Quaternary Science Reviews xxx (2015) 1–13

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

# Vegetation, climate and lake changes over the last 7000 years at the boreal treeline in north-central Siberia

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ARTICLE INFO

*Article history:*
Received 8 April 2015
Received in revised form
24 July 2015
Accepted 6 August 2015
Available online xxx

*Keywords:*
Tundra-taiga ecotone
*Larix gmelinii*
Palynology
Sediment geochemistry
Mean July temperature
Ordination
WA-PLS
Procrustes rotation

ABSTRACT

Palaeoecological investigations in the larch forest-tundra ecotone in northern Siberia have the potential to reveal Holocene environmental variations, which likely have consequences for global climate change because of the strong high-latitude feedback mechanisms. A sediment core, collected from a small lake (radius ~100 m), was used to reconstruct the development of the lake and its catchment as well as vegetation and summer temperatures over the last 7100 calibrated years. A multi-proxy approach was taken including pollen and sedimentological analyses. Our data indicate a gradual replacement of open larch forests by tundra with scattered single trees as found today in the vicinity of the lake. An overall trend of cooling summer temperature from a ~2 °C warmer-than-present mid-Holocene summer temperatures until the establishment of modern conditions around 3000 years ago is reconstructed based on a regional pollen-climate transfer function. The inference of regional vegetation changes was compared to local changes in the lake's catchment. An initial small water depression occurred from 7100 to 6500 cal years BP. Afterwards, a small lake formed and deepened, probably due to thermokarst processes. Although the general trends of local and regional environmental change match, the lake catchment changes show higher variability. Furthermore, changes in the lake catchment slightly precede those in the regional vegetation. Both proxies highlight that marked environmental changes occurred in the Siberian forest-tundra ecotone over the course of the Holocene.



## 1. Introduction

The globally occurring warming trend is especially pronounced in the arctic region as a consequence of polar amplification (Serreze et al., 2009; Bekryaev et al., 2010; Hinzman et al., 2013) and is expected to accelerated in the future in northernmost Siberia, particularly around the Taymyr Peninsula (IPCC, 2013). To substantiate this prediction it is useful to interpret reconstructions from the past with similar spatial patterns, but few quantitative climate reconstructions are available from northern Siberia.

Reconstruction of past climate requires an understanding of how the climate proxy is temporally and spatially related to climate change. From the ongoing environmental changes we already know that the timing and strength of the various components of the Arctic environmental systems to climate forcing are extremely variable (Lenton, 2012; Hinzman et al., 2013; Pearson et al., 2013). For example, hydrological changes of permafrost lakes may be abrupt but the direction of change varies locally, e.g. rising lake level at one site and increased outflow at a nearby site (Brouchkov et al., 2004; Smith et al., 2005; van Huissteden et al., 2011; Morgenstern et al., 2011; Kanevskiy et al., 2014; Turner et al., 2014). Accordingly, proxies of hydrological changes in thermokarst lakes may respond immediately but change is not linearly related to climate. On the other hand, the vegetation change in response to climate change may be gradual, i.e. northward species migration and a boreal forest expansion in times of warming (Naurzbaev and Vaganov, 2000; Elmendorf et al., 2012a,b; Berner et al., 2013; IPCC, 2013). This response to climate variation might be consistent over larger areas but its reaction can be masked regionally (Sidorova et al., 2009; Giesecke et al., 2011; Tchebakova and Parfenova, 2012; Kharuk et al., 2013). At the Siberian treeline, the most reasonable scenarios are leading-edge vegetation-climate

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http://dx.doi.org/10.1016/j.quascirev.2015.08.015
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Please cite this article in press as: Klemm, J., et al., Vegetation, climate and lake changes over the last 7000 years at the boreal treeline in north-central Siberia, Quaternary Science Reviews (2015), http://dx.doi.org/10.1016/j.quascirev.2015.08.015

disequilibrium at times of climate warming due to restricted larch migration rates and trailing-edge disequilibrium because of persistent forest despite a cold climate. This indicates that a reasonable ensemble of environmental variables needs to be collected to control for the uncertainties originating from the various scales on which processes operate.

Continuous records of millennial-scale environmental changes in northern Siberia are best obtained from lake sediments that can be explored for various parameters. Here, we present results of palynological and sedimentological analyses of a lake sediment core from the southern Taymyr Peninsula (northern Siberia) covering ~7100 cal years BP to present. Because pollen is still one of the most reliable climate proxies available for the region, we provide a pollen-based climate reconstruction and assess the obtained results in connection with local hydrological changes as inferred from sedimentological and geochemical parameters.

## 2. Regional setting

The Khatanga River Region forms part of the northern Siberian lowlands and is located between the Taymyr Peninsula to the north and the Putorana Plateau to the south, politically belonging to the Krasnoyarsk Krai of Russia. The studied lake's catchment is underlain by thick terrigenous and volcanic sediments that are rich in smectite originating from Siberian Trap basalts of the Putorana Plateau (Wahsner et al., 1999; Petrov, 2008; Vernikovsky et al., 2013). Overlying Quaternary periglacial and, to some extent, lacustrine–alluvial deposits are predominately of Putoran origin and therefore basaltic (Peregovich et al., 1999; Shahgedanova et al., 2002). Loadings in the Khatanga River have been reported to comprise up to 80% of the montmorinolit clay mineral smectite (Rachold et al., 1997; Dethleff et al., 2000). The lowland's landscape is homogeneous with low relief. The region was probably not or only locally glaciated during the Last Glacial Maximum but was situated between the glaciers of the Taymyr and Putoran Mountains, hence, periglacial conditions prevailed (Svendsen et al., 2004; Ehlers and Gibbard, 2007). The region is controlled by continuous, very deep permafrost with medium ground-ice content up to 20% by volume (Schirrmeister et al., 2013; Brown et al., 2014) and numerous lakes are found there (Ananjeva and Ponomarjeva, 2001).

The regional climate is dominated by the polar front, which is located close to the coast of the Arctic Ocean during winter. In summer, the region lies within the arctic front. Prevailing winds are from the north–west and south–east (Treshnikov, 1985; MacDonald et al., 2000b; Pospelova et al., 2004). The subarctic climate of the region is continental, having short and mild summers with a mean July temperature around 12.5 °C and severe winters with a mean January temperature ~−31.5 °C. Annual precipitation is low, around 250 mm with most rain falling during the summer between June and September. Snow cover lasts between 180 and 260 days at depths of up to 80 cm (Grigoriev and Sokolov, 1994; climate station, established in Khatanga town in 1934, http://www.pogodaiklimat.ru/climate/20891.htm).

The vegetation of the region represents the southern fringe of shrub tundra and is composed of a mosaic of vegetation types

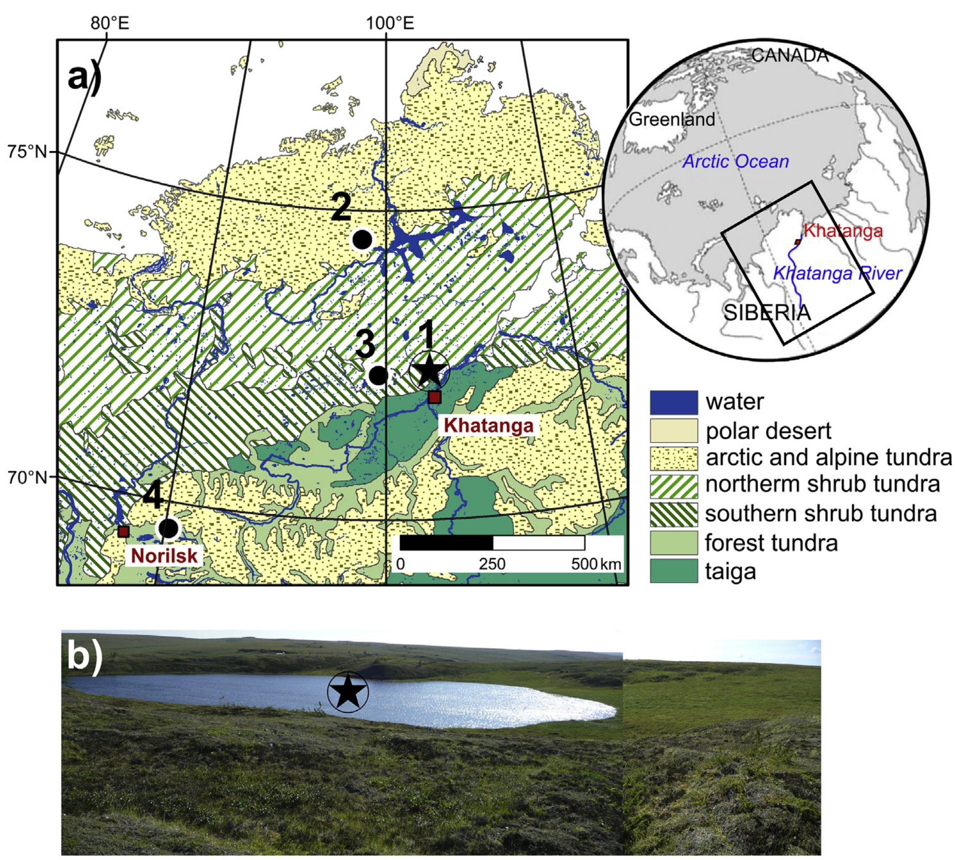


**Fig. 1.** Location of the study region within the Siberian Arctic: a) Map of the Taymyr region with the location of Lake CH-12 (1; star), the towns Khatanga and Norilsk, and other lake studies: Levinson-Lessing Lake (2), Labaz Lake (3) and Lama Lake (4). The modern vegetation zones following Stone and Schlesinger (1993) are indicated. b) Lake CH-12, which measures about 200 × 150 m, with the coring position marked. Also visible is the wetland dominated by sedges and *Salix* shrubs at the eastern end of the lake (opposite the outflow).

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