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The Holocene environmental changes in boreal fen peatland of northern Mongolia reconstructed from diatom assemblages

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ABSTRACT

The Holocene hydrological changes of fen peatland in northern Mongolia were reconstructed using diatom fossils with an aid of *Sphagnum* leaf fossils. Analyses were conducted on three cores taken across the basin and reconstructed water environments were compared to find basin-wide hydrological changes and climate anomalies. The peatland has been covered by sedges during most of its 10 thousand years history, but all cores showed common peatland hydrosere processes from fluvial environment in the early Holocene period, shallow marsh to present acidic fen peatland. The establishment of fen peatland at 6.8–6.4 cal ka BP was marked synchronously by the shift of diatom and *Sphagnum* taxa assemblages and this period was inferred as the onset of the mid-Holocene dry climate which is widely observed around Mongolia. The dry environment lasted until around 2.8 cal ka BP with a temporal wetter condition at 4.4–3.5 cal ka BP. Short term diatom trend shifts indicated temporal wetter environments at 8.7–8.4, 8.0–7.6, 2.4–2.1, 1.2–0.5 cal ka BP and a dry environment at 0.4–0.2 cal ka BP. These periods of hydrology changes were correlative with other studies in Mongolia and East Siberia, so they would represent climate-induced hydrological changes, and those regions might share the same response to long term insolation changes or global climate anomalies. However, disagreements of climate data even within northern Mongolian region suggest large influence of regional geography and the balance of evapotranspiration on climate behaviors as shown by recent dendrological paleoenvironment researches. Coherent differences of main taxa compositions between three cores were attributed to core site-specific local hydrology mainly in terms of relative wetness from wettest core site accompanied by abundant planktonic diatom taxa to driest site with acidic peat indicator taxa. Timings and manners of temporal diatom trend shifts were also largely different between cores suggesting significant difference in each core site sensitivity to basin-wide hydrology changes, confirming the necessity of using multiple cores and proxies in peatland sediments to detect climate-induced environmental changes.

1. Introduction

The land of Mongolia is known for its central location of Siberian High pressure and its variations affect the winter monsoon climate throughout East Asia. Mongolia is distinct from other East Asian countries in that the Asian summer monsoon rainfall generally does not reach the area (Sato, 2009) and climate pattern is more influenced by remote atmospheric behavior in North Atlantic Ocean and Arctic regions (Hurrel et al., 2003) by modulating westerly wind. There are various types of vegetation from forest to desert (Hilbig, 1995) in generally dry and cold continental climate, but they could be largely altered in the near future as the climate in Mongolia is considered susceptible to global climate changes (Sugita et al., 2007). Climate and landscape anomalies are increasingly observed in recent decades, probably due to rapid temperature increases (Batima et al., 2005; Nandintsetseg et al., 2007), melting of permafrost (Kynický et al., 2009) and the reduction of the taiga forest and steppe zone (Dregne, 1986; Tsukuura et al., 2010). In order to understand the mechanism causing these events, knowledge on the past climate changes and subsequent response of natural environment is required.

Recent climate changes in Mongolia for the last millennium are becoming clear on a yearly scale through dendrochronological research (Leland et al., 2013; and references therein), but climate records of the Holocene periods are still lacking to establish even a millennial year scale history. Wang and Feng (2013) and An et al. (2008) compiled previous climate records and suggested the occurrence of mid-Holocene drought in Mongolia. They assumed

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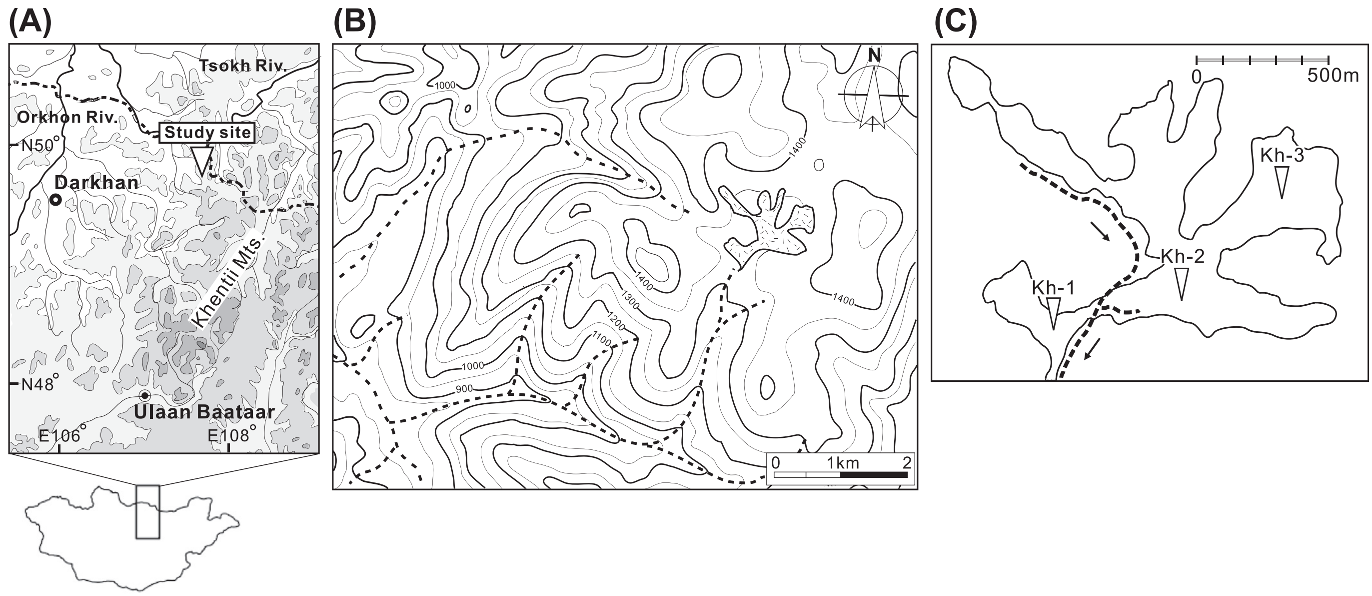

Fig. 1. (A) Sketch of Mongolia, the location of Khentii Mountains and the study site (Nur *Sphagnum* bog). Contour lines are drawn with a 1000 m interval. (B) General description of topography around Nur *Sphagnum* bog (painted with pattern). (C) Locations of core Kh-1, Kh-2 and Kh-3. Thick dotted lines denote river flows.

that it was caused by higher than present summer temperature and strong evaporation, and it was a peculiar phenomenon to the Mongolian plateau and East Siberia in contrast to the southern monsoon climate regions. Short term climate events in centennial scale are often suggested, but their timings are still far from consensus, probably due to regional geography and the balance of evapotranspiration. Mountain orography, for example, was suggested as a strong driver for local climate changes in Lake Baikal region (Bezrukova et al., 2013). Other responsible factors would be difficulty in sediment age control caused by the short sedimentation interval of the Holocene (Prokopenko et al., 2007) and the carbon reservoir effect in lacustrine deposits (Watanabe et al., 2009; Orkhonselenge et al., 2012).

Peatlands have potential to provide high resolution records of climate history because of lesser bioturbation and reservoir effects (Blaauw et al., 2004). Biological proxies such as diatoms, pollen, testate amoebae, and plant materials are good indicators for peatland water environments, and their fossils are widely used to examine past climate changes. Diatom fossil assemblages, in particular, show sensitive responses to various hydrology and peat types such as water quality, types of *Sphagnum* taxa (Round et al., 2000; Klemenčič et al., 2010), humidity (Beyens and Bock, 1989) and seasonality of climate (Kim et al., 2007; Liu et al., 2011). This study analyzed diatom assemblages on three cores taken in a fen peatland located near the southern limit of the East Siberian taiga forest zone in northern Mongolia. *Sphagnum* leaf fossils can be identified only in section level in routine counting, but are useful for the inferring wetness of peatlands (Hájek et al., 2006; Vitt, 2006). The peat cores contain continuous sedimentary records from 10 to 9 cal ka BP. Fukumoto et al. (2012) analyzed diatom, pollen and chemical components on a single peat core and confirmed the extensive mid-Holocene dry condition and short term climate anomalies, including the Medieval Climate Anomaly and the Little Ice Age. However, analysis of a single peat core is often criticized for its low representation of regional climate changes, as autogenic peat growth rhythm and hydrological succession produce numerous site-specific, vegetation, and water environments (Bindler et al., 2004; Yu, 2006). The surrounding topographic characteristics also determine the manner of long term hydrosere successions (Charman et al., 2006). Thus, the analysis of multiple cores and finding similar proxy changes with the same pattern and timing is necessary to remove local hydrological factors. We compared diatom inferred local hydrological and vegetation successions between three cores and tried to discover the evidence of climate changes.

2. Regional setting and study site

The Nur *Sphagnum* bog (49°39′ N, 107°48′ E, 1250 m a.s.l.; Kulikovskiy et al., 2009) is located in Selenge province at the northwestern tip of the Khentii Mountains, which extend from the north of Ulaanbaatar to the Russian border (Fig. 1A). Khentii Mountains have a general elevation of 1500 m and the area is known for high diversity of vegetation types with mixed distributions of wetter Siberian taiga forests and drier Mongolian grass steppe (Dulamsuren et al., 2005). A meteorological station in Yeroo village at 600 m a.s.l., located 80 km west of Nur *Sphagnum* bog, documents mean air temperature of −27.1 °C in January and 18.3 °C in July, and annual precipitation of 288 mm. Mean air temperatures above zero are recorded only from April to September at the station but much lower temperature is expected at the study site due to its higher altitude. *Pinus sibirica*, *Picea obovata* and *Abies sibirica* are distributed in the upper hills surrounding the peatland (Kulikovskiy et al., 2009), corresponding to vegetation of the upper montane belt (1200–1600 m) in Mongolia (Hilbig and Knapp, 1983). *Betula platyphylla* widely occupies peatland margins and river banks.

The Nur *Sphagnum* bog has a small catchment area and there are no large inflowing rivers due to its location on a mountain saddle (Fig. 1B). There is a main outflowing river from the southwest which gathers network streams of the peatland basin (Fig 1C). The peatland surface is apparently flat but the northern area is higher by a few meters, and topographical relief is slightly inclined to southwest along the outflowing river. The outflow is a tributary of Tsokh River that drains into Lake Baikal via Selenga River. The vegetation of the peatland is covered by *Carex rostrata*, various species of *Sphagnum* (mainly *Sphagnum angustifolium*) and brown mosses (such as *Pseudobryum cinclidioides* and *Drepanocladus*