Short communication

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Late-Glacial and Early Holocene history of Lake Khotavets (Mologa-Sheksna Lowland, NW Russia): a geodiversity conservation case study

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ABSTRACT. Evolution and regional climate changes during the Late Glacial/Holocene transition were studied using organic and inorganic geochemical proxies and pollen data from Lake Khotavets (NW Russia). Palaeoclimatic and palaeosedimentation sequence was described for the time slices 13.5 – 12.9, 12.9 – 11.8 and 11.8 – 11.1 cal. ka BP, attributed to the Allerød, Younger Dryas and Preboreal, respectively. Rapid organic accumulation, decrease of minerogenic input and woods expansion ~11.8 cal. ka BP were associated with the Holocene warming. The presented reconstruction determines scientific justification for specific geodiversity conservation.

Keywords: palaeolimnology, Early Holocene, Late Glacial, pollen, geochemical proxies, sedimentation, geodiversity

1. Introduction

Chronology of the climatic changes in the central Mologa-Sheksna Lowland (MSL) during the Last Glacial Termination and the Holocene onset is still poorly investigated. First reliably dated materials for the MSL Late Glacial climate dynamics, supported with geochemical evidence, were obtained for Lake Beloye of the northern MSL, where detailed palaeosedimentation cyclicity, starting from Bölling, was studied by Sadokov et al. (2022).

Bogs and mires span over 80% of the Darwin Nature Reserve territory, and more than 30 minor lakes are located on the boggy plains. These landscapes are essential for the biodiversity and geoheritage conservation in the central MSL, due to their biosphere effect for the wildlife and the local hydroclimate, and as well due to high scientific value (Crofts et al., 2020).

A multiproxy approach (geochemistry, AMS dating, palynology) enabled to disclose a series of palaeoclimatic and palaeohydrological changes, recorded in the lacustrine sediments.

2. Materials and methods

Lake Khotavets (N 58.568°, E 37.603°) is located within the Mologa river basin in the Vologda region. The lake is situated at 102.4 m above sea level (a.s.l.), covers an area of 1.24 km^2 and is an average 2 m depth.

The sediment cores were extracted in 2018 by Russian corer (diameter 5 cm, chamber length 1 m). Total length of the sediment sequence was 425 cm, which corresponds to the depth range 210 - 635 cm from the ice surface. X-ray fluorescence scanning was conducted in the University of Cologne (Germany) on the ITRAX XRF Core Scanner with Cr-anode tube, 30 kV, 55 mA, dwell time 5 sec and step size 2 mm. Upper 109 cm of the core was not used for measurements due to the laboratory error, so the measured core length was 316 cm. Total organic carbon (TOC) and total carbon (TC) content were measured on Dimatoc 2000 and Vario MICRO cube respectively, after freeze-drying and grounding. Total inorganic carbon (TIC) amount was calculated as a difference between TOC and TC. Pollen analysis was performed in the Institute of Limnology RAS (Russia). Technical treatment of samples for pollen analysis followed a standard method (Grichuk, 1940).

Age values were determined using accelerator mass spectrometry (AMS) at the Laboratory of the Radiocarbon Dating and Electronic Microscopy (Institute of Geography, Moscow). The obtained ^{14}C ages were calibrated using IntCal20 calibration curve (Reimer et al., 2020). An age-depth model was generated in R

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software ('rbacon' package), with the use of Bayesian inference.

3. Results and discussion

Three zones were outlined in the studied sequence according to the XRF and carbon measurements (Fig.). Zone I (635-588 cm, 13.5 – 12.9 cal. ka BP) embraces deposits of the interstadial environment, which is most prominently expressed during the sub-zone Ia in the decrease of minerogenic input of K and Ti and slightly enhanced TOC values (Davies et al., 2015) (Fig.). Allerød age of Zone I was confirmed by pollen and age-modelling, with relatively warm and wet climate reconstructed by the abundance of wood pollen (Sapelko and Sadokov, 2022).

The onset of cold and dry climate is related to the Younger Dryas, evidenced by the decline of the trees pollen and dominance of herbs pollen (*Artemisia*, Poaceae, Chenopodiaceae, Cyperaceae, *Dryas octopetala, Ephedra*) and by enhanced accumulation of K and Ti, presumably induced by the higher weathering rate (Davies et al., 2015) (Zone II (587-530 cm, 12.9 – 11.8 cal. ka BP), Fig.). The lake level started to fall stepwise from the sub-zone IIb, as documented by the Mn/Fe and distribution (Davies et al., 2015) (Fig.).

The Holocene onset is recorded by the most of the applied proxies. A shift to organic sedimentation is marked by lithological changes, rapid TOC growth and lithogenic elements (Ti, K) decrease. Elevated lacustrine bioproductivity is proposed for the sub-zone IIIa (529-507 cm, 11.8 – 11.2 cal. ka BP) (Fig.), confirmed by the sharp peaks of Ca and TIC content, which are probably related to the excessive carbonates formation in the water column (Kelts and Hsü, 1978). Expansion of pine and birch woods towards the Lake Khotavets basin over the grassy xerophyte plains indicates warmer and wetter climate conditions of Preboreal. Enhanced oxygenation of the bottom water (high Mn/Fe values) (Davies et al., 2015) is interpreted as a proxy of the ultimate palaeolake drainage~10.7 cal. ka BP.

4. Conclusions

New data on the Lake Khotavets sediments chemical and pollen composition provide basis for the palaeoclimate reconstruction for the Late Glacial and Early Holocene in the central MSL. The outlined geochemical and pollen units correspond well to the accepted Late Glacial climatostratigraphy of the Northern Europe. Allerød – Younger Dryas – Preboreal transition is documented in the vegetation changes derived from the pollen data. Weathering rate was the highest 12.9 – 11.8 cal. ka BP, altered by the rapid organic sedimentation and endogenic carbonates accumulation from ~11.8 cal. ka BP. The palaeolake level had dropped successively ~12.3, ~11.8 and ~10.7 cal. ka BP.

Palaeolimnological research of the Lake Khotavets basin became the first of a kind to investigate the Late Glacial evolution of the Darwin Nature Reserve natural systems. A series of the disclosed short-term palaeoenvironmental shifts recorded in the lacustrine sediments creates an insight into the origins of the local relief, hydrographical network and landscape structure, thus raising the scientific value of the geoheritage significantly.

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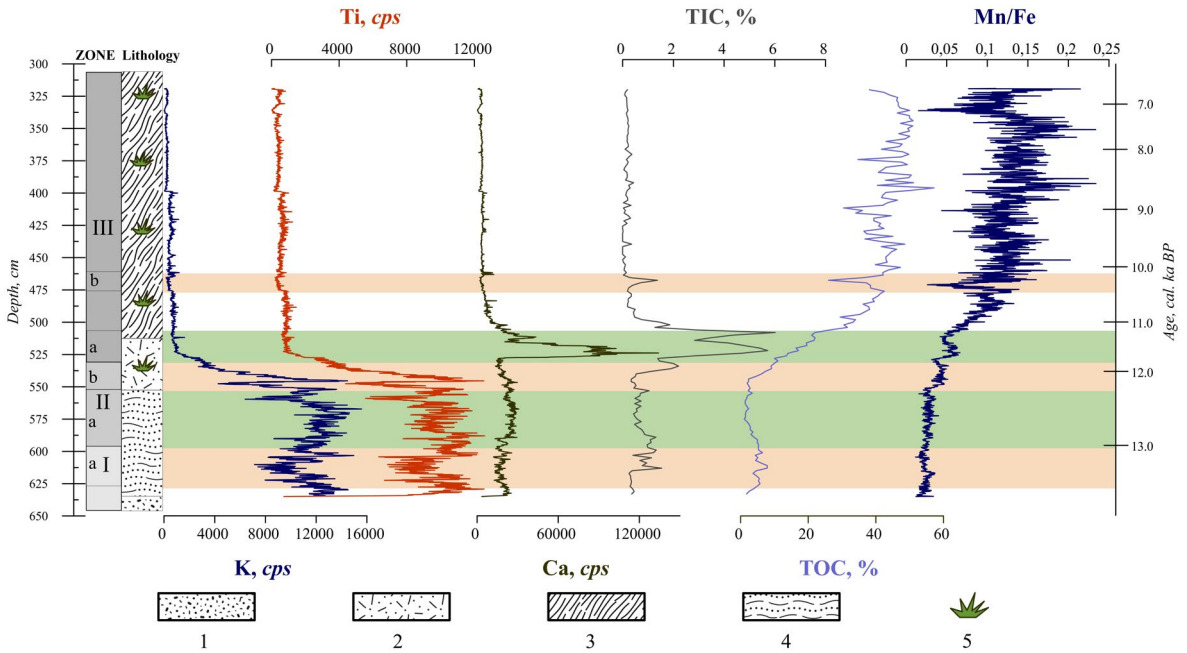

Fig. Lithology and vertical distribution of K, Ti, Ca, ratio Mn/Fe, TOC and TIC in Lake Khotavets sediments. Intensity of x-ray reflection is given in counts per second (cps). Age axis is built according to the age-depth modeling in 'rbacon'. 1 –layered sandy silt, 2 – silt with organic matter, 3 – organic muds, 4 – rhythmically layered silt with organic matter, 5 – plant fossils

Darwin State Nature Biosphere reserve», 2019, 2020). The authors are grateful to Martin Melles and Nicole Mantke for the laboratory studies conducted in the University of Cologne in frames of the joint academic grant scholarship program “Dmitrii Mendeleev” of St. Petersburg State University, University of Cologne and German Academic Exchange Service (DAAD) (2018).

Conflict of interest

The authors declare no conflict of interest.

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