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Modelling silicon supply during the Last Interglacial (MIS 5e) at Lake Baikal

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ABSTRACT

Limnological reconstructions of primary productivity have demonstrated its response over Quaternary timescales to drivers such as climate change, landscape evolution and lake ontogeny. In particular, sediments from Lake Baikal, Siberia, provide a valuable uninterrupted and continuous sequence of biogenic silica (BSi) records, which document orbital and sub-orbital frequencies of regional climate change. We here extend these records via the application of stable isotope analysis of silica in diatom opal ($\delta^{30}Si_{diatom}$) from sediments covering the Last Interglacial cycle (Marine Isotope Stage [MIS] 5e; c. 130 to 115 ka BP) as a means to test the hypothesis that it was more productive than the Holocene. $\delta^{30}Si_{diatom}$ data for the Last Interglacial range between +1.29 and +1.78‰, with highest values between c. 127 to 124 ka BP (+1.57 to +1.78‰). Results show that diatom dissolved silicon (DSi) utilisation, was significantly higher ($p = 0.001$) during MIS 5e than the current interglacial, which reflects increased diatom productivity over this time (concomitant with high diatom biovolume accumulation rates [BVAR] and warmer pollen-inferred vegetation reconstructions). Diatom BVAR are used, in tandem with $\delta^{30}Si_{diatom}$ data, to model DSi supply to Lake Baikal surface waters, which shows that highest delivery was between c. 123 to 120 ka BP (reaching peak supply at c. 120 ka BP). When constrained by sedimentary mineralogical archives of catchment weathering indices (e.g. the Hydrolysis Index), data highlight the small degree of weathering intensity and therefore representation that catchment-weathering DSi sources had, over the duration of MIS 5e. Changes to DSi supply are therefore attributed to variations in within-lake conditions (e.g. turbulent mixing) over the period, where periods of both high productivity and modelled-DSi supply (e.g. strong convective mixing) account for the decreasing trend in $\delta^{30}Si_{diatom}$ compositions (after c. 124 ka BP).

1. Introduction

Primary productivity is a key ecosystem function synthesizing organic matter. In deep lakes production is usually dominated by phytoplankton. Over long timescales, primary production is controlled by a number of external and internal drivers such as climate change, landscape evolution and lake ontogeny. Species composition also has an important influence on productivity-diversity relationships (e.g. Dodson et al., 2000). On Quaternary timescales palaeoproductivity may be estimated using a number of different techniques, including palaeoecological (e.g. diatom analysis), biogeochemical (e.g. biogenic silica or pigment analysis) or stable isotope approaches. Palaeoproductivity records allow us to test key hypotheses related to climate variability, including differences between interglacial periods, which may act as analogues to a future warming world. One of the most studied interglacials is the Last Interglacial, a possible analogue for a future, warmer Earth (although in terms of orbital configuration, this comparison is imperfect).

The Last Interglacial, corresponding to Marine Isotope Stage (MIS) 5e (130–115 ka BP; Past Interglacials Working Group of PAGES, 2016; Railsback et al., 2015), is often referred to as the Eemian in Western European continental records, or in Siberia, the Kazantsevo. In order to more fully understand the nature, duration

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and synchroneity of MIS 5e across the globe, the comparison of independent continental and oceanic climate records are needed. Lake Baikal, Siberia (103°43′-109°58′E and 51°28′-55°47′N; Fig. 1) provides a key uninterrupted, continental sedimentary archive, which spans at least the past 20 million years (Williams et al., 2001), to which further Eurasian continental records (e.g. loess sequences) can be compared (Prokopenko et al., 2006). Lake Baikal is the world's deepest and most voluminous lake (23, 615 km^2) with a catchment of over 540,000 km^2. Its mid-latitude location in central Asia means that the lake is highly continental (Lydolph, 1977) and sensitive to obliquity- and precessional-driven forcing (Short et al., 1991), which has allowed an astronomically tuned climate record for the entire Pleistocene (Prokopenko et al., 2006).

Prokopenko et al. (2001) argued that biogenic silica (BSi) records from Lake Baikal register regional climatic fluctuations (e.g. glacial-interglacial cycles) and are linked to incoming solar radiation (hereafter insolation) forcing, via heat balance exchanges within the lake (e.g. Prokopenko et al., 2006; Prokopenko et al., 2001). At sub-orbital frequencies, BSi concentration may be related to regional climate change, linked to teleconnections with shifting Atlantic Meridional Overturning Circulation (e.g. Karabanov et al., 2000). On orbital timescales, Lake Baikal BSi records are interpreted as a palaeoproductivity proxy (Mackay, 2007; Prokopenko et al., 2001, 2006). Seasonal phytoplankton succession at Lake Baikal today is influenced by the timing of ice-off (end of May–June) and ice-on (after October), which promote a period of rapid diatom growth via upper water column turbulent mixing (Popovskaya, 2000). The thermal regime of Lake Baikal in spring and autumn periods is therefore very important in regulating diatom bloom development, together with the availability of dissolved silicon (DSi) (Panizzo et al., 2018; Popovskaya et al., 2015). While these productivity proxies (e.g. BSi, in tandem with diatom assemblages) can provide an insight into variations in limnological characteristics (e.g. length of growing season, lake turnover) over previous glacial-interglacial cycles, they do not provide the ability to quantitatively assess variations between within-lake, versus catchment, delivery of nutrients (namely DSi). We aim to address this in this study, via the use of silicon stable isotope geochemistry to reconstruct such changes over the Last Interglacial.

There are three stable isotopes of silicon (Si: ^{28}Si, ^{29}Si and ^{30}Si),

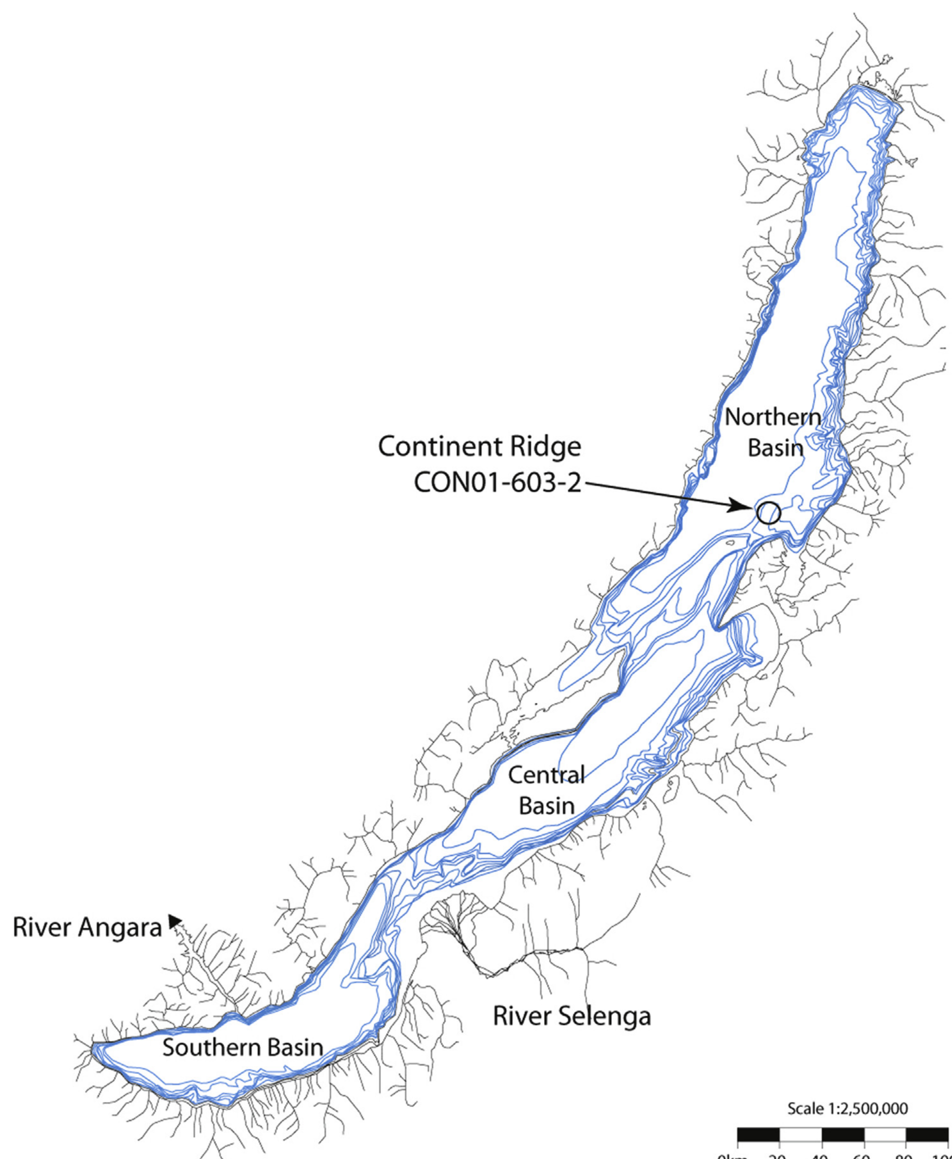

Fig. 1. Map of Lake Baikal and its catchment with core CON-01-603-2 drilling location identified.