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Changes of environments and climate during the Late Pleistocene and Holocene reconstructed from aeolian and colluvial deposits of the Zaktui site (Tunka rift valley, Baikal region)

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ABSTRACT

Integrated study of the multilayer Zaktui site supplied a large volume of paleontological materials and a series of radiocarbon dates falling within the MIS 3–MIS 1 interval. Multidisciplinary data provided evidence of the past dynamics of environments and climate. Paleontological data point to a mosaic structure of landscapes, and suggest a temperate warm and humid climate in the south-western Baikal region during MIS 3 interval, with some regional deviations.

1. Introduction

Recently, investigations of the climate and environmental changes in the Lake Baikal region (Southern Siberia) through the Late Pleistocene–Holocene have been considerably intensified. Palaeoecological data derived from sediments of different genesis including bottom sediments of Lake Baikal and Lake Hovsgol (Karabanov et al., 2000; BDP Members, 2001, 2005; Kataoka et al., 2003; Demske et al., 2005; HDP Members, 2007, 2009; Mackay et al., 2011), and those of small lakes and peat bogs in the same region (Bezrukova et al., 2005, 2008, 2010, 2011, Shichi et al., 2007, 2009; Mackay et al., 2012, 2013), river terrace alluvial deposits (White et al., 2008, 2013; Arslanov et al., 2011), and cultural horizons of archaeological sites (Khenzykhenova and Alexeeva, 1999; Khenzykhenova, 2008; Sato et al., 2008, 2014; Erbaeva et al., 2011; Khenzykhenova et al., 2011). Studies of the cores obtained by drilling in Lake Baikal and Lake Hovsgol revealed the sediments to be heavily compressed, which prevents obtaining paleogeographic reconstructions of a satisfactory accuracy for the Late Pleistocene–Holocene interval. In dealing with this problem we made recourse to other natural records, such as bottom sediments of small lakes in the vicinity of Baikal and Hovsgol lakes, peat-bog deposits, and sections of subaerial and fluvial deposits.

The position of the Tunka rift valley extending from Baikal to Hovsgol lakes forms a kind of "connecting link" between the North Asian taiga zone and steppe landscapes of Central Asia. This location makes the Tunka rift an important area for analyzing environment and climate dynamics in the Baikal region. One of the key sections of the Upper Pleistocene in the Tunka rift was described at the Zaktui site.

This paper deals with results of integrated research of the Zaktui section. The principal aims of the paper may be stated as follows: (1) to describe the geological and stratigraphical context of the Zaktui site; (2) to present results of the studies of pollen assemblages and theriofauna successions from the Late Pleistocene (MIS 3) to Holocene (MIS 1); and (3) to integrate these new data with key local and regional multi-proxy data on the Late Pleistocene–Holocene climate and environments.

2. Locality setting

The Zaktui site (51°42.184′ N, 102°39.615′ E, 740 m a.s.l.) is at the southeastern end of the Tunka basin (Tunka rift valley), on the

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gently sloping piedmont plain fringing the northern slope of the Khamar-Daban Range (Fig. 1), 80 km south of Lake Baikal. The Khamar-Daban elevation in this region reaches 2700 m, bordering the chain of tectonic depressions of the Tunka rift valley on the south. On the north, the rift valley is bounded by the alpine-type Tunka Range up to 3100 m high.

In the 1960s–1980s, the area near the Zaktui site was actively used as arable land. The farming stopped in the early 1990s, but the plain surface suffered badly from the gully erosion, a dense network of rills and ravines being developed. One of the largest gullies cuts through the entire sequence including loess-like deposits, mostly of colluvial genesis of 5 m thickness overlying the solid rock of the basement. This exposure is known as the Zaktui cross-section.

The basement of the Tunka basin is composed mainly of the Early Paleozoic granitoids and metamorphic rocks. The basin is filled with a series of Oligocene-Quaternary deposits up to 3 km thick. The Cenozoic geology of the Tunka region is dealt with in a number of papers (Ravskii et al., 1964; Mazilov et al., 1972; Adamenko et al., 1975, 1984; Popova et al., 1989; Kashik and Mazilov, 1994; Ufimtsev et al., 2002, 2003, 2004a,b; Hase et al., 2003). In the Tunka basin, several stratotype sections of Cenozoic stratigraphic units were described (Logachev, 1958a, b; Florensov, 1960), including recent investigations (Shchetnikov and Ufimtsev, 2004; Shchetnikov et al., 2009, 2013) (Shchetnikov et al., 2012).

During the Late Pliocene–Quaternary, tectonism formed basins that are now filled with coarse clastic materials highly variable in composition. Early and Middle Pleistocene sediments are exposed only occasionally, usually overlain by Late Pleistocene deposits. Three Late Pleistocene sedimentary facies are dominant: boulder–pebble gravels (proluvial, glaciofluvial, and alluvial sediments); alluvial sands; and loess-like sediments with associated slope deposits altered by post-depositional wind processes. The relationship between these complexes, as well as radiocarbon and other chronological data and fauna and flora remains, suggests the onset of the deposition c. 70 ka (Shchetnikov et al., 2012). Glacial deposits and cryogenic material indicate that at times the climate was cool or cold. During the early Late Pleistocene, renewed tectonism caused an increase of the coarse material deposition. The middle Late Pleistocene deposits consist mostly of sandy floodplain alluvium. By the end of the Late Pleistocene–Holocene, alluviation was reduced and gave way to erosion and aeolian deposition.

The Tunka rift valley position, at the center of the continent far away from seas and oceans, accounts for the climate characteristics: its continentality and moderate humidity, with a large proportion of sunny days. The microclimate of the region is largely controlled by topography: the latter is extremely diversified, the relative altitudes exceeding 2 km. The entire region features a relatively cold winter with a small amount of snow, drought-afflicted spring and the first half of summer, while the second half of summer is usually rainy. The precipitation is irregularly distributed over the region. Bottoms of the basins are the least supplied with moisture (less than 300 mm per year), while windward slopes of the mountain ranges obtain as much as 500 mm (Zhukov, 1960). Mean annual temperature is negative (from $-1°$ to -9 °C) everywhere in the Tunka rift (Zhukov, 1960). The highest air temperature, occasionally up to 40 °C, occurs in July–August, and the lowest January (to -45 °C).

The vegetation in the Tunka rift valley is rather diversified. The upper part of the forest zone in mountains (1800–1200 m) is dominated by Siberian stone pine (*Pinus sibirica*) and Siberian fir (*Abies sibirica*). Foothills are occupied by mixed forests of Siberian larch (*Larix sibirica*), pine (*Pinus silvestris*), and birch (*Betula*). Siberian spruce *Picea obovata*) and poplar (*Populus*) are confined to river valleys. Floodplains in the rift basins are occupied with shrubs (mostly of *Salix*), marshy meadow and wetlands.

3. Materials and methods

The mineralogical analysis of the sediments was performed in the Institute of the Earth's Crust, Siberian Branch of the Russian Academy of Sciences (Irkutsk, Russia). First, the samples were sieved, and then the fraction to be analyzed (0.25–0.05 mm) was separated into light and heavy fractions using a heavy liquid (bromoform) with specific gravity of 2.8. The mineral grains were analyzed using an immersion technique. Six samples were analyzed from each layer except for layer 1 (from which 2 samples were taken).

The age of the sediments was determined by ^{14}C. Large mammal bones were dated in the Oxford University (Great Britain) using AMS technique with ultrafiltration, while for dating fossil soils the benzol-scintillation method was used (Institute of Geography RAS, Moscow, Russia). Eight samples were dated.

The pollen diagram was compiled using Tilia 1.5.12 software developed and kindly provided by Dr. Eric Grimm (Illinois State Museum, Springfield, the USA). According to that technique, the general composition of the spectra is counted (arboreal pollen + non-arboreal pollen + spores = 100%), and a proportion of individual components of the pollen assemblage is expressed as a percentage of the total number of counted grains. The Zaktui cross-section was sampled at 10 cm intervals, and 33 samples have been analyzed.

Remains of large mammal fauna were collected directly in the process of excavation. Those of small mammals and birds were mostly recovered by way of wet sieving. In the laboratory, the bones were carefully cleaned and impregnated with glue using standard procedures, and determined to a species level. The total number of faunal remains collected during the excavations is as follows: large mammals – 38, small mammals – 482, and birds – 2.

3.1. Sedimentology and stratigraphy

The recent soil is developed on sandy loam with an admixture of silt, light to dark brown, with occasional lenses of dark humified sandy loam. They are underlain with light brown gravelly sands, showing cross bedding and wavy lamination. The sands, in turn, overlie wavy laminated loess-like sandy loams including thin laminae of non-sorted silty sands, gravel and gruss, with occasional lenses of humified material. The proportion of coarser sands and gravel, as well as angular debris and blocks varying in size, increases towards the base of the sequence.

The upper part of the sequence is exceedingly rich in carbonates, which is a distinctive feature of loess in the Tunka rift (Shchetnikov et al., 2012). In the fine fraction (sand, silt, clay) the size of particles increases noticeably towards the base of the section. Dominance of quartz, plagioclase, and potassium feldspar in the sediments suggests some local sources of those minerals within the area of granitic rock outcrops. A layer-by-layer description, from base to top of the sequence, includes (Fig. 2):

Layer 1. Gray silty sands with gravel and gruss, with interlayers and lenses of brownish-gray loam and inclusions of angular rock debris and blocks. The sand and loam boundary is marked with an ocherous fringe due to iron hydroxides. There is S-like and lens-like lamination. The layer is broken with numerous micro-faults of 6–7 cm amplitude. Colluvial deposits. Total thickness – 1.4–1.7 m.

Layer 2. Cocoa-colored loam and clays with lenses of fine sands and sandy loams, abounding in charcoal fragments. Individual laminas within the sandy loam lenses bear an ocherous fringe. The lower boundary is distinct, uneven. Colluvial deposits. Thickness – 0.3–0.5 m.

Layer 3. Sandy loams with interlayers and lenses of gravelly sands and occasional rock debris and blocks, ocherous due to