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Particulate fluxes in South Baikal: evidence from sediment trap experiments

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Abstract

We present original data on fluxes of particulate matter through a 1366 m thick water column, measured with sediment traps near the Neutrino Telescope Station in South Baikal. The research was part of a long-term international research project which started in March 1999 in order to investigate current sedimentation in the lake. The total flux of sedimenting particles was considerably higher in 2000 as compared with 1999. This was due to the exceptional growth of siliceous diatoms of the genus *Aulacoseira* in 2000, leading to the so-called *Melosira* year. Biogenic silica is predominant in the particulate matter and might reach 56%, while the concentrations of organic carbon and total nitrogen do not exceed 16% and 1%, respectively.

Keywords: sediment traps; sediment particle flux; biogenic silica; organic carbon; total nitrogen; diatoms; Lake Baikal

Introduction

Bottom sediments of Lake Baikal is an exceptional natural archive which stores a record of regional and global climate change (BDP Project, 2000; BDP-99, 2005; Kuzmin et al., 2001). It has been commonly agreed that interpretation of past sedimentation patterns and paleoreconstructions require knowledge of present sediment accumulation. Namely, Strakhov (1971) noted that the views of past lithogenesis at each stage of geological history eventually stemmed from the wealth of knowledge on current deposition, and Lisitzin (2004) stressed the importance of *in situ* studies of marine and lake sediments. Much experience has been gained in investigating fluxes of settling particles collected with sediment traps, in Lake Baikal (Grachev et al., 1996; Mackay et al., 2000; Muller et al., 2005; Ryves et al., 2003; Sturm et al., 2015), as well as in other water basins (Il'yash et al., 2013; Lignell et al., 1993; Lisitsyn et al., 2014; Lisitzin, 2004; Olli et al., 2002; Wassmann et al., 2004). Such work in Lake Baikal is necessary also to monitor the lake state under the ongoing global warming, which is an irrefutable fact (Brohan et al., 2006; Wilson et al., 2007).

The paper presents original data on sediment particle fluxes through a 1366 m thick water column, measured with sediment traps from 11 March 1999 to 6 March 2000 and from 8 March 2000 to 8 March 2001 in South Baikal (Fig. 1). Comprehensive analysis of settling material reveals its composition and provides quantitative constraints on its fluxes. The research was carried out as part of a long-term international project run by the Institute of the Earth's Crust (IEC, Irkutsk), the Institute of Applied Physics of the Irkutsk State University (IAP ISU, Irkutsk), and the Swiss Federal Institute of Aquatic Science and Technology (EAWAG, Dübendorf).

Methods

Current sedimentation in Lake Baikal was studied using a submerged buoy station installed 4 km offshore in the northern part of South Baikal near the Neutrino Telescope Station at 51°46.076′ N, 104°24.948′ E (Fig. 1), where the lake depth reaches 1366 m. Sedimenting material was sampled using traps of two types (see Fig. 2*a* for the experiment layout): (1) EAWAG–130 integrating open sediment traps (Fig. 2*b*) that collect settling particles over the whole period of observations and (2) TECHNICAP®–PPS4/3 automatic traps (Fig. 2*c*) which can operate for prespecified time intervals.

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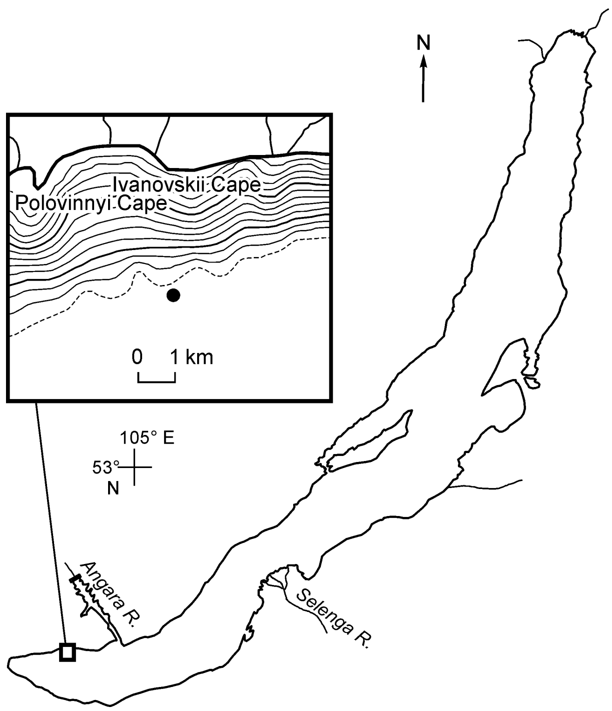

Fig. 1. Map of Lake Baikal and location of buoy station (black circle).

EAWAG–130 integrating two-glassed traps (Fig. 2*b*) consist of two cylindrical tubes and two sampling cups, all made of *Acrylic*® glass. The tubes are 100 cm long and 9 cm in diameter, with an aspect ratio (length/diameter) of 11 and an active surface area of 130 cm^2, which prevents the sampled particles from roiling. Two removable sampling cups, 700 ml in volume each, are mounted at the tube bottom, on removable holders. Sediment accumulates in the cups and water flows out through four drains (500, 400, 300, 200 ml) which are plugged during sampling (Bloesch and Sturm, 1986; Kulbe et al., 2008; Ohlendorf and Sturm 2001).

TECHNICAP®–PPS4/3 automatic traps (Fig. 2*c*) consist of a funnel with a carrousel of 12 sampling bottles, 250 ml each. The carrousel is controlled by a microprocessor motor driver. The sampling interval is from 1 hr to 18 months, programmable for each sampling bottle. The traps are 120 cm high and have a collecting surface area of 500 cm^2. Automatic traps of this model were designed for high-resolution studies in 1980 (Jannasch et al., 1980; Sturm et al., 1982). They can have different sizes and include different numbers of sampling bottles (http://www.technicap.com/products/traps/traps.htm).

Altogether we deployed fifteen EAWAG-130 traps (Z1, Z2, …, Z15) at different water depths and two TECHNICAP automatic traps under 510 m (S-1) and 1361 m of water (S-2) (Fig. 2*a*). Sampling was almost continuous for two years, from 11 March 1999 to 6 March 2000 and from 8 March 2000 to 8 March 2001.

The sampled material was freeze-dried on an *FD ALPHA* dryer and weighed on analytical scales. The qualitative composition of particulate matter was determined using an SK14 optical microscope (magn. ×100).

Each sample collected with EAWAG-130 traps was analyzed for contents of organic carbon and (C_{org}) and total nitrogen (N_{tot}) on a *HEKATECH Euro AE CNS* gas chromatograph at EAWAG. Concentrations of biogenic silica (SiO_{2biog}) were measured in samples collected from 8 March 2000 to 8 March 2001, likewise at EAWAG, following the procedure described by Ohlendorf and Sturm (2008). Total sediment fluxes and fluxes of separate biogenic components were calculated at different water depths in g/m^2/yr for EAWAG-130 traps and in mg/m^2/day for TECHNICAP automatic traps.

Results and discussion

Examination of smear slides shows that sediments collected by the EAWAG-130 traps in South Baikal consist of diatom frustules, mostly of *Aulacoseira, Cyclotella and Synedra* genera; minor amounts of pelitic material (few silt-size mineral grains and pollen particles); remnants of *Gammarus* (genus), and sponge spicules. Thus, biogenic material, mainly diatoms, predominates in all traps.

Results of comprehensive analysis of the sampled material are presented in Tables 1 and 2. Organic carbon in samples collected from 11 March 1999 to 6 March 2000 varies from 3.56 to 8.12% (4.47% on average), the highest in the upper 300 m of the water column and the lowest near the bottom at the depth 1361 m. Total nitrogen is about ten times lower: 0.33 to 0.80% (0.43% on average), the highest in three upper traps above 300 m and the lowest in the lower traps at the depths 1350 and 1361 m (Table 1).

Samples collected from 8 March 2000 to 8 March 2001 contain much higher concentrations of C_{org} and N_{tot} than those of the previous year. C_{org} is from 5.27 to 15.9% and average at 8.10%, and N_{tot} is from 0.67 to 1.11%, 0.80% on average. The highest C_{org} and N_{tot} contents were measured in the lowest trap at 1361 m. Biogenic silica coming mostly from diatom frustules is 50.9% on average in the analyzed samples, with the range between 47.4 and 55.9% (Table 2). Thus, biogenic silica is the predominant biogenic component of the collected material.

The C/N ratio is in the range from 9.40 to 11.0, with an average of 10.4 (Table 1) measured in samples collected from 11 March 1999 to 6 March 2000 and 9.1 to 16.7 (11.7 on average) for those sampled from 8 March 2000 to 8 March 2001 (Table 2). The highest value (16.7) corresponds to the lowest trap (water depth 1361 m), possibly, because of particles roiling on the lake bottom. According to the C/N ratio, which has implications for the origin of organic components in sediments (Durga et al., 2011; Vykhristyuk, 1980; and others), it is mostly autochthonous plankton.

The total sediment flux in the traps deployed from 11 March 1999 to 6 March 2000 ranges between 73.7 and 146 g/m^2/yr, with an average of 121 g/m^2/yr (Table 1, Fig. 3). It is the highest in the lowest trap at the water depth 1361 m, most likely due to mud roiling at the sediment/water interface.