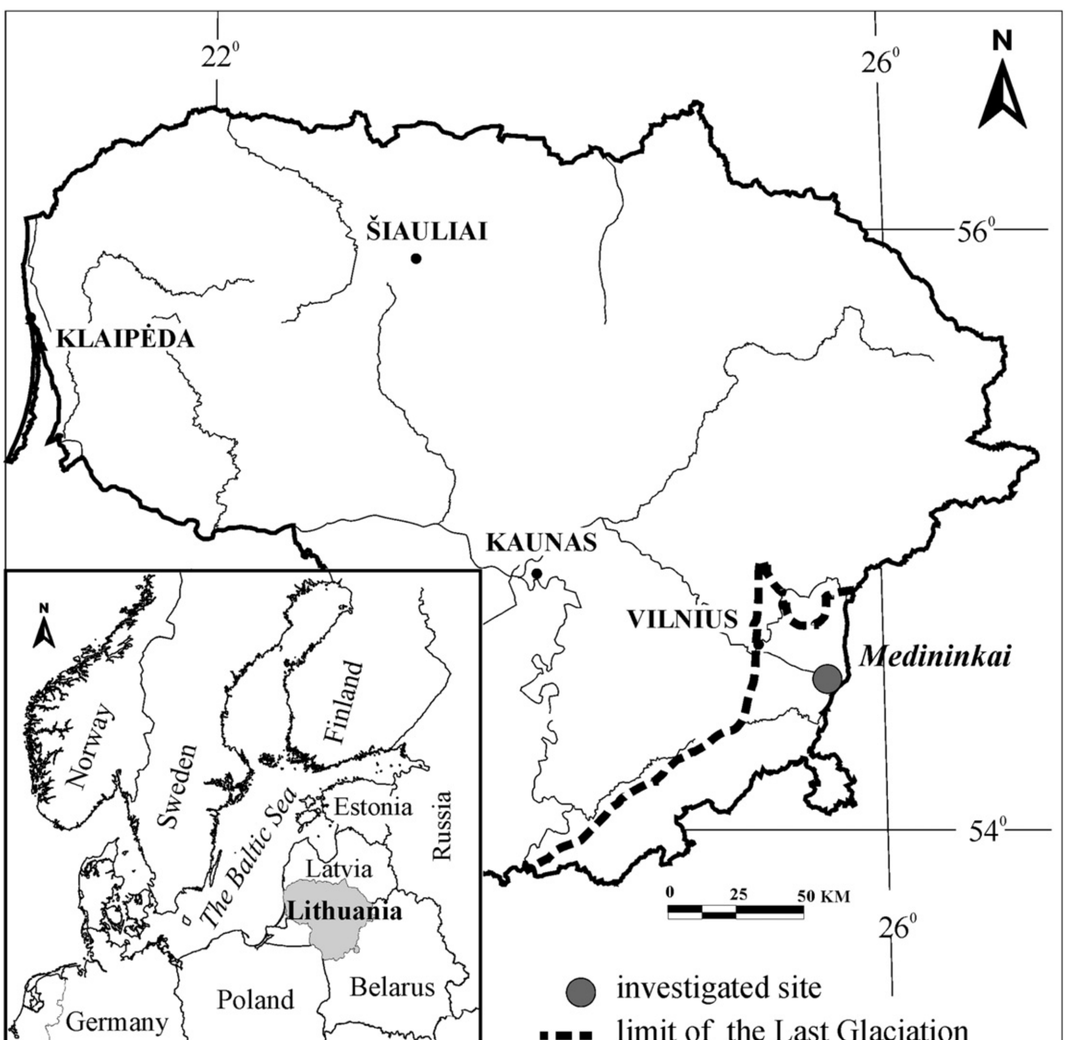

Fig. 1. Location of the site Medininkai-117 for which climate during the Eemian and Early Weichselian is discussed.