

Sedimentation in Proval Bay (Lake Baikal) after Catastrophic Flooding of the Coastal Plain in 1862

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Bottom sediments of lakes bear information on their accumulation history, which reflects changes in the environment. To find the key to this information is the most important lithological task solved on the basis of present-day natural objects. It is fair to assign to them Proval Bay formed in January 1862 in Lake Baikal during a very strong earthquake (magnitude 7.5 [1]) when a considerable fragment (200 km²) of the coastal plain (the Tsagan steppe) was detached and flooded by the Baikal water [2, 3]. Study of the composition of sediments formed after flooding is also very important for assessment of anthropogenic pollution, which has become prominent during the past decades due to intense industrial development.

Figure 1a presents the scheme of the flooded area of the Tsagan steppe according to the survey carried out by the expedition of the Russian Geographic Society in the summer of 1862 [4]. Old small lakes, which existed in this area and turned out to be buried under Proval Bay after the flooding, are of great interest for understanding sedimentation. The comparison of the 1862 scheme and the current map of the bay (Figs. 1a, 1b) showed that the boundary of the Selenga River delta has shifted eastward over the past 140 yr (Fig. 1a). After the earthquake, sediments up to 3.6 m thick accumulated on the bottom [5]. Soils of the Tsagan steppe represent a reference horizon defining the lower boundary of these sediments. A series of works is devoted to study

of the bottom sediments [5–7]. However, the devices used in these works did not yield undisturbed sections of sediments and, as a consequence, the upper layer was lost [5, 7]. At present, we have the technical possibility to study sedimentation conditions and to trace in detail the influence of the climatic factor in the zone of sediment delivery to Lake Baikal by its largest tributary (the Selenga River).

To study present-day sedimentation in Proval Bay during the period after the catastrophe, cores of surface (0–1 m) sediments were taken in March 2005 along a profile about 15 km long in the direction from southwest to northeast (Fig. 1b). The depth of the bay at sampling sites was 1.5–4 m. A UWITEC-CORER piston corer was used to retrieve undisturbed cores. The sampling site for Core 14 coincided with Lake Beloe on the 1862 scheme (Fig. 1). Therefore, the section was chosen as a reference one. The cores recovered were cut along the length and photographed. Description of their lithology was accompanied by examination of smear slides. Magnetic susceptibility was determined with a spacing of 1 cm. The concentrations of biogenic silica (SiO₂ biog) were analyzed in cores 9 and 14. We carried out diatom analysis, ²¹⁰Pb dating of sediments using gamma-spectrometry (Core 14), measurement of the concentrations of total organic carbon (C_{org}), and elemental analysis by the RFA SI method with a spacing of a 5-mm step for the same core.

Sediments are stratified and represented by silty pelite, pelitic silt, and sand (Fig. 2). The predominant terrigenous material consists of clastogene mineral grains and plant remains. The biogenic admixture is represented by diatom valves and sponge spicules. The upper part of the sections is oxidized. Sediments in this zone are dark brown, and their thickness varies from 1.5 to 4 cm. Reduced sediments are olive-black and brown-black.

A black peat-type bed, 20 cm thick, mainly composed of plant remains was found in core 14 in the interval of 33–54 cm. The bed is underlain by sand and overlain by silty-sandy sediment with interlayers enriched in plant remains (Fig. 2).

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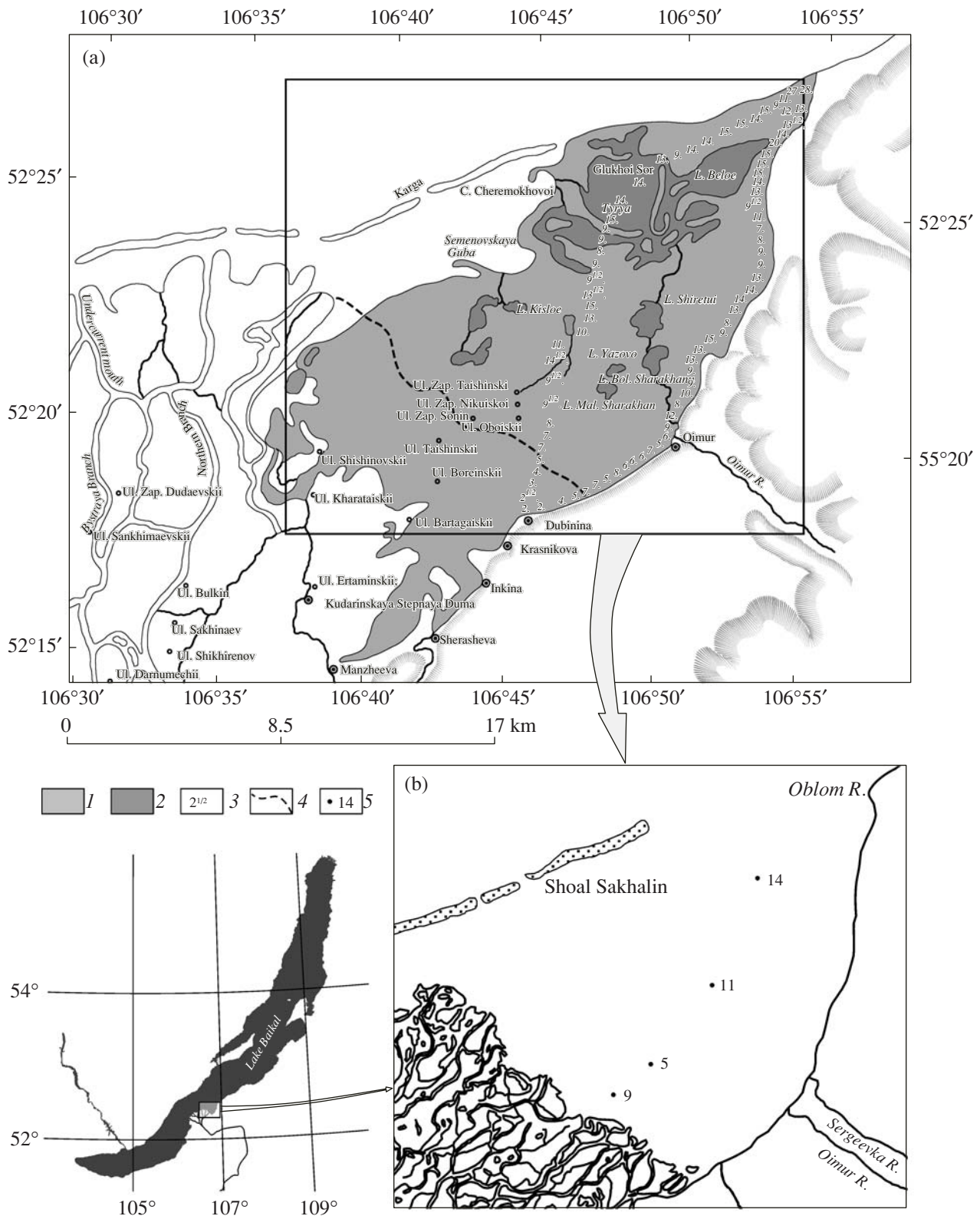


Fig. 1. Map of the Tsagan steppe based on the survey of the expedition of the Russian Geographic Society in the summer of 1862 [4]. (a) Coordinates are denoted approximately. (b) Location of sampling sites in Proval Bay (based on the present-day topographic base). (1) The Tsagan steppe territory flooded after the 1862 earthquake; (2) lakes that existed in the Tsagan steppe prior to the earthquake; (3) sounding depth (in feet) carried out by the expedition of the Russian Geographic Society [4]; (4) present-day boundary of the Selenga River delta; (5) sites of bottom sediment sampling.

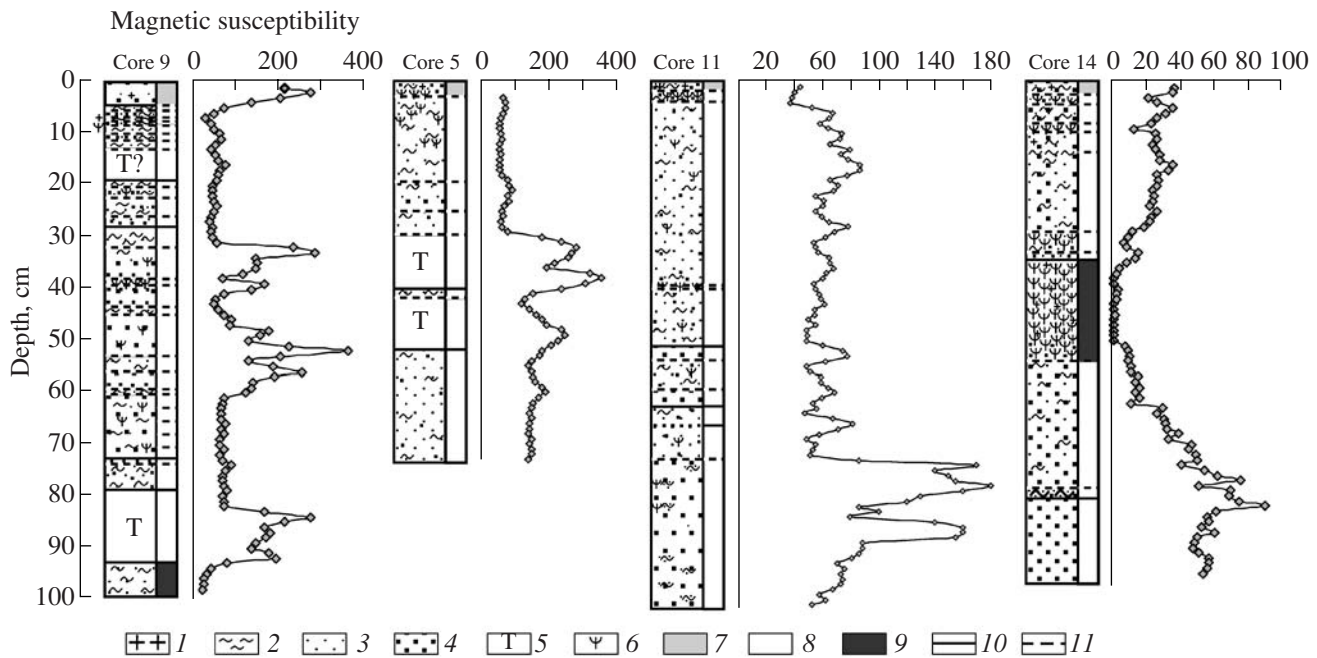


Fig. 2. Cores and magnetic susceptibility of sediments in Proval Bay. Left column: (1) diatoms; (2) pelite; (3) silt; (4) sand; (5) turbidite; (6) plant remains. Right column: (7) oxidized sediment; (8) reduced sediment; (9) black beds. Bed boundaries: (10) clear; (11) unclear.

In the southwestern part of the profile, Core 9 recovered a soil-type dense black bed beneath the alternation of pelitic silt and sand (Fig. 2). In the southern part of the bay, deposits accumulated after the 1862 earthquake are as thick as 3.6 m [5]. At the same time, the soil-type bed in Core 9 occurs at a depth of 93 cm. Therefore, we can infer that the bed was buried much later and, probably, was related to the rise of the Baikal water level in 1959–1964 after construction of the Irkutsk hydroelectric power station (HPS) [8]. At that time, lower coastal and river delta zones of the Baikal coast were flooded and drowned. The largest flooded areas (more than 350 km²) were located in the Selenga River delta [8]. Turbidite beds were established in cores 5 and 9 recovered in the immediate vicinity of the Selenga River delta (Fig. 2). The beds are characterized by a gradation structure: coarser-grained sediment (mainly coarse sand) at the base gives way to fine-grained sediment upward the section.

The magnetic susceptibility of sediments varies both along the profile from northeast to southwest and in separate cores. Minimal values ($0\text{--}20 \cdot 10^{-6}$ SI units) were established for the organic-rich black bed material (Fig. 2). The value for pelitic silt and silty pelite varies within $(20\text{--}80) \cdot 10^{-6}$ SI units. Maximum magnetic susceptibility is characteristic of sandy and turbidite beds due to the high content of heavy minerals in them [9]. The magnetic susceptibility increases from $(25\text{--}90) \cdot 10^{-6}$ SI units in sands in the northeastern part of the profile (Core 14) to $(80\text{--}230) \cdot 10^{-6}$ SI units at the center (Core 10) and reaches $370 \cdot 10^{-6}$ SI units in sands in the

southwest (Core 9) (Fig. 2). This variation is likely to be governed by the proximity of the Selenga River.

The content of biogenic silica in surface sediments of Proval Bay is low (0.3–2.7%) against the background of intense inflow of terrigenous material with the Selenga River water [10]. It is only in the peat-type black bed with an insignificant clastic admixture (Core 14) that the SiO₂ biog content reaches 10.2% (Fig. 3). High C_{org} contents are also characteristic of this bed (Fig. 3).

The results of the diatom analysis of sediments in the reference section are presented in the table. The total content of diatoms is maximal (61.8 and 95.3 million valves per gram of dry sediment, m.v./g) in core samples from the black peat-type bed at a depth of 39 and 44 cm, respectively. They are dominated by epiphytic types of biofouling (89%). The planktonic (1–3%) and bottom (5–7%) species are rare (table). Abundance of diatom biofouling indicates the accumulation of sediments in a shallow paleobasin overgrown with higher aquatic plants. Scarcity of bottom representatives indicates low transparency of water in the paleobasin. In the upper part of the section (depth 2 cm), the diatom assemblage corresponds to the present-day assemblage (in terms of ecology and taxonomic composition) from bays and saline marshes of Lake Baikal [11].

Based on isotopic measurements, the present-day sedimentation rate at the Core 14 sampling site is 0.232 cm/yr. Hence, the 22-cm-thick sediment overlying the black peat-type bed was accumulated in 142 yr, which is close to the period after the 1862 earthquake. According to A.K. Tulokhonov et al., the annual mean

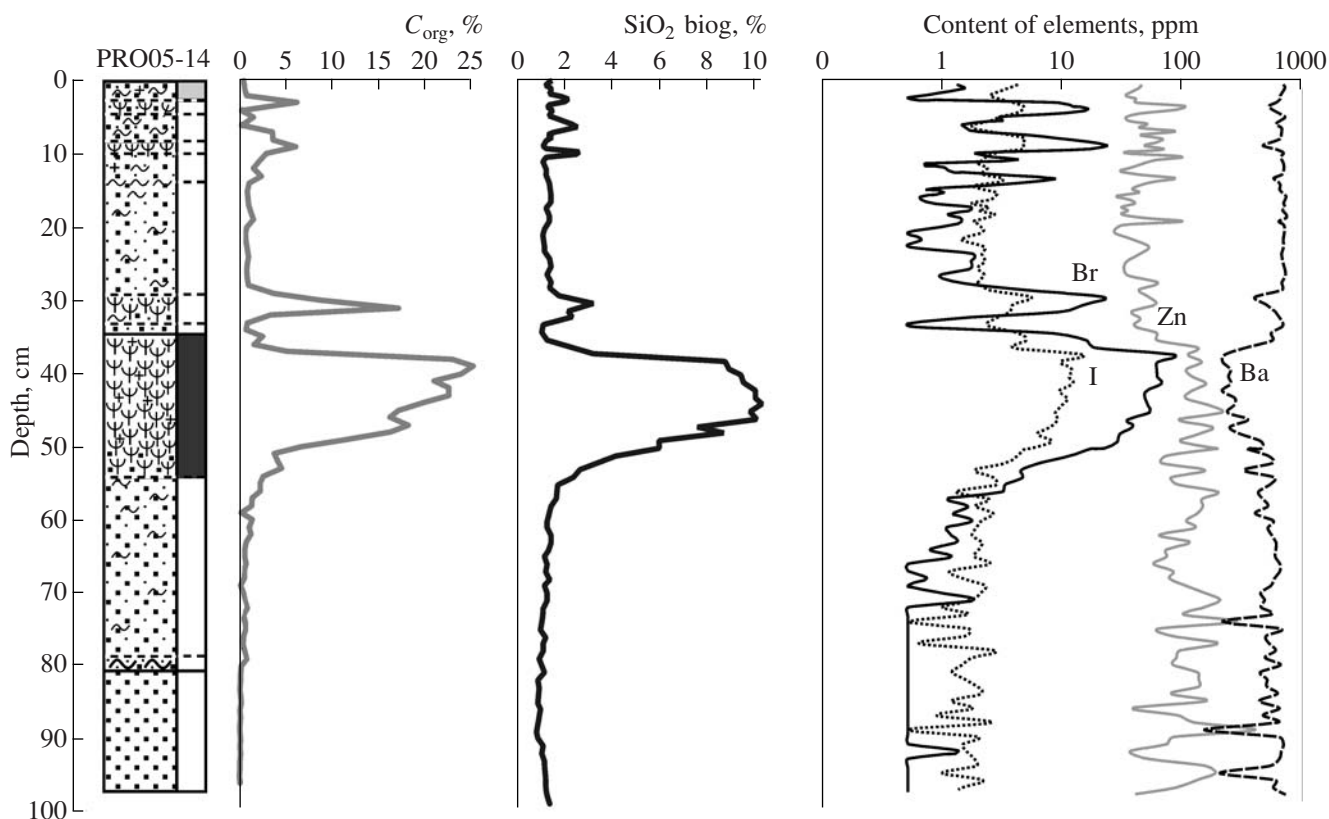


Fig. 3. Contents of SiO_2 biog, C_{org} , and admixture elements in bottom sediments of Proval Bay (Core 14).

sedimentation rate in the central part of the bay is 1.07 cm [11]. Thus, sedimentation rates in different parts of Proval Bay differ greatly and depend directly on the proximity of the Selenga River.

The position of Station 14 and the section structure suggests the following conclusion: along with sediments of Proval Bay, sediments of Lake Beloe, which existed in the Tsagan steppe, have been recovered here

(Fig. 1a). Sandy deposits in the lower part of the core (interval 54.5–97 cm) (Fig. 2) are likely to correspond to the early stage of existence of this lake. The lake was overgrown later with higher aquatic plants. The peat-type bed formed at that time (interval 34–54.5 cm, Fig. 2). The diatom analysis indicates that the lake was shallow and eutrophic at that stage. Surface sediments at the bottom of Lake Beloe (Core 14, interval 0–34 cm, Fig. 2) accumulated in Proval Bay.

Composition and abundance of diatoms in bottom sediments of Proval Bay (Core 14)

Depth, cm	Number of taxons	Diatom abundance									Dominant diatoms and their share, %
		Total, m.v./g	planktonic		bottom		biofouling		valves of poor preservation		
			m.v./g	%	m.v./g	%	m.v./g	%	m.v./g	%	
2	46	2.6	0.5	19	0.4	15	1.4	54	0.3	12	<i>Planothidium ellipticum</i> —12
22	18	7.3	—	—	0.7	10	6.5	89	0.1	1	<i>Stausosirella pinnata</i> —48 <i>Pseudostaurosira binodis</i> —14 <i>Martyana martyi</i> —11
39	54	61.8	1.6	3	3.3	5	55.2	89	1.6	3	<i>Stausosirella pinnata</i> —52 <i>Pseudostaurosira binodis</i> —11
44	35	95.3	0.8	1	7.1	7	84.4	89	3.0	3	<i>Stausosirella pinnata</i> —47 <i>Pseudostaurosira brevistriata</i> —13
79	12	0.04	—	—	0.009	23	0.03	75	0.006	2	—

The geochemical analysis of sediments from Lake Beloe and Proval Bay showed a substantial difference in their elemental composition. Contents of Fe, Ti, Mn, Ni, Cu, Zn, I, and Br are higher in sediments of Lake Beloe. At the same time, the content of anthropogenic elements, such as Zn, Cu, and Ni, increases at the interval of 0–15 cm approximately corresponding to the last 60 yr. In addition, some organophile elements (I, Br, and Y) show a correlation with fluctuations in temperature and humidity recorded at the Ulan Ude weather station in the years 1887–1989. This fact opens up possibilities for reconstruction of a detailed record of climate in the region.

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