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GEOCHEMISTRY

Oxygen and Carbon Isotope Variations in Ostracode Shells from Lake Hubsugul (Mongolia) and Regional Paleoclimate Changes for the Last 140 ka

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It was established in the middle of the past century that $\delta^{18}O$ and $\delta^{13}C$ values in biogenic carbonates are correlated with variations in the climate and basin productivity [1]. These variations are most contrasting in the isotopic composition of lacustrine species.

The large freshwater Lake Hubsugul, the second basin in size after Baikal, is located in the northern part of Central Asia at 1645 masl and extends in the meridional direction over 136 km. It is 20 km wide and 139 m deep on the average. The maximal depth is 262 m [2]. The high carbonate content in lake waters [2] is favorable for development of ostracodes with carbonate shells [3].

The purpose of the present work is to check the applicability of Hubsugul ostracode shells for paleoclimatic reconstructions. We used the uppermost 7 m of the 53-m-long KDP-01 core section of sediments deposited during the last 1 Ma [4]. Based on the distribution of the Mono, Lachamp, Straight, and Black paleomagnetic excursions, the age of the examined core interval is estimated at ~140 ka [5].

In order to estimate the limits of isotope ratio variations under different climatic regimes, we sampled intervals approximately corresponding to temperature maximums and minimums in the marine isotope scale [6]. The samples containing both monospecific and polyspecific ostracode assemblages that included *Leucocythere* sp., *Limnocythere inopinata,* and the dominant *Candona lepnevae* and *Cytherissa lacustris*.

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The measured $\delta^{18}O_{PDB}$ ranges from –3 to –10.6‰. In most cases, the obtained difference between isotope ratios determined by interspecific differences does not exceed 0.4–0.7‰, although this value can be as high as 3‰ in lakes of Europe and America. We assume that this is explained by the existence of a paleolake with depths exceeding at least a few tens of meters (the present-day depth of the sampling site is 232 m). According to [7], the kinetic effect that governs the species and age selectivity of isotope accumulation is smoothed at depths below 20 m. Low present-day water temperatures in Lake Hubsugul (average 5°C at depths below 20 m) smoothed the kinetic effect as well. The lower the water temperature, the slower the growth of shells and more regular the isotope exchange between biogenic carbonate and water [8].

The main factors controlling fractionation of oxygen isotopes in the carbonate–water system are temperature, salinity, and isotopic composition of water [1, 7, 8]. It was established that Paleo-Hubsugul was characterized by negative water balance during the last Pleistocene glacial periods; i.e., evaporation prevailed over precipitation and the lake was closed. Its level was lower as compared with the present-day one by at least 100 m and waters were oversaturated with calcium carbonates and sulfates [4, 9].

The comparison between the sulfate profile and $\delta^{18}O_{PDB}$ values shows that the high sulfate contents in sediments correspond to high $\delta^{18}O_{PDB}$ values and vice versa (Fig. 1). According to [8], the isotopic composition of water has a positive correlation with ostracode shells. Moreover, the heavy oxygen isotope content in water demonstrates linear correlation with its salinity [10]. The revealed positive correlation between heavy oxygen isotope and water salinity confirms the hypothesis of the existence of periods when the lake was characterized by negative hydrological balance and confirms that the effect of evaporation in the formation of

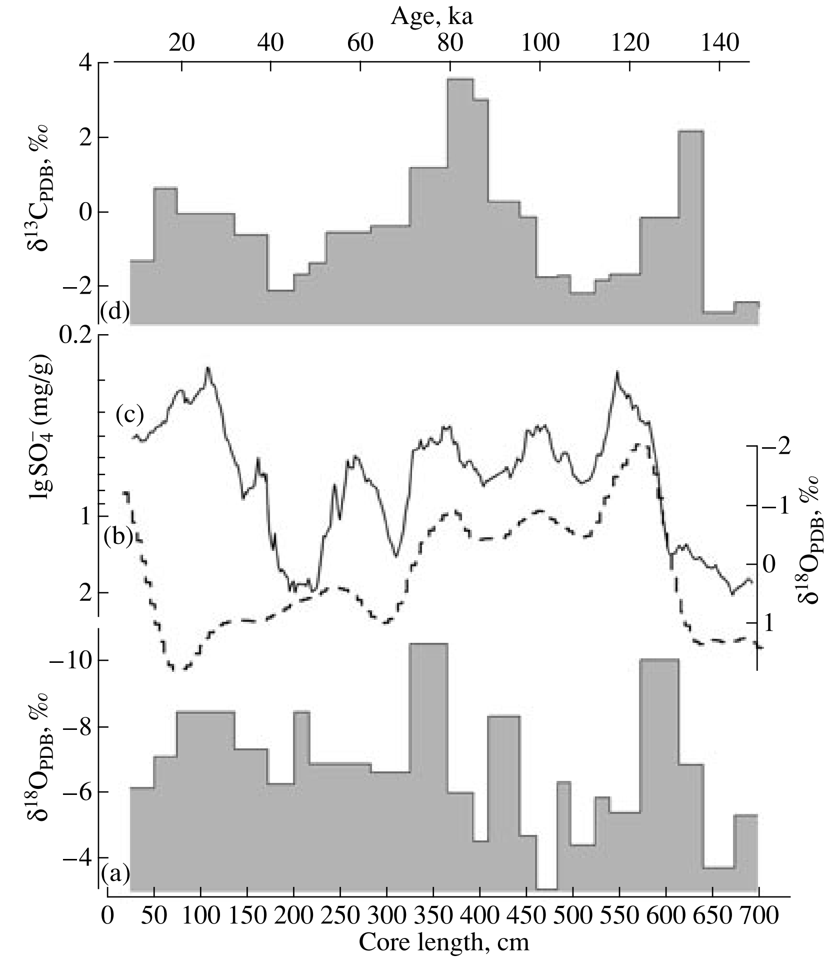

Fig. 1. $\delta^{18}O_{PDB}$ (a) and $\delta^{13}C_{PDB}$ (d) ratios in ostracode shells as compared with changes in the $\delta^{18}O$ (b) in foraminifers [6] and sulfate contents (c) in bottom sediments of Lake Hubsugul.

the isotopic composition of lake water was more significant than that of atmospheric precipitation.

The present-day $\delta^{18}O_{SMOW}$ value in regional atmospheric precipitation averages –10.5‰ [11]. A decrease in the $\delta^{18}O_{PDB}$ value in ostracode shells points to water freshening in Paleo-Hubsugul due to more intense atmospheric precipitation with lighter isotopic composition. The possibility of $\delta^{18}O_{PDB}$ value decrease due to the influx of isotopically light melt waters from melting glaciers in the Hubsugul drainage area cannot be ruled out, either. The intervals with low $\delta^{18}O_{PDB}$ values correspond frequently to warm marine isotope stages (Fig. 1).

At present, Lake Hubsugul represents an ultraoligotrophic freshwater basin with a low primary bioproductivity of the active (uppermost 50 m) layer (~2.7–3.0 mg/m^3 of carbon) [12]. If we accept that ^{13}C concentration in water has a positive correlation with an intensity of ^{12}C consumption by phytoplankton [1] during photosynthesis, the increase in ^{13}C content should only be 0.073‰, which is insufficient for a substantial impact on the $\delta^{13}C$ ratio. In the case of Hubsugul, changes in $\delta^{13}C$ are most likely determined by the reaction between gaseous CO_2 and water-soluble carbonates.

Correlations between $\delta^{13}C$, $\delta^{18}O$, and sulfate concentration (Fig. 2) indicate that negative $\delta^{13}C_{PDB}$ values usually correspond to high sulfate contents and $\delta^{18}O_{PDB}$ values, while positive $\delta^{13}C_{PDB}$ values correspond to low values of these parameters. In our opinion, such a correlation is explained by the intense influx of dissolved carbonates into the lake from the drainage area dominated by carbonate rocks (30%) [2]. For example, field I in Fig. 2 corresponds to conditions with the limited influx of dissolved carbonates from the drainage area and intense chemogenic precipitation of carbonates. Field II marks conditions with the intense cycle of suspended carbonates in the drainage area–river runoff system, i.e., conditions similar to the present-day ones. Conditions corresponding to field III were similar to those of field II, but its low $\delta^{13}C$ values are related to the elevated influx of organic suspended particles from the drainage area.

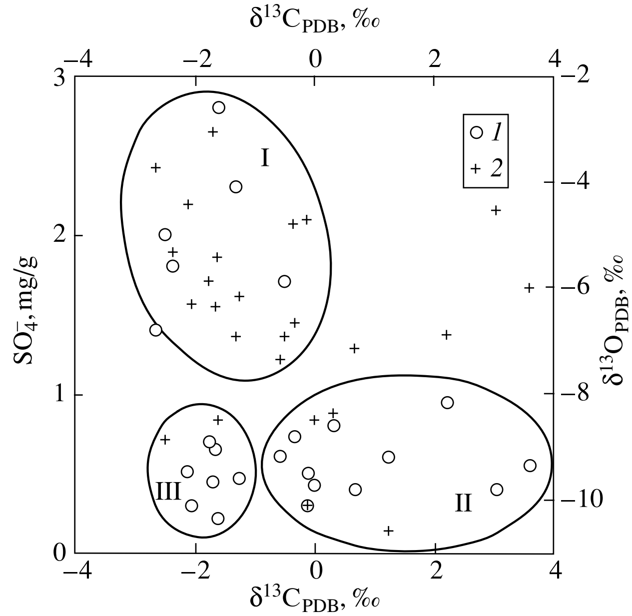

Fig. 2. The carbon isotope ratio vs. (*1*) sulfate and (*2*) oxygen contents. (I–III) Fields of different types of the $\delta^{13}C$ influx and accumulation.

Thus, the obtained results indicate that evaporation in the atmospheric precipitation–evaporation system plays a dominant role in the formation of the isotopic composition of lake waters. These results show that ostracodes can be used for reconstructing the parameters of the above system.

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