Lithological and mineralogical characteristics of Late Pleistocene-Holocene sediments from Lake Turgoyak

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In this work, we present the results of studying the material composition of Late Pleistocene-Holocene sediments from Lake Turgoyak located on the eastern slope of the Southern Urals Mountains (fig. 1). Based on seismoacoustic profiling data, a sediment core measuring 5.8 meters in length was collected using a specialized corer from the central deep-water part of the lake. The age of the sediments was determined based on an updated depth-age model derived from AMS 14C dating data. The material composition of the sediments was studied by methods such as laser granulometry, X-ray diffraction, LOI and scanning electron microscopy.

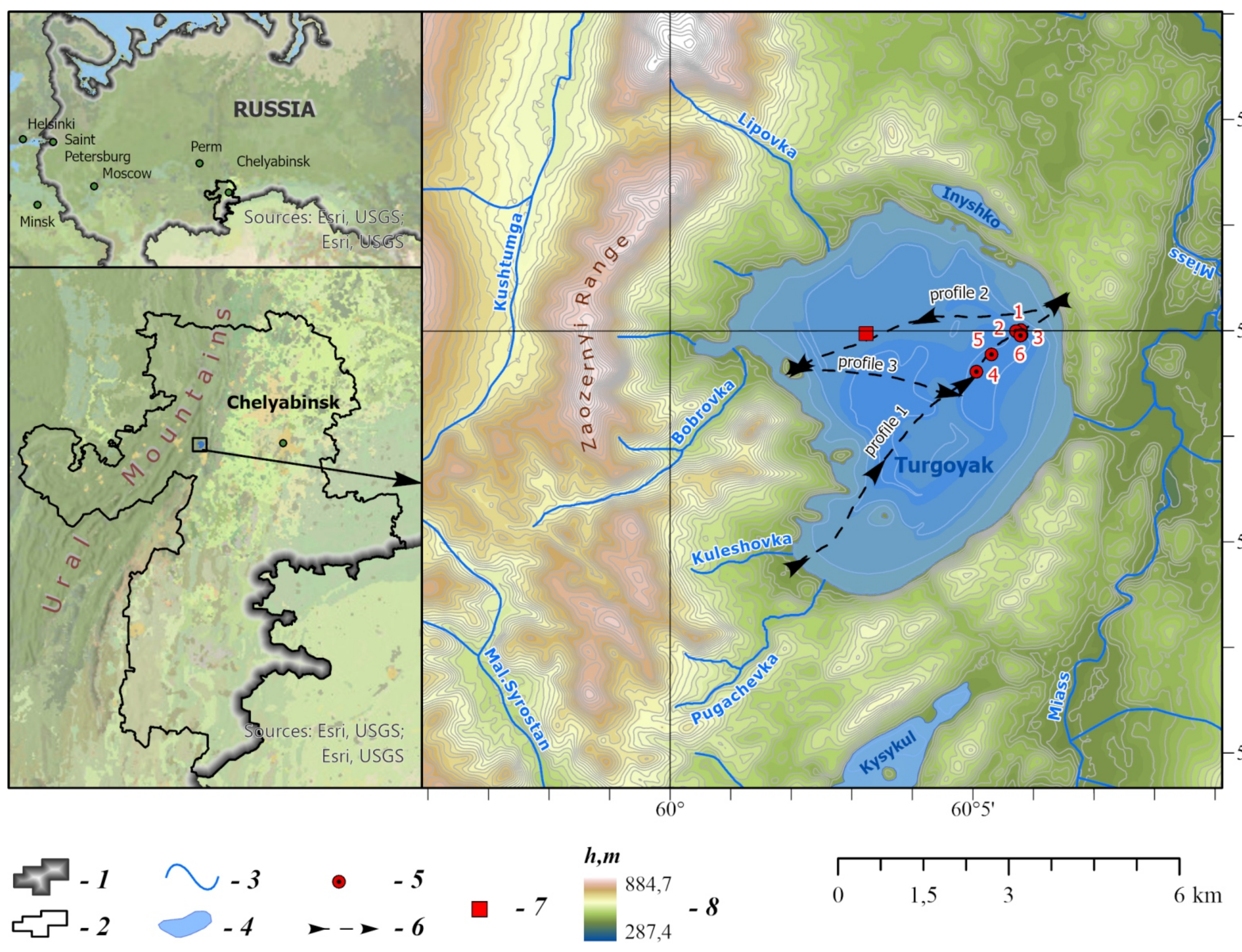

Fig. 1. Overview map: a) study area on the map of Russia; b) Southern Urals region; c) location of Lake Turgoyak in an intermountain basin; Legend: 1 - border of Russia; 2 - border of Chelyabinsk region; 3 - rivers; 4 - lakes; 5 - core sampling points; 6 - seismoacoustic profiles [Kosareva et al., 2023]; 7 - location of the core column presented in the study [Maslennikova et al., 2018]; 8 - absolute altitude marks, m.

It has been established that the sediments consist of minerogenic-organic, mineralized sapropel deposits, and mineral muds predominantly composed of particles of silt size fraction (53-78%). We identified and classified the following mineral groups: oxides (quartz, ilmenite, chromite, rutile); amphiboles (hornblende); island silicates (garnet, zircon, titanite, humite); micas (muscovite, biotite); framework alumino-silicates (feldspars, plagioclase); chain silicates (augite, hedenbergite); phosphates (apatite, vivianite, monazite); carbonates (calcite, witherite); sulphates (gypsum, barite); sulphides (pyrite); native elements (gold); intermetallics (nickel-iron, chrome iron, nickel-chrome iron) (fig. 3 - 8). It has been found that allochthonous minerals dominate in the lacustrine sediments (from 84 to 100%), while the share of authigenic minerals varies from 0 to 15%.

The composition of the introduced allochthonous material in the lake's bottom sediments includes a rich variety of rock-forming and accessory minerals typical of the Turgoyak granitoid massif, which serves as their primary source. Authigenic minerals were formed through bio-chemical processes occurring within the lake itself.

A comprehensive analysis of the data revealed that during the late Pleistocene climate stages (fig. 9 - 10), deposition occurred at the stage of shallow lake conditions with increased salinity resulting from cold arid climatic conditions. At this time, drainage basin areas were larger. Sedimentation took place under relatively high-energy sedimentary conditions and low productivity of the lake ecosystem. Differentiation of by instability of hydrodynamic regime in the lake. Terrestrial material input was mainly carried out through eolian processes, gradually diminishing as humidity increased and closed vegetation cover appeared. Terrigenous material supply came primarily from actively eroding contact-metasomatic zones of the Turgoyak massif and Sakmar complex. Yang Dryas marks the beginning of transition from predominance of aeolian transport of terrigenous matter to fluvial transport from watershed areas. During this period, the process of wetting begins, leading to an increase in accommodation capacity of the reservoir. The boundary between the Pleistocene and Holocene epochs, marking the onset of epochal warming, is indicated in the core by an AMS 14C date of 11710 ± 255 cal. years BP and characterizes the transition from a shallow lake phase with elevated salinity to one characterized by increasing accommodation capacity, greater depth, and reduced water salinity.

The litho-geophysical cross-section (lithological and seismic-acoustic characteristics, LOI, grain-size distribution of mineral components, and granulometric parameters) of the reference core from Lake Turgoiak, compiled based on the refined AMS14C dating model and compared with the stratigraphic scheme and climatic stages of Blytt-Sernander [Blytt A.G. 1876a,b; Sernander R. 1894; Ravazzi C. 2003], shown in Fig. 2, served as the basis for the lithological zonation of the studied sediment thickness.

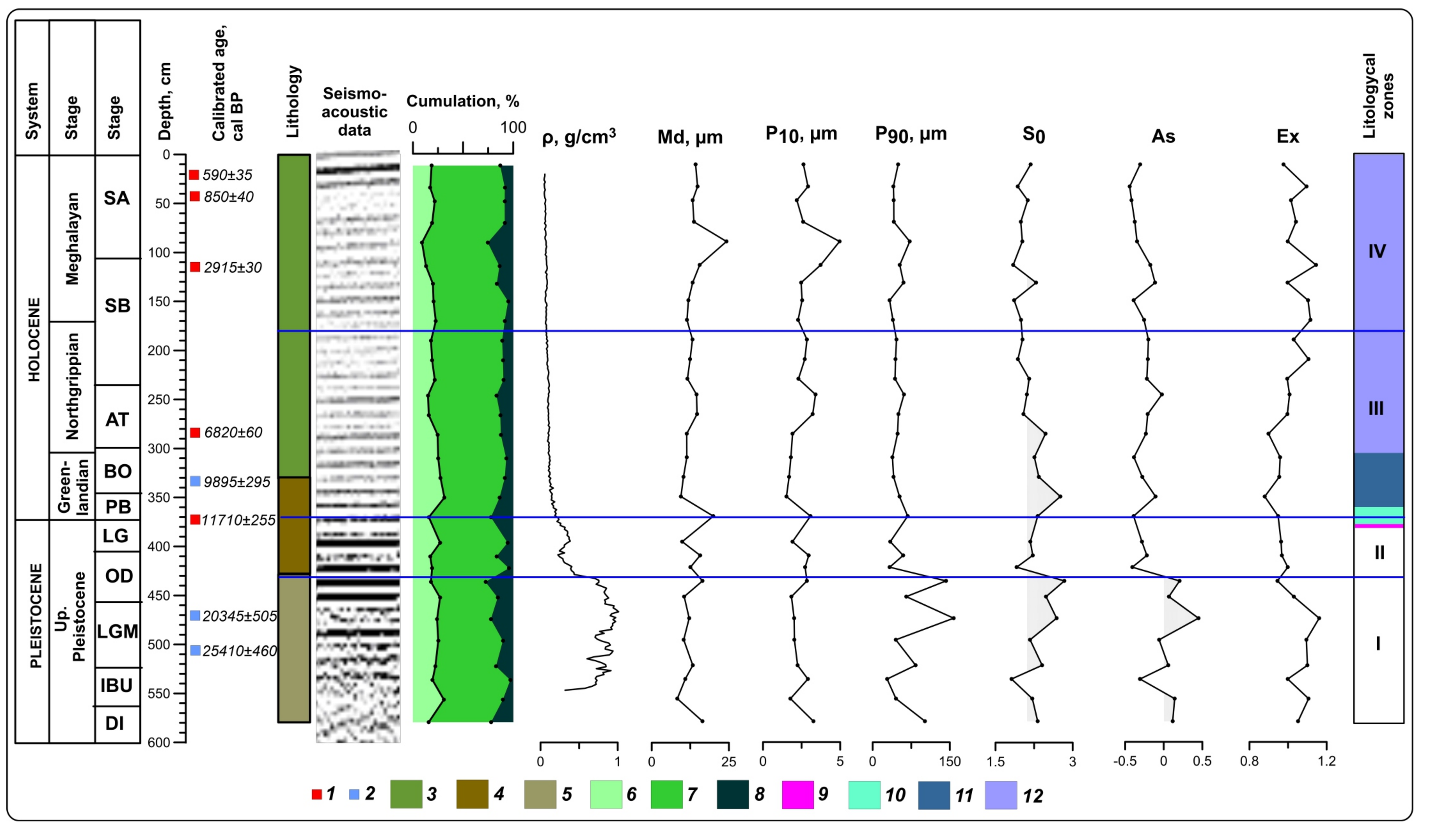

Fig. 2. Lithogeophysical profile of Core 1 from Lake Turgoiak. Climatic stages after [Blytt A.G. 1876a,b; Sernander R. 1894; Ravazzi C. 2003]: DI – Denekamp Interstadial, IBU – Ice Build-up, LGM – Last Glacial Maximum, OD – Old Driasian, LD – Late Glaciation including Early and Middle Dryas, Allerød and Bølling warmings, PB – Pre-Boreal, BO – Boreal, AT – Atlantic, SB – Sub-Boreal, SA – Sub-Atlantic. Symbols: 1 – Sampling locations for AMS14C dating, 2 – AMS14C dates transferred from Core 5 [Kosareva et al. 2023]; Sapropel deposit types by ash content: 3 – Mineral-organic, 4 – Mineralized, 5 – Mineral silts; Granulometry: 6 – Clay, 7 – Silt, 8 – Sand; 9–12 – Four developmental stages of the lake [Maslennikova et al., 2018]. Roman numerals denote lithological zones.

Electron microscope images of mineral grains from Lake Turgoiak sediments

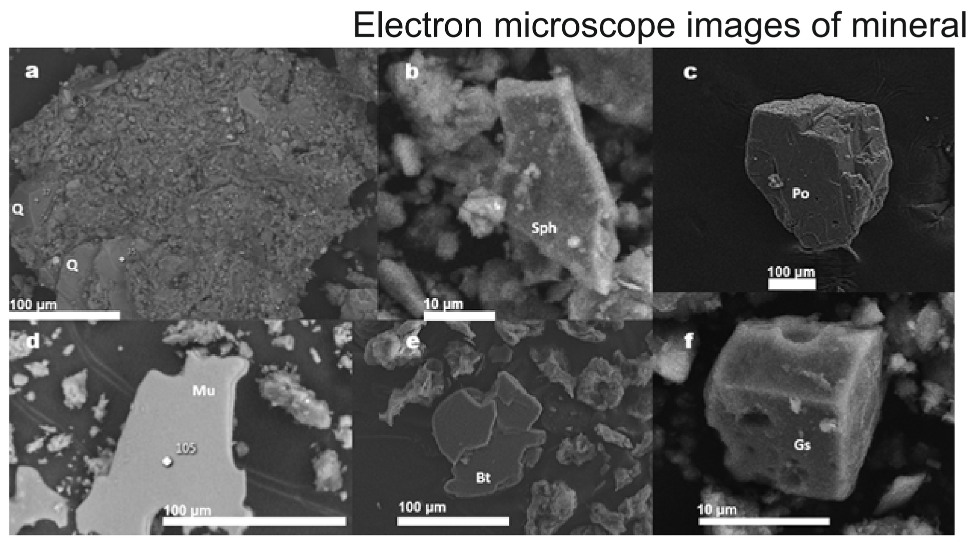

Fig. 3. a – quartz (Q), b – sphene (sph), c – pyrope (Po), d – muscovite (Mu), e – biotite (bt), f – grossular (Gs)

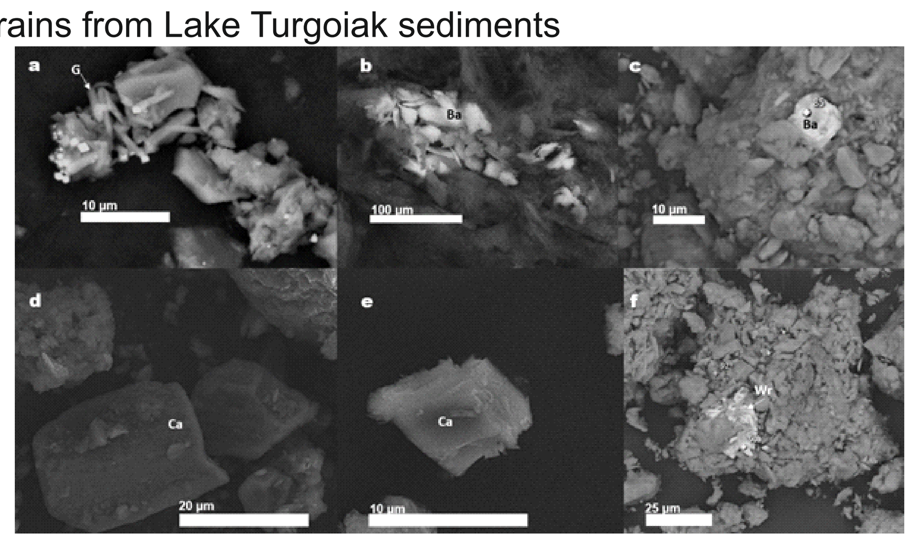

Fig. 4. a – gypsum (G), b,c – baryte (Ba), d,e – calcite (Ca), f – witherite (Wr)

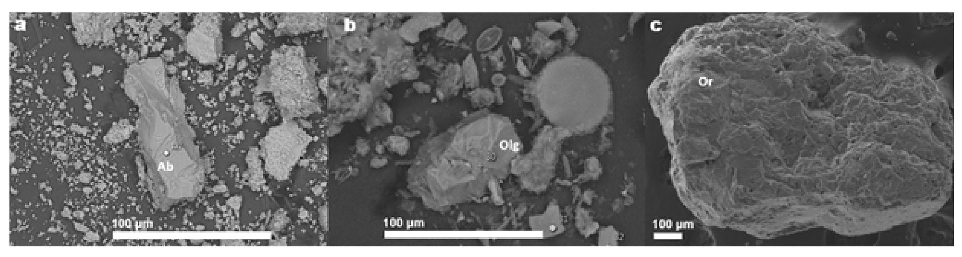

Fig. 5. a – albite (alb), b – oligoclase (olg), c – orthoclase (or)

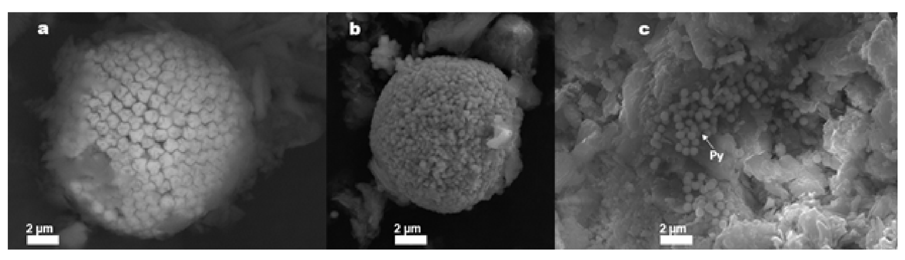

Fig. 6. Pyrite (Py) aggregates

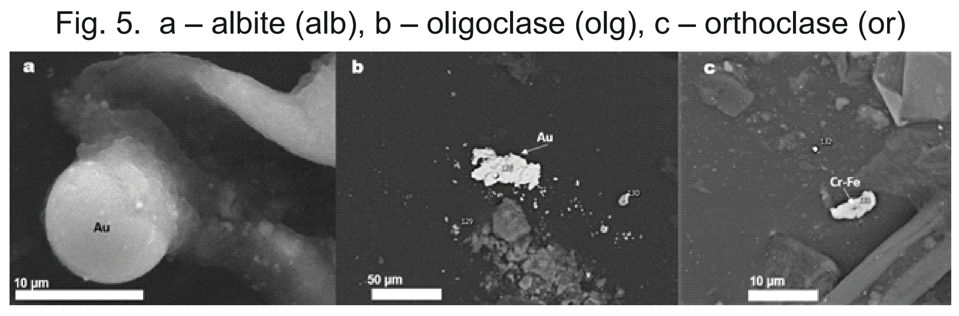

Fig. 7. a, b – native gold (Au) aggregates, c – Cr-Fe intermetallide.

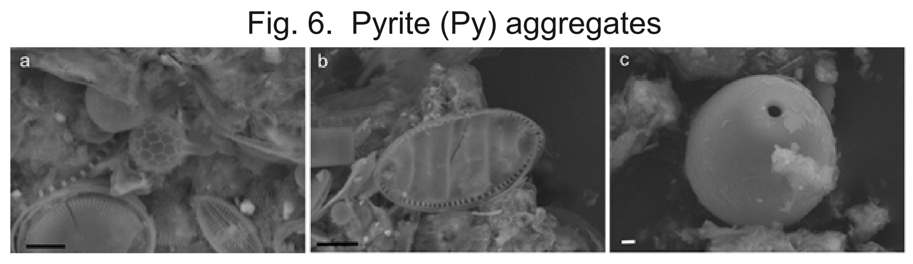

Fig. 8. Biogenic silica replacing parts of phytoplankton, zooplankton, protozoans, etc.

Sedimentation throughout the Holocene occurred under conditions of a deep-water basin with lower water salinity due to humidification and warming of the climate. Increasing accommodation capacity of the basin leads to gradual reduction of catchment area sizes. Sediment accumulation occurs under calm sedimentary conditions with high biological productivity of the lake ecosystem. Input of terrestrial material was provided by permanent and temporary streams, with influence of aeolian transport gradually decreasing as climate became more humid and dense vegetation cover developed. By the beginning of the Holocene, there is a noticeable increase in the contribution of allochthonous components. Organic content remains at Late Glacial levels, sharply increasing in the Boreal period and maintaining these levels throughout the entire Holocene. Throughout the Holocene, terrigenous material input originated from rocks belonging to five structural-geological zones surrounding the lake, but the dominant source remained the Turgoyak granitoid massif in the east. The composition of allochthonous minerals reflects the complex history of destruction and re-deposition of materials from these sources.

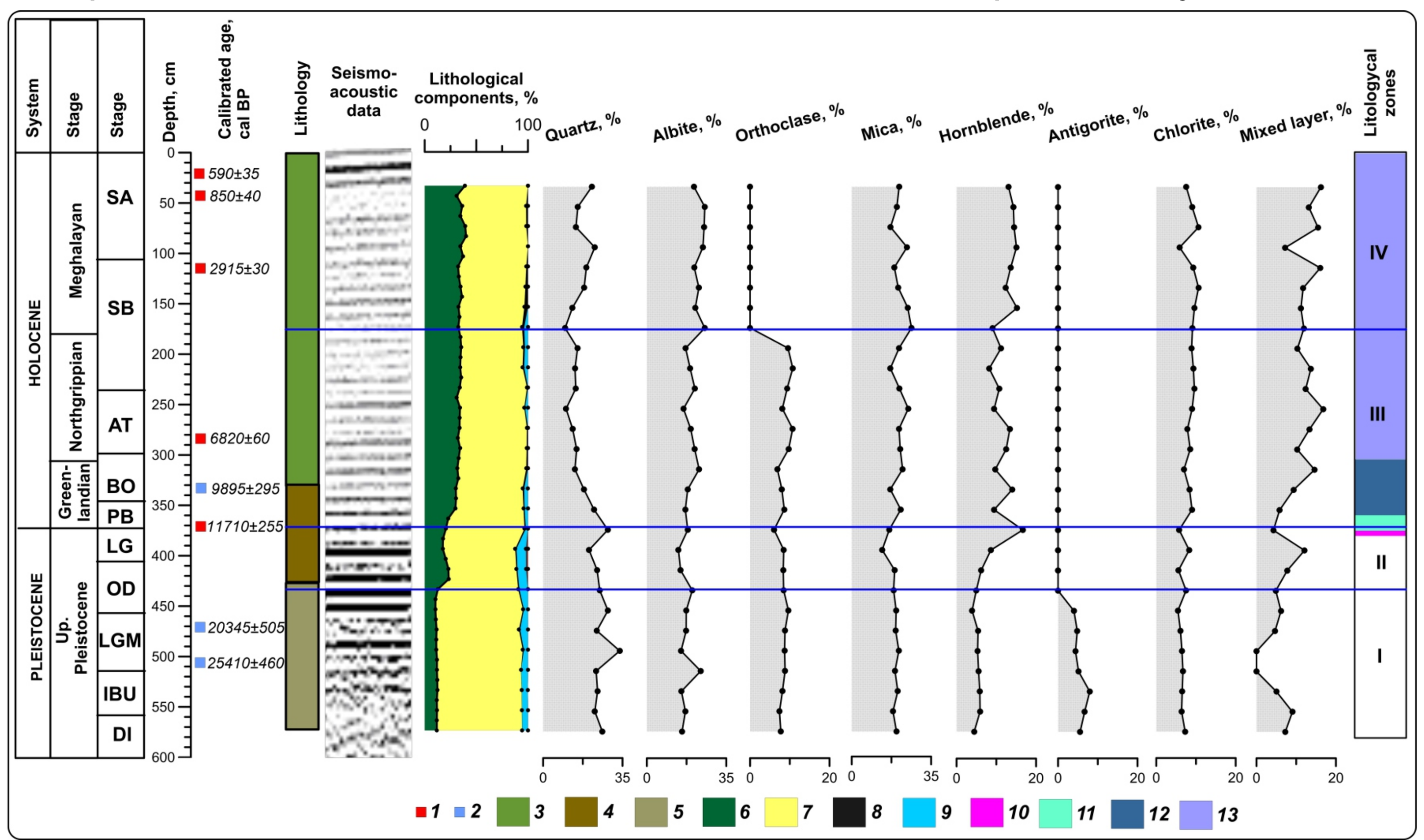

Fig. 9 Lithogeophysical profile of Core 1 from Lake Turgoiak.

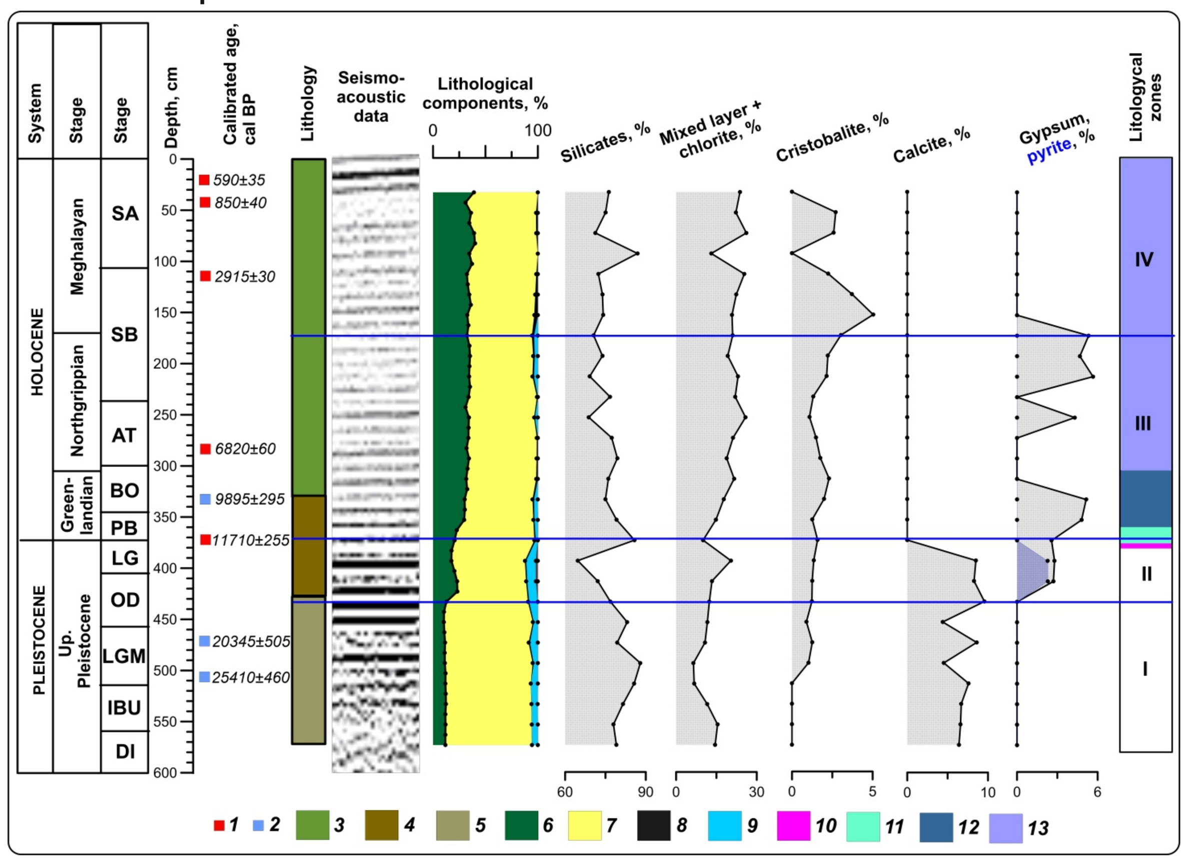

Fig. 10. Lithogeophysical profile of Core 1 from Lake Turgoiak and variations in sediment mineral components

Climate stages according to [Blytt A.G. 1876a,b; Sernander R. 1894; Ravazzi C. 2003]: DI – Denekamp Interstadial, IBU – Ice Build-up, LGM – Last Glacial Maximum, OD – Old Driasian, LD – Late Glaciation including Early and Middle Dryas, Allerød and Bølling warmings, PB – Pre-boreal, BO – Boreal, AT – Atlantic, SB – Sub-boreal, SA – Sub-atlantic. Symbols: 1 – Sampling sites for AMS14C dating, 2 – AMS14C dates transferred from Core #5 [Kosareva et al., 2023]; Sapropel deposit types by ash content: 3 – Mineral-organic, 4 – Mineralized, 5 – Mineral silts; Lithological components: 6 – Biogenic component extracted using LOI, 7 – Allochthonous component, 8 – Biogenic silica; 9 – Carbonates, 10–13 – Four stages of lake evolution according to [Maslennikova 2018]. Roman numerals mark lithological zones.

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