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# Quantitative reconstructions of mid- to late holocene climate and vegetation in the north-eastern altai mountains recorded in lake teletskoye

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ABSTRACT

We report the first high-resolution (20–50 years) mid- to late Holocene pollen records from Lake Teletskoye, the largest lake in the Altai Mountains, in south-eastern West Siberia. Generally, the mid- to late Holocene (the last 4250 years) vegetation of the north-eastern Altai, as recorded in two studied sediment cores, is characterised by Siberian pine–spruce–fir forests that are similar to those of the present day. A relatively cool and dry interval with July temperatures lower than those of today occurred between 3.9 and 3.6 ka BP. The widespread distribution of open, steppe-like communities with *Artemisia*, Chenopodiaceae and Cyperaceae reflects maximum deforestation during this interval. After ca. 3.5 ka BP, the coniferous mountain taiga spread significantly, with maximum woody coverage and taiga biome scores between ca. 2.7 and 1.6 ka BP. This coincides well with the highest July temperature (approximately 1 °C higher than today) intervals. A short period of cooling about 1.3–1.4 ka BP could have been triggered by the increased volcanic activity recorded across the Northern Hemisphere. A new period of cooling started around 1100–1150 CE, with the minimum July temperatures occurring between 1450 and 1800 CE.



## 1. Introduction

The Altai Mountains provide an important connection between the Central Asian steppe and the North Asian forest-steppe. Holocene environmental changes might have had a significant influence on the development of human societies in this region. Many well-known archaeological sites from the Paleolithic to the Middle Ages, such as Denisova Cave, the Pazyryk necropolis, and the Ukok tombs, are situated in the Altai Mountains (Polosmak, 2001; Derevianko et al., 2003). The Altai, which is shared by China, Kazakhstan, Mongolia and Russia is a prominent sub-longitudinal mountain range of Central Asia that extends approximately 1200 km in a north–south direction and rises up to 4500 m a.s.l. (Atlas of geological maps of Central Asia and adjacent areas, 2008). It is an important climatic and natural boundary at the limits of both Pacific and Atlantic influences and a divide between Boreal and Ancient Mediterranean floristic sub-kingdoms of the Holarctic (Takhtajan, 1986). The Altai Mountains also contain relic vegetation types and paleoenvironmental studies can shed light on the vegetation history of the region. This is important, because a sizeable part of the Altai, including Lake Teletskoye, is a UNESCO World Heritage site, named the "Golden Mountains of Altai" (http://whc.unesco.org/en/list/).

Pollen records represent one of the most powerful tools to understand past environmental changes. Several Holocene pollen records from the Altai Mountains with varying time resolutions have been

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published in recent decades (Gunin et al., 1999; Tarasov et al., 2000; Blyakharchuk et al., 2004, 2007, 2008; Andreev et al., 2007; Schlütz, Lehmkuhl, 2007; Rudaya et al., 2009, 2012). However, these records and their resolutions are insufficient for detailed palaeoenvironmental reconstructions, taking into account the size and heterogeneity of the territory.

Here, we report on the first high-resolution (20–50 years) mid- to late Holocene pollen records from Lake Teletskoye, obtained from the underwater Sofia Lepneva Ridge in 2006 (core Tel 2006) and from the deepest part of the lake in 2001 and 2004 (combined core Tel 2001–2004). The uppermost part of the Tel 2001–2004 core was palynologically examined by Andreev et al. (2007), but was never used for quantitative reconstructions. In addition to taxonomy, newly developed statistical approaches strengthen the use of pollen data and allow numerical reconstructions of climate parameters. This paper presents (i) the results of palynological analysis of the cores; and (ii) quantitative reconstructions of the late-Holocene regional vegetation, woody coverage and climate. Regional comparisons were performed, to infer the paleoenvironmental and paleoclimatic history of this poorly documented region. These new results lead to a better understanding of the role of the northeastern Altai in the Holocene environmental history of Central Asia.

## 2. Regional setting

The northeastern Altai (51–52°N, 86–88°E) is an extensive plateau with isolated massifs of approximately 2000 m a.s.l. that are bisected by deep river valleys (Kuminova, 1960). The region possesses a unique evergreen coniferous taiga that is dominated by Siberian fir and Siberian pine, as well as deciduous trees and some relic herbaceous species. The vegetation in the region is floristically close to the Subatlantic type of European hemiboreal forests (Ermakov, 2003). Despite significant afforestation, the region is classified within the Holarctic zone of the Eurasian steppe (Lavrenko, 2000). The montane forest belt of the Altai Mountains connects to the taiga zone of Siberia via forests of the Kuznetsky Alatau, a part of the Sayan Mountains.

Lake Teletskoye (spanning 51°20′ to 51°47′N and 87°15′ to 87°50′E) is the largest lake in the Altai Mountains (Figs. 1A, 2) and is 77 km long and 330 m deep and filled by approximately 40 m of sediments. The lake appeared by the end of the Late Pleistocene, when water filled a tectonic depression (Seleznev et al., 1995). Lacustrine and alluvial deposits in the southeastern part of the lake (Bele terrace located above the modern lake level) were radiocarbon-dated to 27,060 ± 850 ka BP. These are the oldest known lacustrine sediments in the lake basin (Rusanov and Orlova, 2013). The Chulyshman River, one of the largest rivers of the Russian Altai, flows into the lake from the south and drains 84% of the lake catchment area. Several smaller rivers also flow into the lake. The Biya River flows out of the lake to the north (Selegei and Selegei, 1978). The altitude of the mountains surrounding the lake is 1900 m a.s.l. on average. Due to the lake's influence, the climate of the basin is relatively mild, especially in the south. The mean annual temperatures of 3.2–4.0°C are approximately 1 °C higher than in other regions surrounding the lake (http://wcatlas.iwmi.org). The mean January temperatures are about −8.5 °C, and mean July temperatures are approximately 17.5 °C (data from the Yailu weather station). The mean annual precipitation varies between 822 mm/yr in the north and 460 mm/yr in the south (Kuminova, 1960).

As this north-eastern part of the Altai Mountains is characterised by higher annual precipitation, it results in the absence of the steppe belt that occurs, at least fragmentarily, in other parts of the mountains (Kuminova, 1960). Only very small patches along the lakeshore represent steppe-like vegetation. Birch forests mixed with meadows occur at lower altitudes, up to 700 m a.s.l. Unique evergreen (so-called 'dark') coniferous forest with dominating Siberian fir (*Abies sibirica*), aspen (*Populus tremula*), dense understory with bird cherry (*Padus avium*), mountain ash (*Sorbus sibirica*), viburnum (*Viburnum opulus*) and a number of relic herbaceous species such as *Dryopteris filix-mas*, *Brachypodium sylvaticum*, *Festuca gigantea*, *Poa remota*, *Asarum*

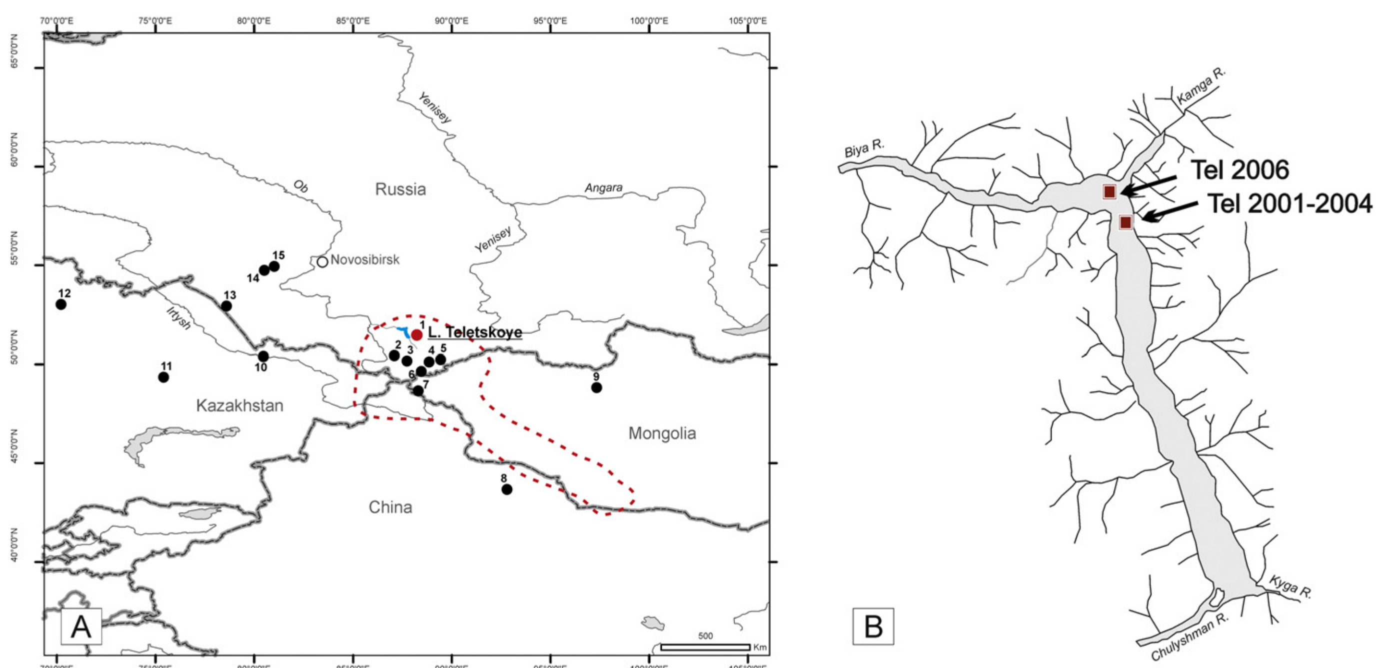


**Fig. 1.** A. Map of the study area and summary chart showing the distribution of the mid-late-Holocene palaeoclimate records from Altai Mountains and the neighboring regions discussed in the text: 1. Lake Teletskoye (51°35′N, 87°40′E; this study), 2. Lake Uzun-Kol (50°29′00″N, 87°6′30″E; Blyakharchuk et al., 2004), 3. Lake Dzhangyskol (50°11′N, 87°44′E; Blyakharchuk et al., 2008), 4. Kuray Range (50°08′04″N, 88°51′10″E; Schlütz and Lehmkuhl, 2007), 5. Lake Ak-Kol (50°15′N, 89°37′30″E; Blyakharchuk et al., 2007), 6. Tarkhata Valley (49°39′01″N, 88°28′10″E; Schlütz and Lehmkuhl, 2007), 7. Hoton-Nur Lake (48°40′N, 88°18′E; Rudaya et al., 2009), 8. Lake Bakikun (An et al., 2011), 9. Telmen Lake (Peck et al., 2002), 10. Ozerki Swamp (50°24′N, 80°28′E; Kremenetski et al., 1997), 11. Pashennoe Lake (49°22′N, 75°24′E; Kremenetski et al., 1997), 12. Lake Karasye (53°02′N, 70°13′E; Kremenetski et al., 1997), 13. Lake Big Yarovoe (52°51.156′N, 78°37.601′E; Rudaya et al., 2012), 14. Suminskoye Zaimitsche (54°45′N; 80°31′E; Klimanov et al., 1987), 15. Kayakskoye Zaimitsche (54°57′ N; 81°01′ E; Levina et al., 1987). Dashed line is contour of Altai Mountains. B. Lake Teletskoye with the core locations marked and associated hydrological network.