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Research article

Warm summers and rich biotic communities during N-Hemisphere deglaciation

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ABSTRACT

Detailed studies on fossil remains of plants or animals in glacial lake sediments are rare. As a result, environmental conditions right at the moment of deglaciation of the large N-Hemisphere ice-sheets remain largely unknown. Here we study three deglacial phases of the Fennoscandian Ice Sheet as a unique, repeated element in a long sediment record preserved at Sokli in northern Finland. We summarize extensive multi-proxy data (diatoms, phytoliths, chironomids, pollen, spores, non-pollen palynomorphs, macrofossils, lithology, loss-on-ignition, C/N) obtained on glacial lake sediments dated to the early Holocene (ca. 10 kyr BP), early MIS 3 (ca. 50 kyr BP) and early MIS 5a (ca. 80 kyr BP). In contrast to the common view of an unproductive ice-marginal environment, our study reconstructs rich ecosystems both in the glacial lake and along the shores with forest on recently deglaciated land. Higher than present-day summer temperatures are reconstructed based on a large variety of aquatic taxa. Rich biota developed due to the insolation-induced postglacial warming and high nutrient levels, the latter resulting from erosion of fresh bedrock and sediment, leaching of surface soils, decay of plant material under shallow water conditions, and sudden decreases in lake volume. Aquatic communities responded quickly to deglaciation and warm summers and reflect boreal conditions, in contrast to the terrestrial ecosystem which responded with some delay probably due to time required for slow soil formation processes. Birch forest is reconstructed upon deglaciation of the large LGM ice-sheet and shrub tundra following the probably faster melting smaller MIS 4 and MIS 5b ice-sheets. Our study shows that glacial lake sediments can provide valuable palaeo-environmental data, that aquatic biota and terrestrial vegetation rapidly accommodated to new environmental conditions during deglaciation, and that glacial lake ecosystems, and the carbon stored in their sediments, should be included in earth system modeling.

1. Introduction

Glacial lake sediments are a persistent element in the geological record (Carrivick and Tweed, 2013; Lunkka et al., 2015) and former extents of glacial lakes have been mapped in different regions globally (Lundqvist, 1972; Björck, 1995; Dyke, 2004; Glasser et al., 2016). Particularly the drainage of large glacial lakes has received significant attention as it has the potential of influencing ocean circulation and climate on a global scale (Broecker and Denton, 1990; Barber et al., 1999).

Extensive ice-marginal retreat in the Fennoscandian and Laurentide Ice Sheets occurred at the last peak of high-latitude summer insolation around ca. 10 kyr cal BP (Dyke, 2004; Stroeven et al., 2016). The postglacial warming allowed for the production of large amounts of meltwater and, with the land-surface inclined towards the retreating ice-fronts due to isostatic depression, glacial lakes were formed

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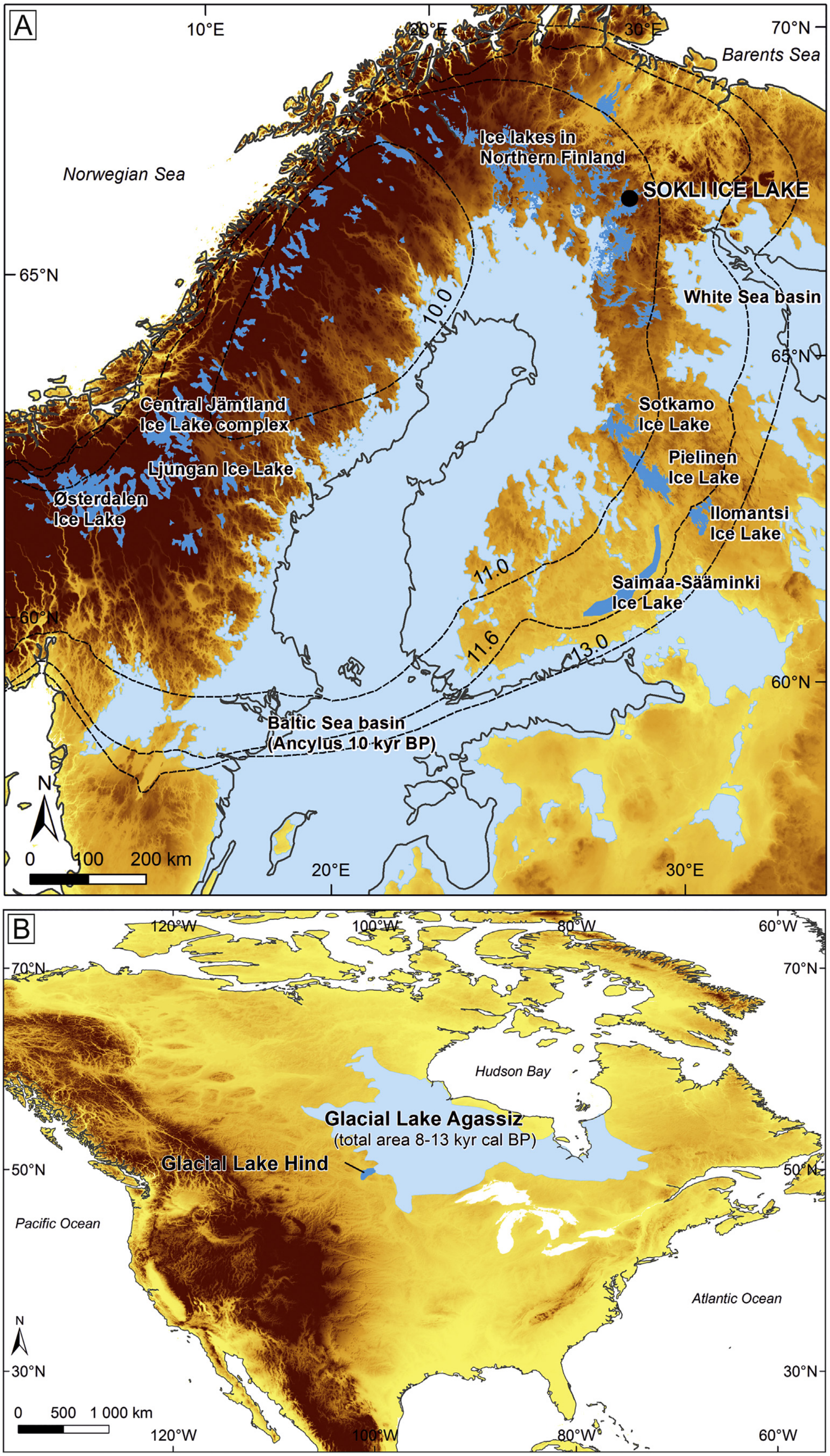

Fig. 1. The extent of glacial lakes in northern Europe (A) and North America (B) during the last deglaciation around 10 kyr cal BP. A shows the maximum extent of the Ancylus Lake in the Baltic Sea basin at 10 kyr cal BP (Björck, 1995). The other lakes are time-transgressive. The extent of Ice Lakes along the western margin of the Fennoscandian Ice Sheet, and the glacial retreat chronology, are according to Stroeven et al. (2016, and references therein), whereas Ice Lakes along the northern and eastern margin of the ice-sheet follow Johansson (2007) and Ojala et al. (2013, and references therein), respectively. The Sokli Ice Lake which is the subject of this study is highlighted. B shows the total cumulative area covered by Glacial Lake Agassiz in North America in the time interval 13–8 kyr cal BP (Teller and Leverington, 2004).