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Vegetation response in the southern Lake Baikal region to abrupt climate events over the past 33 cal kyr

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ABSTRACT

We reconstructed vegetation changes and fire events in the southern Lake Baikal region over the past 33 cal kyr using a sediment core from the Buguldeika Saddle, southern Lake Baikal, to examine vegetation response to past short-term climate variations. Herbs, such as *Artemisia* and Asteraceae, were dominant just before the Last Glacial Maximum (LGM). Low pollen accumulation rates (PARs) with little herb pollen indicate sparse herbaceous vegetation cover during the LGM. *Picea* expanded after the Bølling interval, suggesting expansion of riparian areas, and shrub *Alnus* rapidly increased during the following Allerød interval. *Abies* and *Pinus* subgen. *Haploxylon* began to increase at the beginning of the Holocene and *Pinus* subgen. *Diploxylon* has been highly dominant since the middle Holocene. The vegetation change after the LGM is similar to that from other sites in the Lake Baikal region, but the responses to short-term climate events are pronounced. Fluctuations in herb elements and vegetation cover as indicated by the PAR correspond to the Younger Dryas (YD) cooling event. The decline in the PAR and increase in herb taxa were remarkable at the beginning of the YD, but *Larix* and *Picea* trees were distributed in river valleys near Lake Baikal in the latter half. The rapid expansion of *Betula* and *Artemisia* following frequent fires in the early Holocene may have been in response to the 8.2 cal ka BP cooling event. From these findings, the southern Lake Baikal region, including the Selenga River basin, may possibly have been more sensitive than other parts of the region to abrupt climate changes.

1. Introduction

The Lake Baikal region, which is located in inland southeastern Siberia far from oceanic influences, is influenced by continental climatic conditions. Eastern Siberia, including the Lake Baikal region, is one of the most sensitive regions to seasonal changes in solar insolation (Short et al., 1991), and thus climate is thought to have greatly fluctuated in the past as well. Lake Baikal has been rich in biodiversity, with many endemic species throughout its long history beginning in the Miocene (Hutchinson et al., 1992). Although terrestrial plant diversity is not as rich as lacustrine diversity, the Baikal region is widely covered by coniferous forests, which play an important role as an organic carbon sink, including the soils under the forests. Previous studies of the interactions between past climate and the ecosystem were performed by mainly analyzing the bottom sediments of Lake Baikal, which is currently one of the most intensely studied sites in Siberia. These studies are useful for obtaining a longer-term perspective on the recent warming trend.

Numerous studies of Lake Baikal show that its sediments allow for the reconstruction of continuous and detailed paleoclimatic and paleoecological changes (e.g., Williams et al., 1997; Kashiwaya et al., 2001; Prokopenko et al., 2002). Palynological studies using the sediments have been performed over the last two decades and provide many new data on paleovegetation and paleoclimate since the Miocene (e.g., Bradbury et al., 1994; Kawamuro et al., 2000; Demske et al., 2002; Maki et al., 2003; Granoszewski et al., 2005; Shichi et al., 2007). In particular, vegetation changes in the region since the Last Glacial Maximum (LGM) were revealed by both the bottom sediments (Miyoshi et al., 1999; Horiuchi et al., 2000; Bezrukova et al., 2005a; Demske et al., 2005; Tarasov et al., 2007) and the coastal small lake and mire sediments (Bezrukova et al., 1996; Takahara et al., 2000; Kataoka et al., 2003; Bezrukova et al., 2005b; Shichi et al., 2009; Tarasov et al., 2009). However, detailed pollen records with stable dating controls before the LGM are still limited (Bezrukova et

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al., 2010) and more palynological studies are needed to compare with other proxies, such as biogenic silica and total carbon content (e.g., Prokopenko et al., 2006; Soma et al., 2007).

Vegetation changes in response to climate oscillations related to orbital forcing and vegetation responses to abrupt climate events, such as the Dansgaard–Oeschger (D–O) cycles and the Younger Dryas (YD) cooling, were detected in the Lake Baikal region. Bezrukova et al. (2010) showed that fluctuations in biome scores for steppe and taiga calculated by pollen composition from Lake Kotokel near Lake Baikal may be related to the D–O cycles. However, the scores do not clearly indicate responses to the Heinrich events and no current report has been published on the vegetation impact of the cooling events. Brownish mud layers with enriched terrestrial organic carbon relating to the Heinrich events are present in the sedimentary record from the Buguldeika Saddle (Prokopenko et al., 2001a,b).

The YD event is widely recognized in the sediments of Lake Baikal through variations in diatom abundance, organic matter, and $\delta^{13}C$ and $\delta^{18}O$ values (Prokopenko et al., 1999; Tani et al., 2002; Prokopenko and Williams, 2004; Morley et al., 2005; Watanabe et al., 2009a). The variations in each proxy are considered to be due to decline in biological activity and change in sedimentation conditions accompanied by climatic deterioration. The YD is also present in palynological data. Demske et al. (2005) found that an increase in shrub birch, *Artemisia*, and Chenopodiaceae in the pollen sequence from the lake is indicative of the YD. Bezrukova et al. (2005a) observed a decrease in spruce pollen corresponding to the event from the Selenga delta area. However, the influence of the YD is not clearly apparent in the pollen records from the Academician Ridge of Lake Baikal (Horiuchi et al., 2000; Bezrukova et al., 2005a) and the northeastern coastal mire sediments (Kataoka et al., 2003). Regional differences may thus exist in vegetation response in the YD.

With regard to other short-term climate events in the Holocene, Demske et al. (2005) noted that fir and spruce declined in the southern mountains and that this may be related to the 8.2 cal ka BP cooling event. However, the vegetation response remains chronologically uncertain and no age data are available from other proxies. Whether such short-term climate events had an influence on the vegetation of the region is still difficult to judge due to the lack of data. An examination of how the climate and vegetation of inland Siberia responded to the dissolution of the Northern Hemisphere ice sheets would help to clarify the mechanism of paleoclimatic change in the Asian interior.

In this study, we conducted pollen and charcoal analyses of approximately the past 30 kyr using a sediment core extracted from the Buguldeika Saddle of southern Lake Baikal with higher time resolution than those of previous studies (e.g., Bezrukova et al., 2005a; Demske et al., 2005; Tarasov et al., 2007, 2009). From these results, we considered vegetation responses to past abrupt climate events in the southern Lake Baikal region.

2. Site description and regional environment

Lake Baikal belongs to the Baikal Rift Zone of southeastern Siberia and is surrounded by the steep mountain ranges of the Khamar-Daban, Barguzin, and Baikalsky (Fig. 1). More than 300 rivers flow into Lake Baikal and the Selenga River, one of the largest and most important rivers from Northern Mongolia, contributes ~50% of the total annual river inflow (Mackay, 2007). In the near-shore areas, lowlands less than 600 m a.s.l. stretch around the river mouths of the Selenga and other rivers from several to dozens of kilometers in width and wetlands are well developed. Plateaus and mountainous areas up to 2500 m a.s.l. are present in the upper and middle reaches of the Selenga River.

The Buguldeika Saddle is geomorphologically separated by underwater uplifts in Lake Baikal and is formed mainly by the accumulation of terrestrial materials from the Selenga River (Kuzmin et al., 2000). Therefore, the sediments are controlled by the composition of the fine suspended load of the Selenga River and turbidites are extremely rare, at least in the upper several dozen meters of sediment (Prokopenko et al., 2001a,b). The Buguldeika River, flowing from the north to the Buguldeika Saddle, is also thought to supply terrestrial material from the catchment, but only fine-grained material is supplied by a stream-like flow at present and its influence is thought to have decreased since the end of the middle Pleistocene (BDP Members, 1997).

The present climate of the Lake Baikal region is strongly continental as a result of the large atmospheric system known as the Siberian High. The existence of Lake Baikal itself produces different microclimatic conditions in the area and northwesterlies from the lake help to generate a climatic gradient. Meteorological data from Babushkin (51°43′N, 105°52′E), situated on the southern shore of Lake Baikal, indicate that the mean monthly temperature is −16.8 °C in January and 14.2 °C in July, and the mean annual precipitation is ~550 mm (Galazy, 1993). In contrast, in Ulan-Ude, located 100 km southeast

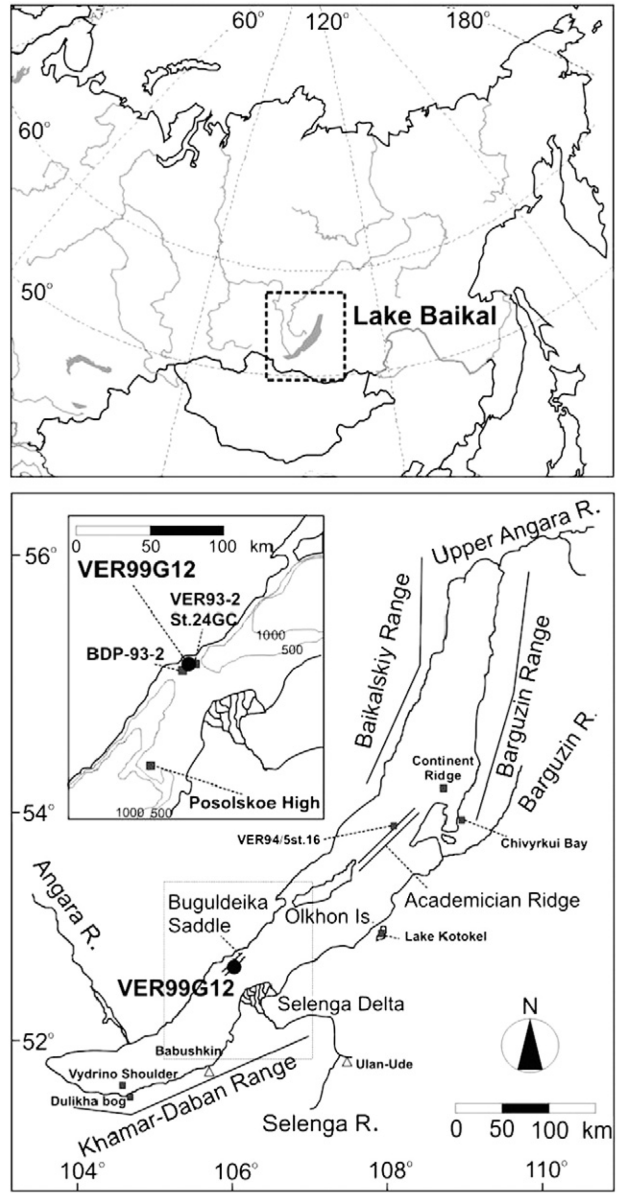

Fig. 1. Map of the Lake Baikal region showing the location of the VER99G12 core drilling site and the other sites discussed in the text.