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The Holocene paleoenvironmental history of central European Russia reconstructed from pollen, plant macrofossil, and testate amoeba analyses of the Klukva peatland, Tula region

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ABSTRACT

Holocene climatic variability and human impact on vegetation are reconstructed from a region in central European Russia, which lies at an important ecotone between broadleaf forest and steppe. For the first time in this region we adopt a multi-proxy approach that combines analysis of local mire conditions from plant macrofossil and testate amoeba analyses with pollen-based quantitative climate reconstruction. The proxies indicate a long-term warming trend from 9700 to 7500 cal yr BP, interrupted by a series of short-term cold events. From 7500 to 5000 cal yr BP the results imply a relatively stable climate, warmer and drier than present, spanning the Holocene Thermal Maximum. Since 5000 cal yr BP the data suggest a change to cooler climate, but with centennial-scale variability. This shift at around 5000 cal yr BP is supported by extensive evidence from other sites. In the early Holocene, the region was occupied mainly by pine and birch forests. Broad-leafed forests of oak, lime and elm expanded after 7800 cal yr BP and remained dominant until the last few centuries. During the historical period, vegetation changes have been driven mainly by human activities.

Introduction

Holocene climate and vegetation dynamics are increasingly recognized as critical to understanding modern environmental processes and for making predictions for the future (Esper et al., 2002; Mann et al., 2009; Wanner et al., 2008). The central part of the East European Plain has received little palaeoenvironmental study, and its Holocene climate and vegetation history is poorly understood. The northwest of the Mid-Russian Upland, which spans the boundary of broadleaf forest and steppe, represents an opportunity to explore responses of an important vegetation ecotone to past shifts in climate during the Holocene. Palynological studies were carried out in the northern and northwestern parts of the Mid-Russian Upland in the 1970s and 1980s (Krupenina, 1974; Serebryannaya, 1976; Klimanov and Serebryannaya, 1986). However, these studies were based solely on pollen analysis, had relatively low sampling resolution, and, in some cases, were based on sub-optimal sedimentary environments that may have led to disturbance of the records. Here we aim to re-evaluate the Holocene vegetation and climate history of this region using a quantitative multi-proxy approach.

Peatlands have a long history as palaeoenvironmental archives (e.g., Blytt, 1876; Sernander, 1908) and in many regions are now the most widespread source of Holocene palaeoclimatic data (e.g., Blackford, 2000; Swindles et al., 2013). Bogs and fens are widespread in boreal and temperate regions and cores can be extracted with simple, manually-operated equipment (e.g., Aaby and Digerfeldt, 1986). Peatlands are effective at trapping atmospheric particles, including pollen grains, and preserving them due to slow decomposition of organic material in acidic, anaerobic and oligotrophic conditions. The highly organic nature of peat, and often excellent preservation of macrofossils, means that peats can be dated both easily and with a high degree of accuracy, allowing highly accurate and precise chronologies to be constructed (e.g., Mauquoy et al., 2008).

Peatland palaeoecological studies have dramatically increased in number since the early 1980s, driven by changing views of the role of climate in peat accumulation (e.g., Barber, 1981) and the development of new proxies and statistical methods. Changes in peatland surface wetness reflect the balance of precipitation and evapo-transpiration,

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and by reconstructing palaeo-wetness it is possible to gain an understanding of changing Holocene hydroclimate (e.g., Charman, 2007), although autogenic feedbacks complicate this situation (Swindles et al., 2012). More than thirty methods for palaeoenvironmental reconstruction from peatlands have been developed and tested (Chambers et al., 2012) with four of these constituting the vast majority of studies (pollen, plant macrofossils, testate amoebae, humification). Peatland palaeo-climate proxies respond to climate variables through different mechanisms and at different scales and all may be affected by non-climatic processes. Consequently, studies have increasingly concluded that better results are produced by combining multiple proxies and examining the extent to which records converge or diverge and the possible causes of any discrepancies (Chambers et al., 2012). Multi-proxy studies from peatlands have been geographically restricted with the vast majority in western and central Europe and North America. There have been few peat-based quantitative multiproxy studies in Russia, despite this region containing more than half the world's peat (Vomperski et al., 1999).

This paper presents new pollen, plant macrofossil, and testate amoeba records from Klukva mire ('Cranberry Mire', informal name), located in the northwestern part of the Mid-Russian Upland at the southern border of mixed conifer–broadleaf forest. The pollen record was used as a proxy for the vegetation composition and quantitative climate characteristics, whereas plant macrofossil and testate amoebae record were used to infer local hydrological and trophic conditions of the peatland. Analyses of these paleoenvironmental data shed new light on Holocene climate and vegetation changes in this region, and they allow us to examine the role of anthropogenic impacts on past vegetation.

Study area

The study area is located in the Upper Oka River basin (Belyov district, Tula region) in the northwest of the Mid-Russian Upland in the central part of the East European Plain (Fig. 1). The landscape is a gently undulating plain, with uplands of 210–240 m in elevation dissected by well-developed gullies and ravines. Bedrock topography and geological structure of the territory have had a great influence on modern relief and geomorphological processes. Lower Carboniferous limestone is widely distributed and close to the surface, affecting the path of the river and shape of the valley, and resulting in active karst processes. The thickness of Quaternary deposits varies from a few tens of meters in upland areas to more than 60 m in the deepest parts of the Oka River valley (Aseev, 1959). Glacial deposits of the area are represented by the lower till of the middle Pleistocene Dnieper Glacial complex (Velichko et al., 2011) extended to the East European Plain after the beginning of MIS 6 (about 200 ka). The till has been reworked considerably by subsequent fluvial processes. In the areas adjacent to the valley of the Oka moraine deposits are covered with a thick sequence of fluvioglacial sediments.

The region is characterized by a temperate continental climate and is located in the transitional zone between moderately moist northwestern

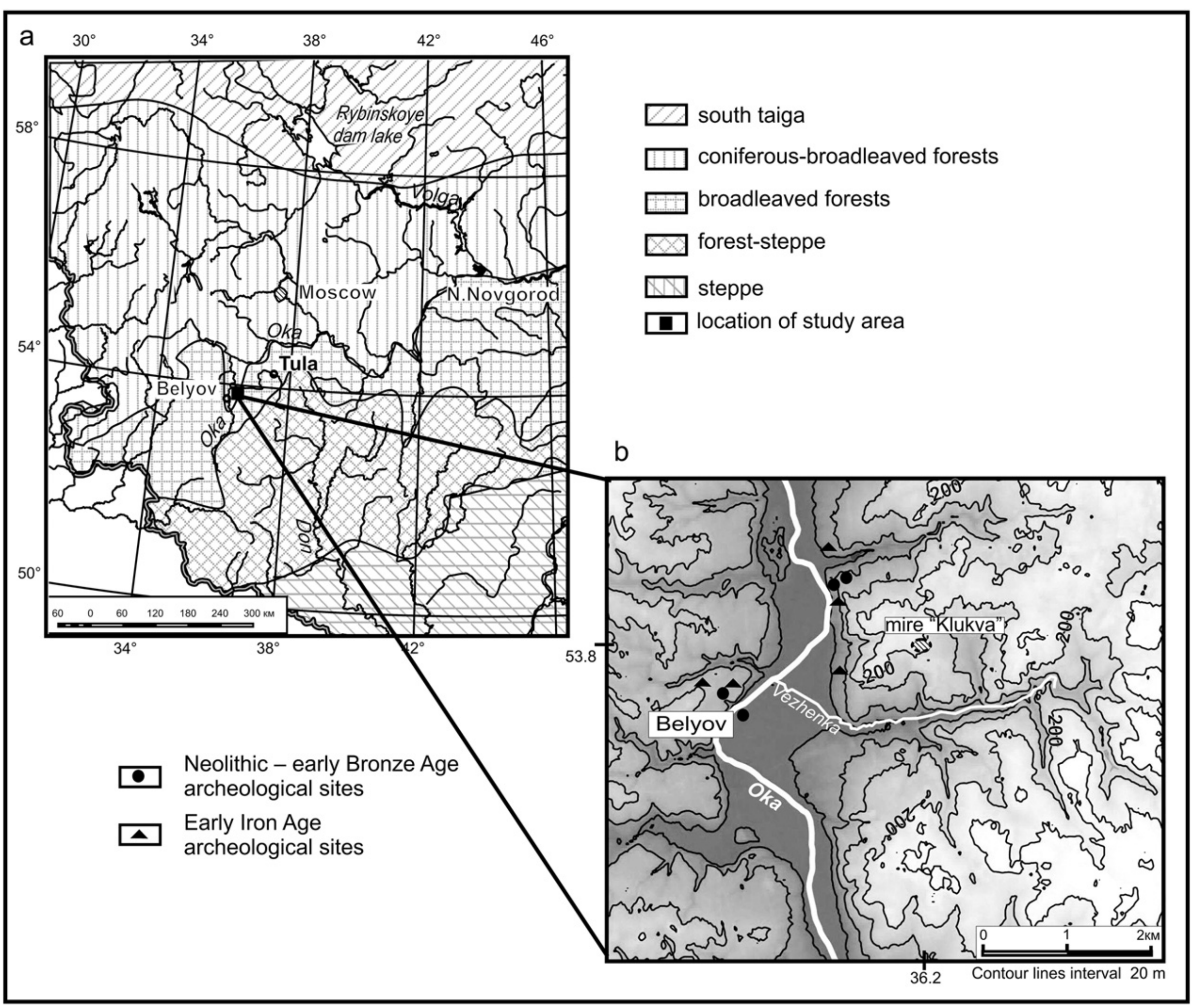

Figure 1. Geographic location of the study area. 1a — Vegetation zones of the central part of the East European Plain (based on Gribova et al., 1980). 1b - Local position of the Klukva mire (archeological sites in vicinity of the Klukva mire are given according to Archeological map of Russia, 1999).