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GEOGRAPHY

Indication of Climate Humidity in Central Asia: Evidence from the Granulometric Record of Bottom Sediments in Lake Khubsugul (Mongolia) for the Last 450 ka

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One of the methods used for recording environmental variations in the past is the reconstruction of sedimentation facies conditions based on distribution of the terrigenous component and mineral associations. This kind of work was previously carried out successfully to study bottom sediments in Lake Baikal [1, 2].

The present paper is devoted to the results of grain size analysis of a part of the drill core (KDP-01) taken from bottom sediments accumulated in Lake Khubsugul over the last 450 ka [3].

Lake Khubsugul is the second largest freshwater basin in Central Asia, inferior in size only to Lake Baikal. Lake Khubsugul is 136 km long, 39 km wide, and located at 1645 masl. The specific orographic position (surrounded by the East Sayan Mountains) and structure (the Khubsugul drainage area is only twice as large as the lake area) of this lake facilitated its contrasting response to climatic fluctuations [5] reflected in sharp, high-amplitude variations in the lake water level. For example, the lake has a negative hydrological balance during arid periods because of drainage loss and low precipitation, resulting in carbonatization and sulfatization of bottom sediments [3, 5, 6].

The studied core is represented by gray, gray-green, and dark gray massive sediments with a rare impregnation of sand. Dried samples of bottom sediments were studied with a Microtrac-X100 laser analyzer. The grain size ranged from 0.02 to 700 µm. Sampling was carried out with a 4-cm spacing. The depth–age model of sediments was constructed based on distribution of paleomagnetic excursions in this core [3].

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The graph of average grain size distribution (Fig. 1a) within the core interval 0–800 cm shows that the sediment is mainly represented by silt (average size ~40 µm). The sediments show a coarsening trend toward the base of the core. Based on the cluster analysis results, we can distinguish the following size groups (µm): <8, 9–15, 18–44, 50–120, 150–500, 600–700.

We believe the terrigenous component is mainly delivered to the lake basin as an alluvial suspension, since the seasonal ice, glacial, and eolian drift is generally selective and sporadic [1] and no turbidite textures have been found. Since the alluvial transportation mechanism prevails in lowland rivers, most suspension particles are less than 50 µm in size [7]. For instance, the share of 10–50-µm particles makes up 40–50% in the Selenga River of the lowland type [8]. Since rivers falling into Lake Khubsugul belong to the mountain type with high-energy flow, the suspended material transported by the rivers can be coarser than silt. It is also obvious that the amount of coarse material (>50 µm) in the Khubsugul bottom sediments is regulated not by the water flow energy but by the distance between the ancient shoreline (settling zone of large particles) and the core sampling site (now corresponding to the lake center). Hence, the decrease in the particle size of sediments accumulated over the last 120–150 ka indicates that the water basin was deeper in the sampling period than earlier.

If our hypothesis—silt fraction distribution in the core serves as a peculiar marker of the intensity of alluvial transportation—is correct, this parameter can be used as an indicator of climate humidity. We compared graphs of grain size distribution along the core with a standard paleoclimatic oxygen isotope profile, which corresponds to water level variations in the World Ocean [9], as well as the distribution of water-soluble salts in the core, which marks the periods of lake water salinization during the past arid stages [3, 5]. It is evident that the distribution plot of particles of size 18–44 µm

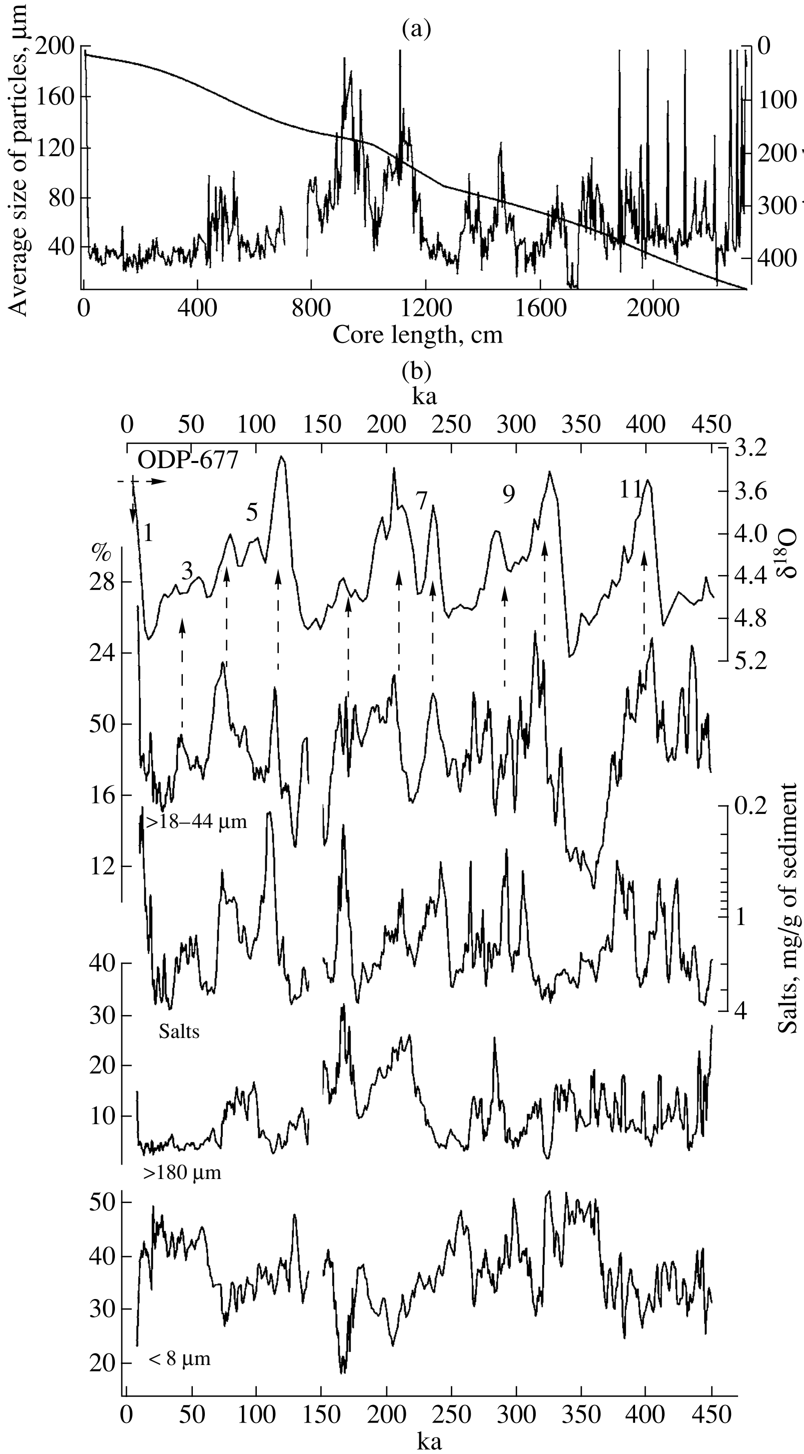

Fig. 1. Graphs of the grain size distribution of bottom sediments in Lake Khubsugul (drill core KDP-01). (a) Depth–age model of the sediment based on paleomagnetic data [3] (gray diagonal line) and variations in the average grain size (black solid line); (b) distribution of sediments of the pelite, silt, and sand sizes, and their correlation with the global paleoclimate record (oxygen isotope curve for Hole ODP 677 with numeration of warm stages according to [9]) and distribution of water-soluble salts in bottom sediments (inverted scale).

yield the best convergence with the studied profiles (Fig. 1b). In general, maximums of the content of this fraction (~22–25 vol % of the bulk sample) coincide with global interglacial periods and a low content of salts in the sediment, i.e., with increase in humidity. The distribution of finer and coarser fractions is not so representative and even conflicting in many respects (Fig. 1b).

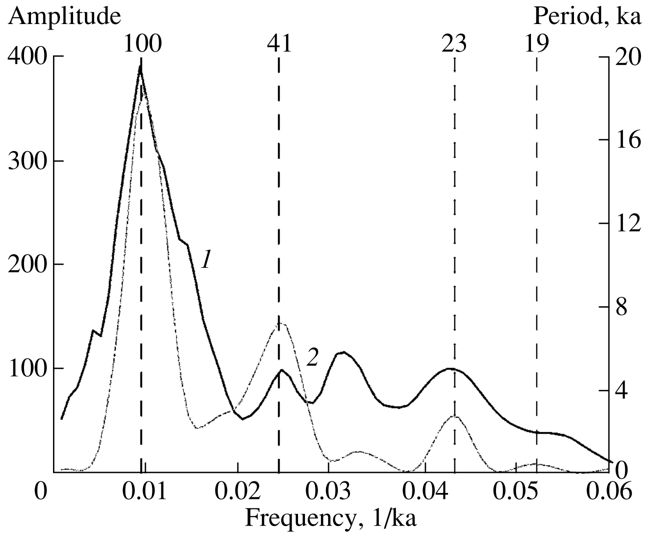

Fig. 2. Results of (*1*) the spectral analysis of the 18–44-μm fraction distribution as compared to (*2*) the $\delta^{18}O$ record [9]. Dashed vertical lines designate peaks with periods close to Milankovitch cycles 23, ~41, and 100 ka.

The distribution graphs of silt and pelite fractions would be expected, but differences in these graphs (Fig. 1b) indicate that the alluvial provenance was supplemented with an additional source and transportation mechanism of the pelite fraction to the lake center. We assume that the additional source was represented by water streams formed during the thawing of glaciers located on the northern edge of the lake. The minimal distance from the core-sampling site to the inferred site of glacier material discharge was ~65 km. This circumstance was most likely unfavorable for the transportation of silt and sand fractions to the lake center, but this did not impede a deep penetration of the pelite fraction. In order to check this assumption, we compared the contents of the pelite and silt fractions. The results showed that the pelitic intervals uncompensated by the silt (alluvial) fraction, as a rule, fall on the glacial/interglacial transitional periods, i e., deglaciation phases. In our opinion, this confirms the assumption that the fluvioglacial source contributes to the pelite fraction formation.

According to [10, 11], the periodicity of terrigenous component accumulation in Baikal sediments correlates with the periodicity of variations in the earth's orbital parameters. Spectral analysis of the silt fraction distribution in sediments of Lake Khubsugul also yielded peaks with periods close to Milankovitch cycles of the earth: 100, ~41, and 23 ka (Fig. 2). The 100-ka cycle dominates in the spectrum. The above-described standard periods in the spectrum are supplemented with a 31- to 33-ka period. A similar, nonstandard period has been detected in the Baikal sediments as well [10].

The North Atlantic is known to be the main source of humidity in the study region [12]. Hence, the results obtained are testimony to the existence of a relationship between silt fraction accumulation and the humidity regime of the region. They also serve as a response to transformations of the moisture pattern in the North Atlantic region during the global climate change.

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