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New data on the Late Pleistocene stratigraphy and paleoenvironment of the southwestern Baikal area (Siberia)

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A B S T R A C T

This paper presents an overview of study of the Upper Pleistocene key sections of the southwestern Baikal area (Tunka rift valley, Baikal rift zone) and Prebaikalia (south of Siberian platform). Geochemical data have revealed some paleoclimatic variations in the region during the Late Pleistocene. The highest values of the lithochemical moduli are present in Kazantsevo deposits of the Ust-Odinsky section. They indicate a high degree of chemical transformation of rocks and accumulation of alumina and iron, which is characteristic of warm humid climate. The upper part of all studied sections, including the Holocene horizon (MIS 1), shows a significant decrease of all moduli values, a result of climate deterioration from Kazantsevo time (MIS 5) through Sartanian time (MIS 2). Moreover, there are two peaks of modulus values, corresponding to the Karginsky (MIS 3) paleosols.

The analyses of the mammal faunal composition of the studied regions have revealed that in the Tunka rift valley the dominant forms of both large and small mammals are Central Asian species, arid open landscape dwellers. In contrast, in the Pebaikalian fauna the inhabitants of tundra, tundra-steppe are predominant. The fauna of Ust-Odinsky section (Murukta time, MIS 4) contains the representatives of a disharmonious fauna (*Lagurus lagurus* and *Dicrostonyx* sp.). The mammal assemblages of the Kazantsevo (MIS 5) suggest rather humid and warm paleoenvironmental conditions, in contrast to the Karginsky (MIS 3) interval which is characterized by drier, moderate cold climate with steppe biotopes.

1. Introduction

During recent decades, due to the extensive investigations of the deep-water sediment cores of Lakes Baikal and Khubsugul, outstanding successive Cenozoic climatic and paleoenvironmental data have been obtained in the area of the Baikal rift zone (BDP Members, 2001, 2005; HDP Members, 2007, 2009, and others). The continental deposits represented by lacustrine sediments, and complex-structured subaerial-alluvial formations widely distributed in the region, were studied by our team as well. Several new sites with mammal and mollusc fossils were discovered, among them the locality of Slavin Yar. The preliminary results of its study were published recently (Shchetnikov et al., 2009, 2012). Moreover, several poorly known sites were restudied on the base of multidisciplinary approaches, including the Late Pleistocene sites Ust-Odinsky and Bely Yar (Fig. 1).

The Bely Yar section was first studied in the middle of the last century (Ravskii and Golubeva, 1960) and later by many geologists (Ravskii et al., 1964; Adamenko et al., 1975; Popova et al., 1989; Kul'chitskii et al., 1994; Ufimtsev et al., 2002; Pokatilov, 2004; Krivonogov, 2010). However, until recently, this section has remained chronostratigraphically uncertain. We continue to study it in detail.

The initial results of the study of the Ust-Odinsky cross-section were presented by Molotkov (1979). Preliminary study was undertaken by Filippov et al. (1995), but not geochronologically characterized.

Intensive investigations in all these sections (Arsalanov et al., 2011; Shchetnikov et al., 2012) have revealed new fossil remains of both large and small mammals, together with numerical dating of mammal bones and geochemical characteristics of sediments. All these new data filled gaps in the Late Pleistocene stratigraphy of the studied region. The main aim of this work in addition is the

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preliminary reconstruction of paleoenvironmental conditions and their successive changes from Kazantsevo through the Holocene.

2. Methods

The studies have been performed using different methods and multidisciplinary approaches. Stratigraphy and correlation of stratigraphic units across the region were based on lithological-mineralogical, granulometric and geochemical methods, on radiocarbon dating (^{14}C), and infrared (IR) and optically stimulated luminescence (OSL) dating.

The ^{14}C dating was performed by accelerator mass spectrometry (AMS) using ultrafiltration in the Oxford University (UK). The radiocarbon dating in laboratories of the Institute of Geology and Mineralogy SB RAS (Novosibirsk, Russia), Institute of Geography RAS (Moscow, Russia), and St.-Petersburg University (Russia) was done using liquid (benzene) scintillation. IR-OSL dating was carried out in the Laboratory of Quaternary Chronology of the Tallinn University of Technology (Estonia).

Paleontological materials are one of the main tools for stratigraphy and paleoenvironmental reconstructions, and this study used traditional methods (Zazhigin, 1980; Khenzykhenova, 2008; Markova et al., 2008; Agadzhanyan, 2009; Smirnov et al., 2009; Erbaeva et al., 2011). In total, in all studied sections more than 2100 small mammal and about 60 large mammal remains have been collected and studied.

For correlations and reconstructions of depositional environments, chemical composition of the deposits has been studied using a standard silicate analysis for the presence of main rock-forming oxides: SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, CaO, MgO, K_2O, Na_2O, P_2O_5, and CO_2 (values normalized to 100%, loss-on-ignition (LOI) at 1000 °C are taken into account). Various geochemical indexes, moduli, and ratios between elements were calculated in the process of the silicate analysis results.

Chemical index of weathering CIW = $[Al_2O_3/(Al_2O_3 + CaO + Na_2O)] \times 100$ (Harnois, 1988); Index of Compositional Variability ICV = $(Fe_2O_3 + K_2O + N_2O + CaO + MgO + TiO_2)/Al_2O_3$ (Cox et al., 1995); and Chemical index of alteration CIA = $[Al_2O_3/(Al_2O_3 + CaO + Na_2O + K_2O)] \times 100$ (Nesbitt and Young, 1982) have been used as proxy data in reconstructing paleoclimate. Some modulus values were used for the same purpose (Yudovich and Kertis, 2011). The hydrolysis modulus was calculated using the formula $(Al_2O_3 + TiO_2 + Fe_2O_3 + MnO)/SiO_2$, ferrous modulus as $(Fe_2O_3 + FeO + MnO)/(Al_2O_3 + TiO_2)$, alumosilicic modulus as Al_2O_3/SiO_2, femic modulus from $(Fe_2O_3 + FeO + MgO)/SiO_2$, titanium modulus as TiO_2/Al_2O_3, and alkaline modulus as (Na_2O/K_2O). Normalized total alkalinity was calculated using the formula $(Na_2O + K_2O)/Al_2O_3$.

3. Results

3.1. Slavin Yar cross-section

Slavin Yar is located on the southwest margin of the Tora basin in the Tunka rift valley on the left bank of the Zun-Murin River, 11 km from its mouth (Fig. 2). This is the largest and stratigraphically most interesting Quaternary sequence found in the basins southwest of Baikal.

3.1.1. Lithology and stratigraphy

The exposure extends around 1 km along the river bank, and the apparent thickness of sediments exposed in the section is up to 30 m (Fig. 2). In the section, three distinct members can be recognized (from top to base):

1) Light-brown sands interlayered with loams. The “sandy” part of the sequence (layers 1–14) may be regarded as a single member.
2) Light-gray boulders with pebbles overlie the conglomerates of member 3;
3) Brown-ocherous boulder and pebble conglomerates with interlayers and lenses of sands.

The conglomerates (member 3) overlie crystalline bedrock that is exposed at the southwestern end of the section and rises to 2 m above the Zun-Murin water level. The conglomerate unit can be traced for a distance of about 200 m and wedges out upstream. The entire unit dips NE, its base being inclined at an angle of 10° (in its visible part) and the top at 3–4°. Bedding in the conglomerate unit

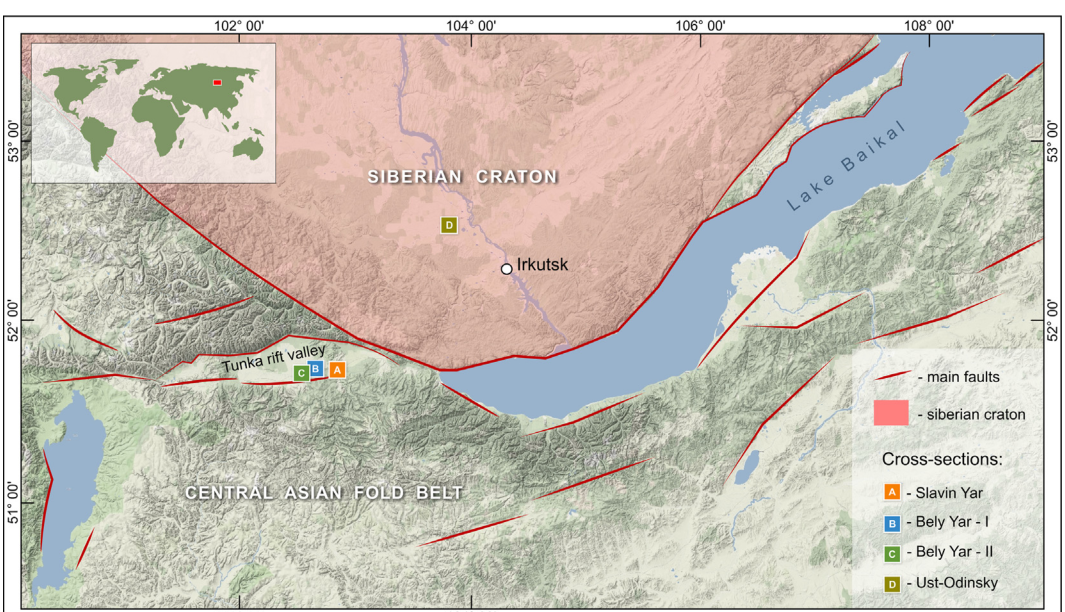

Fig. 1. Location map of the Cis-Baikal region (based on SRTM digital elevation data) and its general tectonic elements.