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Regional climate changes in the south part of East Siberia for the last 4.5 ka (Lake Frolikha, Northern Baikal area, Russia)

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ABSTRACT. East Siberia is a large region extending from Mongolia to the Arctic seas. The main atmosphere circulations of the Northern Hemisphere (the Northern Atlantic, Arctic and East Asia Oscillations) appear in this region. In addition, Lake Frolikha is situated at 55°N, and the high latitude area is probably sensitive to variation in insolation and solar activity. Therefore, even minor shifts of the global climate may cause drastic climate changes within the study area. We analysed diatoms and mineralogical records of sediment core from Lake Frolikha situated near Lake Baikal. We interpreted these records in terms of the changing regional temperature, precipitation, vegetation and lake bio-productivity.

Keywords: Climate Changes, Holocene, bottom sediments, Lake Frolokha, diatoms, FTIR

1. Introduction

Reconstructions of the past environmental conditions provide a context for present and future climate changes and extend our understanding of natural climate variability. Climate changes during the middle and last Holocene were not so contrasting and dramatic compared to those in the Pleistocene glacial periods or Early Holocene. However, the base of modern people civilization was formed from the middle Holocene – the so-called Bronze and Iron ages, and climate changes were some triggers for socio-economic developments. For example, climate cooling in Central Asia can be seen as a triggering for the actions of peoples such as the Huns and Mongols in the history of the vast parts of Eurasia from China to central Europe (Schlütz and Lehmkuhl, 2007).

To distinguish between distinct natural and anthropogenic long-term climate influences, it is necessary to revise longer-term archives of information. Lake ecosystems of all types are likely to be sensitive to climate changes. However, the information on fluctuations of East Siberian climate during the Late Holocene and in particular the last few centuries is still scarce. The region is very sensitive to moisture regimes because it is located in a margin area, where moisture from the North Atlantic is strongly depleted, and the penetration of the East Asian monsoon is weak and rare (Kuznetsova, 1978; Ding, 1990). In addition, the high latitude of the study area (55°N) is probably sensitive to variation in insolation and solar activity. Therefore, even minor shifts of the global climate may cause drastic climate changes within the study area.

In the present study, we used lake sediment sequences to investigate changes in the landscape climate of East Siberia (Russia) during the last 4.5 ka.

2. Regional setting and Methods

Lake Frolikha is situated in the south part of East Siberia (Russia), in the foothills of the Barguzinsky Ridge, approximately 6 km to the eastern shore of Lake Baikal. Lake Frolikha (55° 26’N, 110° 01’E) is a small freshwater lake situated at 529 m above sea level with an area of approximately 16.5 km^2 and deep up to 80 m. The climate in this region is continental, as reflected in the large differences of temperature.

Sediment core was collected from Lake Frolikha in August 2011 at a depth of 2.3 m (core Frol-2/2.3m) using a Uwitec Corer. The lengths of core Frol -2/2.3m were 86 cm.

Diatom analysis. The core was sampled with 2 cm intervals. Siliceous microfossils were quantitatively determined by counting permanent smear slides prepared according to the method described in Grachev et al. (1997). Diatom frustules (from 400 to 800 frustules per sample) were identified using keys, atlases and a reference collection (Round et al., 1990; Glezer et al., 1992).

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Total content of quartz, feldspar, biogenic silica ($BiSiO_2$) and organic carbon (TOC). Core Frol -2/2.3m was sampled with 1 cm intervals. Total content of these components were investigated using the Fourier-transform infrared (FTIR) technique with KBr (3 mg sample/170 mg KBr) at wavelength from 700 to 4,000 cm^{-1}. Absorbance bands for the calculation of these components were approached according to Petrovskii et al. (2016).

Depth-age model. A depth-age model was constructed based on radiocarbon (^{14}C) calibration performed by Poznan Radiocarbon Laboratory. Layers 42-46 cm (Poz-51220) and 78-82 cm (Poz-5122) were dated in core Frol-1/2.3m. Radiocarbon ages were converted in calendar years with CalPal 4.0. All age estimations were expressed in calendar thousand years before present (cal. ka BP).

3. Results and Discussion

Bottom sediments of the core was presented by brown silty-clay, which is typical of oxidation sediments. There are not any lithological and gran size markers of hiatus or turbidity layers. Based on these lithologic features, we assumed the cores formed under lake conditions. The layers 42-46 cm depth was 2.05 ka BP while 78-82 cm layer formed *ca.* 4.27 ka BP.

The content of diatoms in core Frol-2/2.3m was 94.1-548.65x10^6 frustules g^{-1} dry weight, while benthic taxa accounted for 65.6-93.4% of the total amount. The amount of cysts changed from 0.48 to 6.5x10^6 fr. g^{-1}. Maximal amount of diatoms was recorded at 40-60 cm (*ca.* 3-1.8 ka BP) of the core, benthic diatoms of the genera Tetracyclus, Eunotia, Gomphonema, Fragilaria and Pinnularia being dominant. In contrast, the total content of diatoms along core Frol-1/8m varied from 2.06 to 34.02 x 10^6 fr. g^{-1}. Benthic diatoms Pinnularia, Navicula, Amphora, Eunotia, Fragilaria, Cymbella, Gomphonema and others dominated (33-94 % of the total abundance). The content of planktonic diatoms was 0.28-18.76 x 10^6 fr. g^{-1} (5.5-66.6 % of the total number). *Pliocaenicus costatus* (0.01-17.4 x 10^6 fr. g^{-1}, 0.12-61.7%), *Discostella pseudostelligera* (0.01-0.14 x 10^6 fr. g^{-1}, 0.03-1.3%) and the genus Aulacoseira (0.14-2.85 x 10^6 fr. g^{-1} or 3.5-12.3 % of the total number) prevailed in the plankton assemblage within the entire record.

Planktonic diatoms *P. costatus, A. valida* and *A. lirata* were dominant *ca.* 4.5-3.5 cal. ka BP. These diatoms are known in oligotrophic lakes of Siberia, Mongolia, North America, Europe and Miocene-Holocene (Genkal et al., 2011). Currently, the diatom species often occur in the mountain lakes around Lake Baikal (Fedotov et al., 2015; Vorobyeva et al., 2015). In general, we assume that climate was most likely warm and humid in this part of Eurasia at 4.5-3.5 ka BP. Winters were mild and humid due to the SH low activity.

Notably, maximums in the total diatoms (core Frol-1/2.3m) and $BiSiO_2$ flux in Lake Huguang Maar (China) occurred synchronously at 3.5-1.9 ka BP. High flux of BiSiO is explained by the increase of wind mixing at Lake Huguang Maar due to the strengthening of the winter monsoon (Wang et al., 2005). The increase of benthic diatoms and TOC indicates that the lake level dropped from 3.5 to 2.5 ka BP (Fig. 1). However, the interval from 3.8 to 2.0 ka closely corresponds to the period of increased winter precipitation in North Europe (Bakke et al., 2008; Balascio and Bradley, 2012). In this reason, the Siberian High was strong during 3.2-2.5 ka BP, and blocking of westerlies was effective. Responses of diatom and “FTIR”-records to changes in moisture were weak ca. 3.4-2.4 ka BP. Clear trends to the increase in content of quartz and

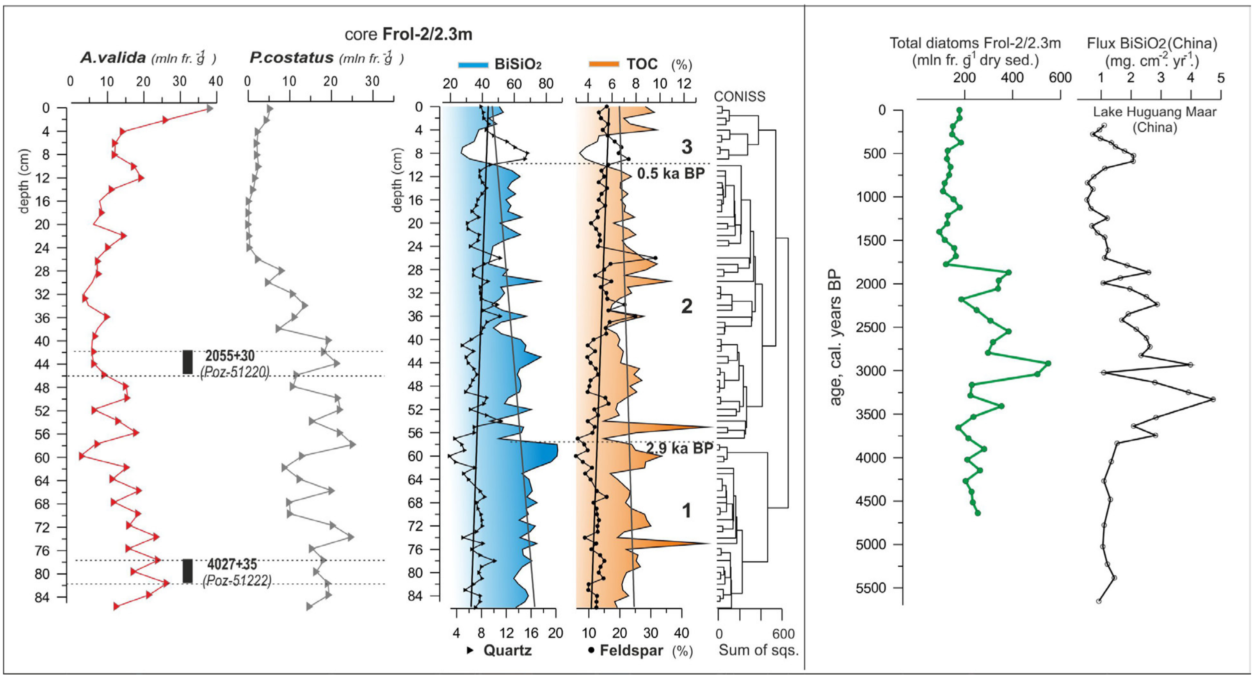

Fig.1. Diatom records, distribution of $BiSiO_2$, TOC, quartz and feldspar along cores Frol-2/2.3m and flux $BiSiO_2$ into Lake Huguang Maar - Yancheva et al. 2007

feldspar were recorded from bottom to top of the cores, while trends of $BiSiO_2$ and TOC were opposite. The significant changes in distribution of minerals and organic components were found *ca.* 2.9 and 0.5 ka BP (Fig.1). The content of benthic diatoms in core Frol-2.3m decreased ca. 1.7-0.8 cal. ka BP. is most likely that influence of the Northern Atlantic on the Baikal region was more pronounce compared to the East Asian monsoon.

4. Conclusions

We have analysed sediment cores from Lake Frolikha (Lake Baikal area, East Siberia) using biological and mineralogical methods. The July air temperatures were reconstructed based on chironomid analyses. Maximum in regional moisture occurred at *ca.* 4.5-3.5 cal. ka BP and mean JAT was ca. 14 °C. The following episode of 3.5-1.7 ka BP was characterised by tendency to dry conditions. During 1.7-0.8 ka BP dry conditions decreased.

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