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Climate signals in the Holocene bottom sediments of shallow saline lakes of the Southwestern Siberia

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ABSTRACT. We present the results of the study of the Holocene sediments from two shal low lakes of different salinity located in the East Baraba lowland (Southwestern Siberia). The research methods: X-ray diffractometry (XRD), IR spectroscopy, laser particle size analysis, AMS dating, etc. By the mathematical modeling of complex XRD patterns Mg-calcites with different Mg contents, excess-Ca dolomite and aragonite have been established in the assemblages of carbonate minerals. Based on studies of mineralogical-crystallochemical features and quantitative ratios of Ca-Mg carbonates the evolution stages of lakes corresponding to the regional cycles of aridization/humidization were identified and the correlations with global climatic events were carried out. The obtained results is an important source of new information about the Holocene climate in the Southwestern Siberia.

Keywords: saline lake, bottom sediments, carbonates, XRD analysis, Holocene, paleoclimate, Western Siberia

1. Introduction

One of the key sources of information about the environmental and climate changes in intracontinental regions is represented by the sections of bottom sediments from lakes characterized by different mineralization and trophicity (Last, 2002). Among the numerous shallow lakes of the Western Siberia, a specific group consists of saline and brackish basins confined to areas dominated by arid and semiarid climatic conditions. The Holocene sedimentary records are of special interest because, first, they have not undergone significant post-sedimentary transformations and, second, the Holocene environments are often considered to be close analogues of the modern conditions and/or potential analogues of the future ones. Associations, compositions, and crystalline structures of authigenic components of lacustrine sediments carry information about the water chemistry, temperature and other parameters, which are determined in the end by the regional climate. In turn, changes in the characteristics of authigenic minerals allow us to identify the intervals of a stable environmental state in the dated sections, to establish the boundaries marking the changes of natural settings, and to correlate the revealed climate conditions to the already known regional and global paleoclimatic records. This work aimed to obtain a high-resolution Holocene climate record of the Southwestern Siberia from the sedimentary sections of two shallow saline lakes with carbonate sedimentation: Lake Itkul and Lake Bolshoy Bagan. The author's approach to paleoclimatic reconstructions is based on the detailed mineralogical and crystallochemical studies of the lake sediments, the results of which are considered in combination with data from other types of analysis.

2. Materials and methods

Both lakes are located in the East Baraba lowland. It is a plain covered with alluvial-lacustrine deposits and situated within the forest-steppe landscape zone in the south of the Western Siberia. The basin of Lake Itkul consists of the main depression and a shallow bay in the western part. The average depth is ~1.5–1.8 m, surface area of the lake is 15.1 km^2, water is hydrocarbonate sodic with total mineralization of 2098 mg/L (brackish waters), pH = 9.1. Lake Itkul is replenished by spring high waters and atmospheric precipitation. The water surface area of Lake Bolshoy Bagan is about 5.6 km^2 with the depth in the central part of the basin 0.65 m. The waters of the Bolshoy Bagan belong to brines with a total mineralization of 282 g/L and pH = 7.32. The

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lake is the final drainage basin of the Bagan River.

The samples were studied by X-ray diffractometry (XRD), IR spectroscopy, laser particle size analysis, X-ray fluorescence spectrometry and radiocarbon dating (AMS). The differential diagnostics of carbonate minerals in the lake sediments was made by mathematical modeling of high-resolution XRD profiles (Solotchina and Solotchin, 2014). Decomposition of diffraction profiles of Mg-calcites into individual peaks using the Pearson VII function revealed the positions, integrated intensities, and quantitative relations of the peaks (Fig.). The $MgCO_3$ content was determined from the calibration curves (Deelman, 2011).

3. Results

The total length of the Lake Itkul core is 180 cm, the uppermost 162 cm of which are lacustrine sediments proper, whereas the lower 18 cm are represented by underlying loess-like deposits. The main minerals in the Lake Itkul sediments are quartz, carbonates and plagioclase. Subordinated minerals are clay minerals (illite, chlorite, kaolinite) and K-feldspar in the entire section. Episodically appearing minerals are pyrite and amphibole; traces of gypsum and ilmenite (Solotchina et al., 2019). The core taken in the central area of Lake Bolshoy Bagan is 362 cm long. The lacustrine pelite-silt sediments are 284 cm thick. The underlying interval of 284-362 cm is mainly composed of sandy loams with a small admixture of gypsum and interlayers of fine-grained sand. Quartz, feldspars, mica, chlorite, occasional amphibole and pyrite represent the terrigenous minerals in the Bolshoy Bagan sediments. Among the authigenic minerals, halite, gypsum and Ca-Mg carbonates prevail at the top of the section aragonite and small amount of Mg-siderite occurs in the middle. The age of the base of lacustrine sediments in Lake Itkul is 8,500 cal. yrs, in Lake Bolshoi Bagan is 9,000 cal. yrs corresponding to the end of the Boreal.

Among the carbonate minerals low-temperature carbonates of the calcite-dolomite series dominate in bottom sediments, aragonite is present in a subordinate amount. It is known that the precipitation of carbonates of the calcite–dolomite series is determined by a combination of a number of factors: the Mg/Ca ratio in water, its total carbonate alkalinity, salinity, pH value, temperature, and organic productivity. All these parameters are under control of the water balance, which in its turn depends on climatic conditions. Previously, we showed (Solotchina and Solotchin, 2014) a humid climate promotes the formation of low-Mg and intermediate Mg-calcites, its aridization is accompanied by the precipitation of high-Mg calcites and Ca-dolomites. Diagnosis of carbonates is carried out by the most intense reflections (hkl = 104) in the range of angles 26.0–32.0 2ΘCuKα (Fig.). Aragonite (orthorhombic symmetry) is concentrated in the chemogenic part of the sediments. It is characterized by an increased content of Sr compared to the reference. Co-precipitation of aragonite with Mg-calcites is possible with increased carbonate alkalinity and salinity of waters.

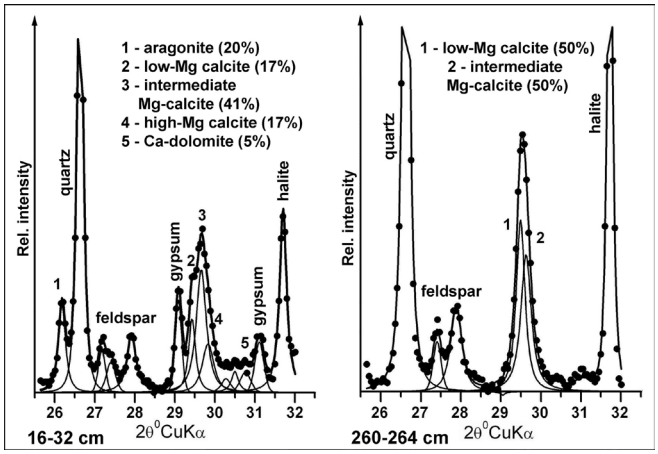

Fig. Modeling of XRD patterns of carbonates from the sediments of Lake Bolshoy Bagan. It is clearly seen there is a good fit between integrated model patterns (solid line) and experimental ones (dots). Diffraction peaks of individual phases are described by the Pearson VII function. The total carbonate content in a sample is assumed to be 100%.

4. Discussion and conclusions

Based on studies of mineralogical-crystallochemical features and quantitative ratios of Ca-Mg carbonates in sections we have identified stages of evolution of both lakes depending on regional climatic changes. In general, these stages coincide with the well - known climatic phases of the Holocene (Blytt–Sernander classification). The formation of the lakes occurred at the end of the Boreal which was relatively humid in the East Baraba territory. During the Atlantic, content of carbonates and their Mg-content in sediments was increased that seem indicate about dry condition. In distribution of carbonates at this stage there are significant peaks (up to 50% in Lake Bolshoy Bagan and up to 80% in Lake Itkul) which, in our opinion, correspond to the global climatic the Bond 4 event. Variable ratios of carbonate phases in the Subboreal sediments indicate unstable environmental conditions but in general, this stage was likely colder than the previous.

According to the carbonate records, the subatlantic was characterized by a moderately warm and humid climate. However, a maximum of carbonate content (up to 50%) was observed in Lake Bolshoy Bagan at ~1400 years which is probably related to the short-term cooling and drying known as the Bond 1 event.

Thus, the lithological and mineralogical studies of bottom sediments of two saline lakes supplemented by the results of several other analyses allowed to obtain high-resolution of the Holocene climatic records of the East Baraba lowland. The evolution stages of both basins according to the regional cycles of aridization/humidization were identified, correlations with global climatic events were carried out. It should be noted that the bottom sediments of Lake Bolshoy Bagan with supersaline water (brine) were successfully used to paleoclimate reconstructions for the first time. The obtained results became an important source of new information about the Holocene climate in the Southwestern Siberia.

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Conflict of interest

The authors declare no conflict of interest.

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