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Changes in diatom and chironomid assemblages of boreal taiga in East Siberia (58N, Lake Aunakit, Russia) during the last 4.2 ka

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ABSTRACT. In this study, we analysed a 64 cm long sediment record from Lake Aunakit located on the Kropotkin Range (East Siberia, Russia) for subfossil diatoms and chironomids to provide an improved reconstruction of the environmental changes in the area for the past 4.2 ka. Diatom record is divided into four zones (0-0.84, 0.95-1.25, 1.3-2.0 and 2.0-4.2 ka BP). Duration of chironomid record is 1.8 ka, and this record is divided into five zones 1.8-1.5, 1.5-1.4, 1.4-1.25, 1.25-0.6, and 0.6-0 ka BP.

Keywords: diatoms, chironomids, reconstruction, lake, bottom sediments, East Siberia

1. Introduction

In the global scale, contrasting climate changes, so-called the Subboreal and Subatlantic periods of the Holocene, characterise time interval during the past 4 ka. Modern warming appears clearly in the high latitudes of the Northern Hemisphere. Probably, the previous climate changes were also contrasting, which paleo records from high latitudes indicate.

Diatom and chironomid records are a good proxy of paleoclimate changes. Thus, chironomid records are sensitive to annual summer air temperatures (Brooks and Birks, 2001; Heiri et al., 2003), and a time lag between changes of air temperatures and chironomid taxa is probably minimal. Diatoms are well-known to depend on water temperature, duration of open and close water, insolation and supply of nutrients into the water.

Lake Aunakit is located in the northern part of East Siberia (Russia), on the Kropotkin Ridge (Fig. 1). Lake Aunakit (58º31'N, 114º86'E) is a small freshwater lake located at 1033 m above sea level, with an area of approximately 0.03 km^2. The climate in this region is continental, as reflected by the large differences of temperature. The annual temperatures are from -5 to -7 ºC, whereas the mean January temperatures are lower than -30 ºC with a drop to -60 ºC, and the mean July ones are 16-18 ºC and up to 38 ºC. There is a stable snow cover from October to May. The annual precipitation ranges from 220 to 380 mm, with the precipitation largely (55-60%) accumulating during the summer months. Duration of the warm period is *ca.*130 day/year.

In this study, we attempted to detail environmental changes in the northern part of East Siberia during the middle Holocene by the diatom and chironomid records.

Fig.1. Location of Lake Aunakit

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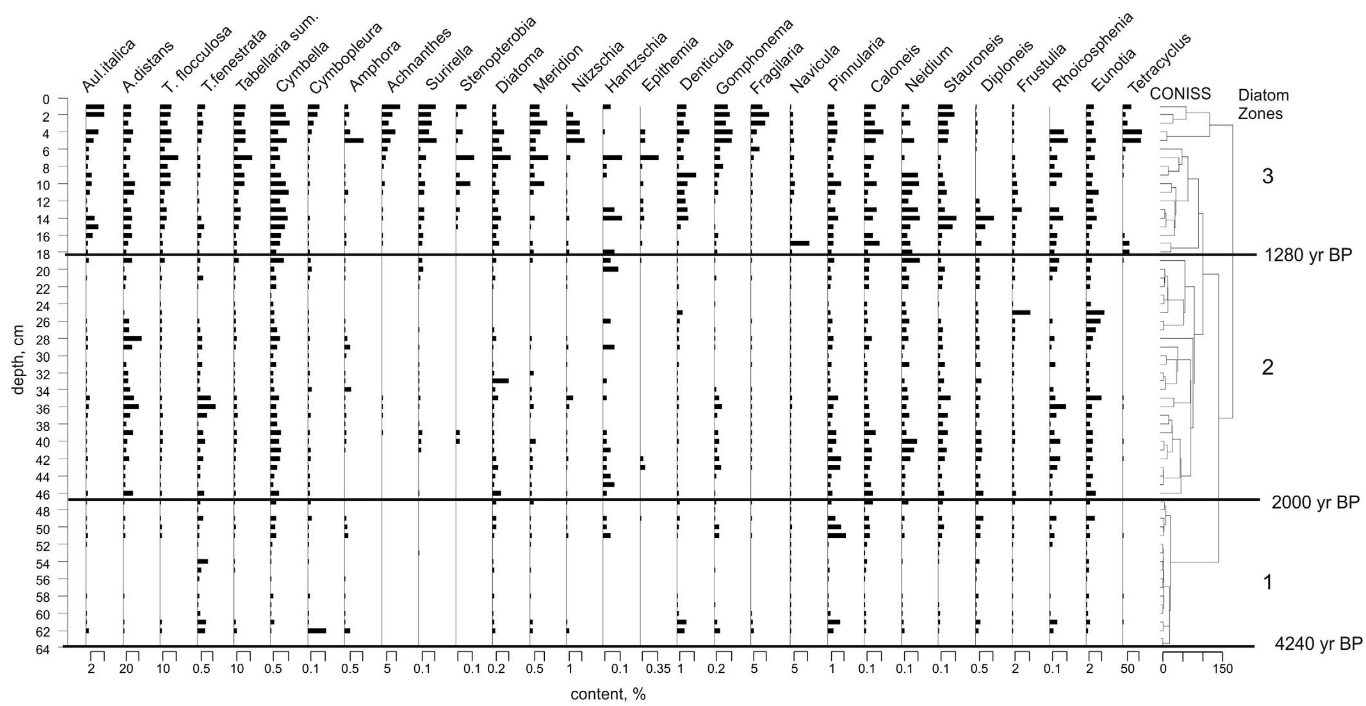

Fig.2. Distribution of main diatom taxa throughout of the sediment core and division of diatom zones (DZ) by CONISS method

2. Methods

In 2018, a sediment core was taken from the central part of Lake Aunakit (64 cm long) using a Uwitec Corer sampler. The water depth was 6 m at the core sampling site.

2.1 Diatom analyses

The cores were sampled with 1 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).

2.2 Chironomid analyses

The cores were sampled with 1 cm intervals. Samples of 1cm^3 for chironomid analysis were immersed in concentrate HF; after 24 h the acid was washed out, and, then, the samples were washed through a 100-μm sieve with a sampling resolution of 1 cm. The remains of chironomid head capsules were identified according to Pankratova (1970; 1977; 1983) and Makarchenko (1982; 2006).

2.3 Depth-age model

The total radiocarbon content in the graphitized samples was quantified by AMS engineered at Budker Institute of Nuclear Physics (Novosibirsk, Russia). The total 14C content was measured relative to ^{13}C and normalized to NIST standards). Chemical pre-treatment and graphitization of samples were carried out in Laboratory of Radiocarbon Methods of Analysis at Novosibirsk State University using laboratory installation (Lysikov et al., 2018). Four sediment layers were dated (Table 1). Calendar date was evaluated from the radiocarbon one by CalPal ver.1.5.

3. Results and Discussion

Table 1. Results of AMS radiocarbon dating of the lake bottom sediments

Depth below sediment surface, cm	Lab.code	^{14}C age, yrs BP	Calendar age, yrs cal BP
7.5	BINP_NSU_1394	1077 ± 65	1006 ± 60
25*	BINP_NSU_1395	2416 ± 74	2524 ± 65
47.5	BINP_NSU_1396	2072 ± 66	2052 ± 65
63.5	BINP_NSU_1397	3783 ± 66	4172 ± 65

* the sample most likely contains old carbon.

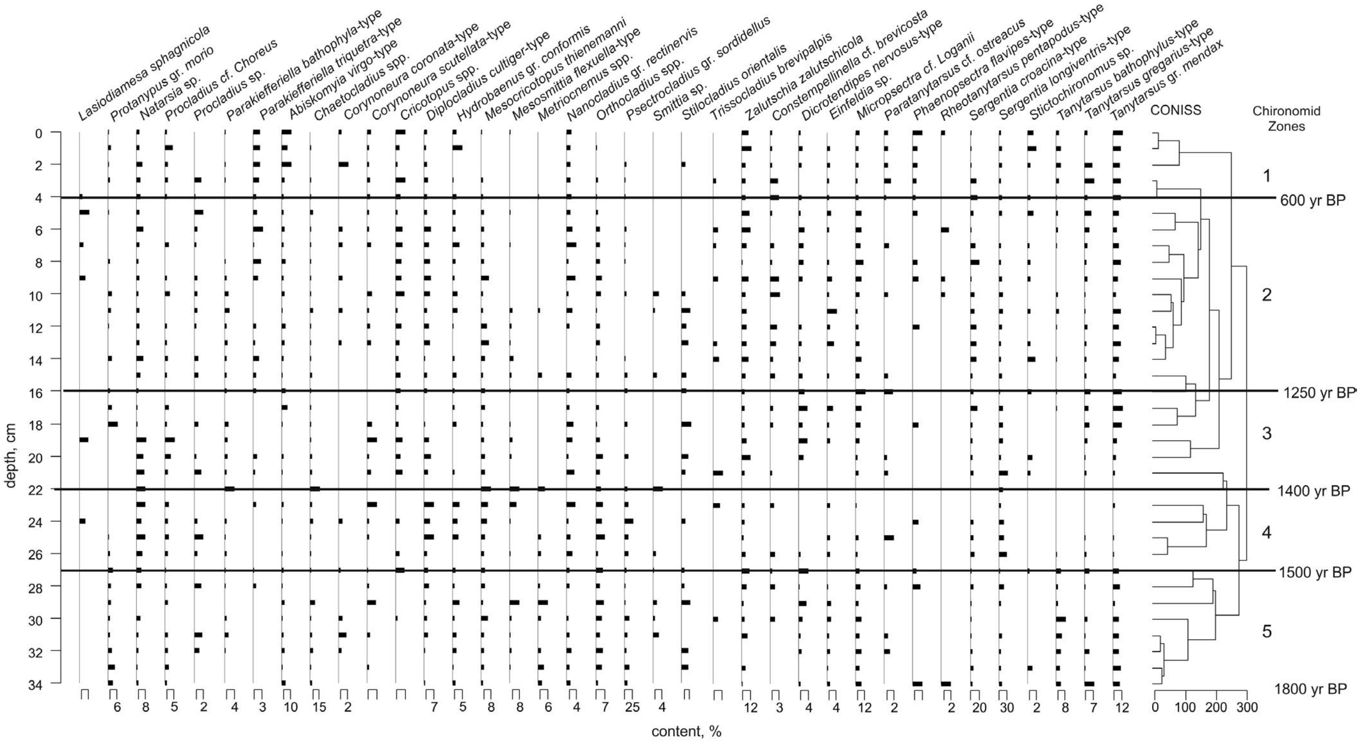

Fig.3. Distribution of main chironomid taxa throughout the sediment core and division of chironomid zones (ChZ) by CONISS method

According to the obtained dates, the bottom layer (64 cm) in sediment core was formed *ca.* 4.2 ka (Table 1). Only one data (25 cm) shows nonlinear chronology due to the presence of old carbon.

Ninety-two species represent diatom assemblages of the sediment core. The number of plankton diatoms changed from 0.02 to 126.6x10^6 frustules g^{-1} dry weight throughout the core. There were six plankton species, with *Aulacoseira italica* (Ehrenberg) Simonsen (up to 8.14x10^6 frustules g^{-1}), *A. distans* (Ehrenberg) Simonsen (up to 117.2x10^6 frustules g^{-1}), *Tabellaria flocculosa* (Roth) Kützing (67x10^6 frustules g^{-1}), and *T. fenestrata* (Lyngbye) Kützing (2.4x10^6 frustules g^{-1}) dominating in all records (Fig. 2). Single frustules of two species of the genera Cyclotella were found in the uppermost sediment layer. These dominant species are typical of oligotrophic-mezotrophic freshwater lakes with low or neutral pH (Barinova et al., 2006; Kharitonov and Genkal, 2012).

The number of benthic diatoms was 0.014-287.3x10^6 frustules g^{-1}. There was a great number of Tetracyclus (up to 228.7x10^6 frustules g^{-1}), Eunotia (up to 12.7x10^6 frustules g^{-1}), Frustulia (up to 12.7x10^6 frustules g^{-1}), and Achnanthes (up to 19.5x10^6 frustules g^{-1}). Content of chrysophycean cysts was 10-112x10^6 specimens g^{-1}.

Based on CONISS analysis, we divided diatom records into four local zones (DZ) (Fig. 2). In the DZ-1 (0-6 cm below the sediment surface, bss, *ca.* 0-0.84 ka BP), the total content of diatoms was 98.24-397x10^6 frustules g^{-1}. Benthic diatoms were dominant, 53.6-73.7% of total diatoms, with the highest content of Tetracyclus. *Aulacoseira distans* (14.2-24.0%) and *Tabellaria flocculosa* (10.4-18.2%) dominated plankton diatoms.

The DZ-2 (7-18 cm bss, *ca.* 0.95-1.25 ka BP) was characterised by a decrease in diatoms to 57.1-159.3x10^6 frustules g^{-1}. *A. distans* (16-56.7%) and *T. flocculosa* (6-43.3%) dominated diatom assemblages.

In the DZ-3 (19-46 cm bss, *ca.* 1.3-2.0 ka BP), the number of diatoms varied strongly between 0.41 and 141.84x10^6 frustules g^{-1}. The minimum content of frustules was at 23 cm bss. *A. distans* (21.3-82.6%), *T. flocculosa* (5.2-18.3%) and Eunotia (2.6-36.6%) fully dominated diatom assemblage.

In the DZ-4 (47-64 cm bss, *ca.* 2.0-4.2 ka BP), the total diatom content varied from 0.014 to 37.8x10^6 frustules g^{-1}. *A. distans* (18.8-46%), *T. flocculosa* (5.5-24.1%) and Eunotia (3.5-21.6%) prevailed in the zone.

In general, diatom records indicate that environmental condition contrast changed three times. The first period was since *ca.* 2.0 ka BP, when contents of plankton diatoms sharply began to increase. The second period was since *ca.* 1.7-1.3 ka BP, when contents of diatoms and chrysophycean cysts rapidly turned from the highest to the lowest ones. The third period is from 1.25 ka BP to the present time, when species diatom diversity is high.

We studied chironomidae assemblages for the upper 34 cm of the core. The assemblages showed 55 larval forms of 46 genera and 5 subfamilies (Podonominae, Tanypodinae, Diamesinae, Orthocladiinae, and Chironominae). Based on CONISS analysis, we divided chironomid records into five local zones (ChZ) (Fig. 3). The ChZ-1 (0-4 cm bss, *ca.* 0-0.6 ka BP) consisted of *Abiskomyia virgo*-type, *Zalutschia zalutschicola, Sergentia longiventris*-type and *Tanytarsus* gr. *Mendax*. *Natarsia* sp., *Procladius* cf. *choreus*, *Parakiefferiella triquetra*, *Chaetocladius* spp., *Diplocladius cultiger*-type, *Hydrobaenus* gr. *conformis*, *Nanocladius* gr.

rectinervis, *Psectrocladius* gr. *sordidellus*, and *Micropsectra loganii*-type were minor.

In the ChZ-2 (4-16 cm bss, *ca.* 0.6-1.25 ka BP) and the ChZ-3 (16-22 cm bss, *ca.* 1.25-1.4 ka BP) *Zalutschia zalutschicola, Sergentia longiventris*-type and *Tanytarsus* gr. *Mendax* dominated. *Procladius* cf. *choreus*, *Chaetocladius* spp., *Diplocladius cultiger*-type, *Hydrobaenus* gr. *conformis*, *Nanocladius* gr. *rectinervis*, and *Psectrocladius* gr. *Sordidellus* were minor. In addition, the number of head capsules of *Protanypus* gr. *Morio* sharply increased in the ChZ-3. Percentage of *Natarsia* sp., *Parakiefferiella bathophyla*-type, *Diplocladius cultiger*-type, *Nanocladius* gr. *rectinervis*, *Constempellinella* cf. *brevicosta*, *Dicrotendipes nervosus*-type, *Einfeldia* sp., *Micropsectra loganii*-type, *Sergentia croacina*-type, and *Tanytarsus gregarius*-type slightly increased in the ChZ-2 and 3 compared to those in the ChZ-1.

Throughout the ChZ-4 (22-27 cm bss, *ca.* 1.4-1.5 ka BP) *Natarsia* sp., *Diplocladius cultiger*-type, *Mesocricotopus thienemanni*, *Orthocladius* sp., *Psectrocladius* gr. *sordidellus*, and *Sergentia longiventris-type* dominated. However, the ratio of *Zalutschia zalutschicola* and *Micropsectra logani* reduced. In the sediment layer of 22-23 cm bss, *Diamesa aberrata*, *Parakiefferiella bathophyla*-type, *Chaetocladius* spp., *Metriocnemus* spp., *Mesosmittia flexuella*-type, *Smittia* sp., and *Sergentia longiventris*-type dominated.

The ChZ-5 (27-34 cm bss, *ca.*1.5-1.8 ka BP) is characterised by a sharp increase in *Diamesa stenboecki* and *Tanytarsus bathophylus*-type, as well as a great number of *Protanypus* gr. *Morio.*

Chironomid compositions of the ChZ-1,2,3 and 5 indicate that regional climate and lake ecological conditions were similar to modern ones. The ChZ-4 shows the low water level in the lake. Thus, *Protanypus* gr. *Morio* and *Zalutschia zalutschicola* inhabiting deep water (Walker et al., 1991; Olander et al., 1997) disappeared from chironomid assemblage. In addition, riverine and stream species also disappeared. It is likely that an inflow into Lake Aunakit strongly reduced. In addition, the number of frustules of plankton diatoms also was minimal within this span.

4. Conclusions

The core from Lake Aunakit formed over the past 4.2 ka BP. Ninety-two species represent diatom assemblages; however, only *A. distans*, *T. flocculosa*, Tetracyclus and Eunotia dominated the records. Four diatom zones divided 0-0.84, 0.95-1.25, 1.3-2.0, and 2.0-4.2 ka BP. The highest diatom diversity was in the past 1.25 ka. Chironomid assemblages of the upper 34 cm of the core showed 55 larval forms of 46 genera and 5 subfamilies (Podonominae, Tanypodinae, Diamesinae, Orthocladiinae, Chironominae). Changes in chironomid taxa occurred between 0-0.6-1.25-1.4-1.5-1.8 ka BP. The most dramatic changes in diatom and chironomid assemblages occurred 1.3-1.5 ka BP. Most likely, the lake level was low at that time.

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