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Background composition of pore waters in Lake Baikal bottom sediments

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ABSTRACT

Bottom sediments were studied from 10 central sites within the pelagic zone of the three basins of Lake Baikal, and 16 sites in other regions of the lake. The composition of pore waters in the first two meters of the sedimentary cover was analyzed at 1–3 cm intervals. It was established that the salt composition of pore waters in the sediments was uniform across the entire lake. Background concentrations of each ion in the pore waters was determined from equations using concentration data profiles obtained from all sites of the three lake basins (1250 samples at 26 sites within the entire lake). Similar to the lake waters, background pore waters of Lake Baikal were dominated by calcium bicarbonate with low mineralization. The total concentration of ions in pore waters increased with depth during diagenetic transformations as did the concentrations of bicarbonate and calcium ions. Biogeochemical processes that affect the chemical composition of pore water in Lake Baikal sediments are discussed.

Introduction

At present, many studies are focused on the subaquatic discharge of oil, gas and deep waters occurring at the bottom of Lake Baikal (Matveeva et al., 2003; Klerkx et al., 2003; Granina et al., 2001, 2007; Zemskaya et al., 2010, 2015; Minami et al., 2010; Pogodaeva et al., 2013). However, there are very few data on the background composition of pore waters in the bottom sediments of Lake Baikal.

Lake Baikal, the world's largest freshwater body, is situated in Central Asia. It was formed as a result of intracontinental rifting (Mats et al., 2001). The basin, with a maximal depth of 1642 m, is situated in the center of the tectonically active rift zone and is filled with sediments (up to 7.5 km thick), the most ancient of which are approximately of Oligocene age (Hutchinson et al., 1992). The lake is morphologically divided into three deepwater basins (Southern Baikal, Central Baikal, and Northern Baikal), which are separated from one another by two underwater elevations: the Buguldeika-Selenga Isthmus and the Academichesky Ridge (Atlas of Lake Baikal, 1993).

The water column of Lake Baikal is an inertial system. It takes Baikal tributaries approximately 400 years to completely renew the lake waters. The time necessary for the surface waters to penetrate into the water column center (i.e., to a depth of 300 m from the surface or 100 m from the bottom) is approximately one decade (Weiss et al., 1991). Horizontal water exchange is caused by cyclonic macrocirculations in all layers within each basin. Moreover, compensated water exchange occurs between neighboring basins (Shimaraev et al., 1995, 1996). Compared to the waters of shallow fresh lakes, each basin of Lake Baikal has an ion composition that is stable in time and space (Falkner et al., 1991; Grachev et al., 2004). A large amount of oxygen (9.6–12.8 mg/L) is observed at all depths of the lake, including the bottom water (Shimaraev et al., 1996; Killworth et al., 1996). Oxygen also penetrates into the bottom sediments, and a layer of oxidized sediment covers the entire lake bottom (Atlas of Lake Baikal, 1993).

The sediments in the three deepwater basins of Southern, Central and Northern Baikal have identical chemical composition as a result of the homogenization of fine fractions of incoming terrigenous material carried by steady currents (Gvozdkov, 1998). There are very few data on the composition of the liquid phase (pore water) of bottom sediments of Lake Baikal. Moreover, these data were mostly collected in anomalous areas and the Selenga River delta. According to these data, the pore waters of bottom sediments show heterogeneity in their chemical composition within the lake bottom area and are bicarbonate-sulfate, sulfate and chloride waters (Mizandrontsev, 1975; Granina et al., 2001, 2007).

This paper presents the results of a study on the background chemical composition of pore waters from bottom sediments in Lake Baikal to determine the extent of variability in pore water composition in this great lake. Equations of chemical composition variation as a function of sediment depth are also inferred from the obtained data to examine diagenetic changes with depth.

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Material and methods

Sampling

Bottom sediments were sampled from areas with regular sedimentation rates within the pelagic zones of the three basins of Lake Baikal (Fig. 1, Table 1), during expeditions between 2003 and 2006. Four cores ranging from 45 to 200 cm in length were collected in Southern Baikal (up to depth of 1480 m) at sites St2GC 2003, St97GC 2003, St1GC 2005, and St1BC 2005. Cores of 100 and 200 cm length were sampled in Central Baikal (up to 1600 m) at sites St81GC 2003 and StGC16 2006, respectively. In Northern Baikal, a 340 cm core was retrieved from site St12GC 2005 (depth of 940 m), and three benthic cores ranging in length from 16 to 40 cm were sampled from sites St12BC 2005, St12BC 2003, and St14BC 2003 (depths > 800 m).

Sediments were obtained using a gravity corer (GC) made by researchers from the Limnological Institute of the Siberian Branch of the Russian Academy of Sciences (LIN SB RAS). The 500–600 kg GC was 3 to 5 m long with an outer steel tube 128 mm in diameter and a 100 mm diameter plastic liner. The tubes had an upper valve and a leaf-type catcher to hold the core inside. Upon retrieval, the core-catcher cut the lower part of the core and the leaves closed tightly around the sediment core. The valve in the upper part of the corer also closed to prevent bottom water percolation inside the liner, thus protecting the core surface from washing out. Sediments and bottom water above the sediments were also sampled with a benthic corer (BC) (100 mm in diameter, 1 m long).

In the summer expedition of 2009, on board the deepwater submersible “MIR”, sediments were collected throughout Lake Baikal (16 sites (Fig. 1, Table 1)) with a 30 cm long sealed corer. This sampling method provided the least disturbance to the uppermost sediment layer, allowing for sampling of the bottom water directly above the sediment.

To prevent contact with oxygen, all sediment cores were placed within an argon glove box onboard the ship immediately after coring. The sediment cores were opened and treated under an argon (O_2-free) atmosphere using plastic disposable utensils. The middle section of the core cross-section was selected for analysis. Each centimeter of sediment was analyzed in the short cores, whereas the long cores were analyzed at 2–3 cm or 5–10 cm intervals. Pore waters were immediately extracted onboard the ship by centrifuging the sample for 20 min at 8000 rpm. Microparticles were separated from the pore water by subsequent ultracentrifugation (10 min, 14,000 rpm). The centrifuge tubes were opened anaerobically; the solutions were filtered with disposable syringes through a 0.20 μm filter (cellulose acetate, Vladisart, Russia) and then injected into chromatography tubes under

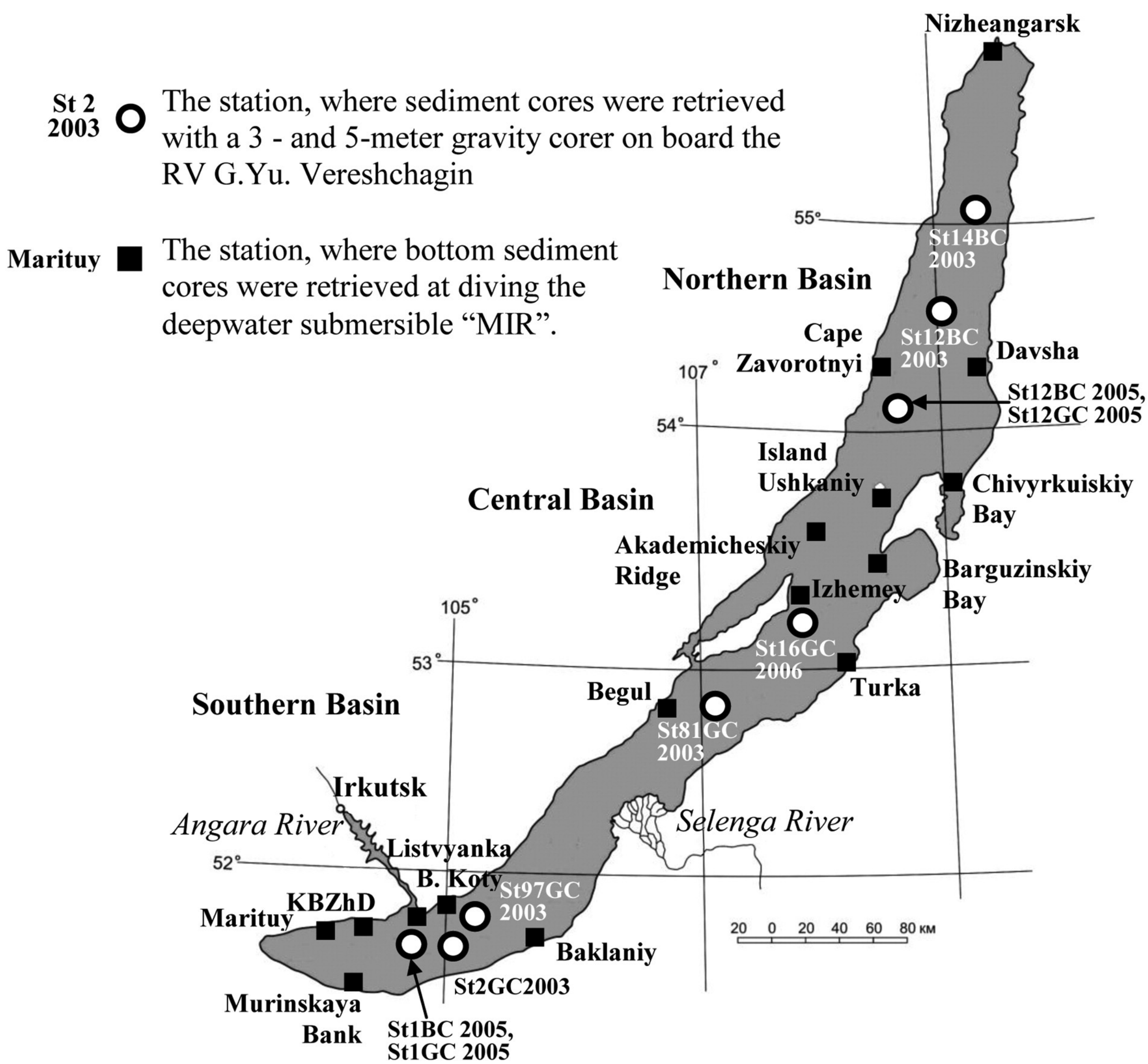

Fig. 1. Schematic map of the locality of sampling stations.

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