Reconstruction of Holocene glacier fluctuations at Kongsbreen based on sediments deposited in lake Sarsvatnet, Ossian Sarsfjellet, Svalbard

Eivind W. N. Støren[1], Ane Brun Bjerkås[1], Jostein Bakke[1], Henriette Linge[1], William D`Andrea[2], Willem van der Bilt[1], Torgeir Røthe[1], Nicholas L. Balascio[3], Raymond S. Bradley[4], Oliver Grant[1], Derek Fabel[5] and Sheng Xu[5]

[1]Department of Earth Science and Bjerknes Centre for Climate Research, University of Bergen
[2] Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, USA
[3] Department of Geology, College of William & Mary, Williamsburg, VA 23187, USA
[4] Department of Geosciences, University of Massachusetts, Amherst, MA, USA
[5] AMS Laboratory, Scottish Universities Environmental Research Centre, East Kilbride G75 0QF, Scotland, UK

Abstract

The Arctic is warming twice as fast as the global average, and the melting of mountain glaciers and ice caps has accelerated over the last two decades accompanied by reduced sea ice in the Arctic Ocean. Here we combine sedimentological and geochemical approaches to reconstruct changes in glacier extent at the marine terminating glacier Kongsbreen in order to put present-day climate changes into a longer time perspective. Glaciers are highly sensitive climate indicators as they rapidly respond to variations in summer temperature and precipitation, two parameters that are closely linked to atmospheric dynamics. This climate response is recorded by variations in glacier extent and moraine formation and by variations in glacial erosion and hence sedimentation rates in distal glacier-fed lakes.

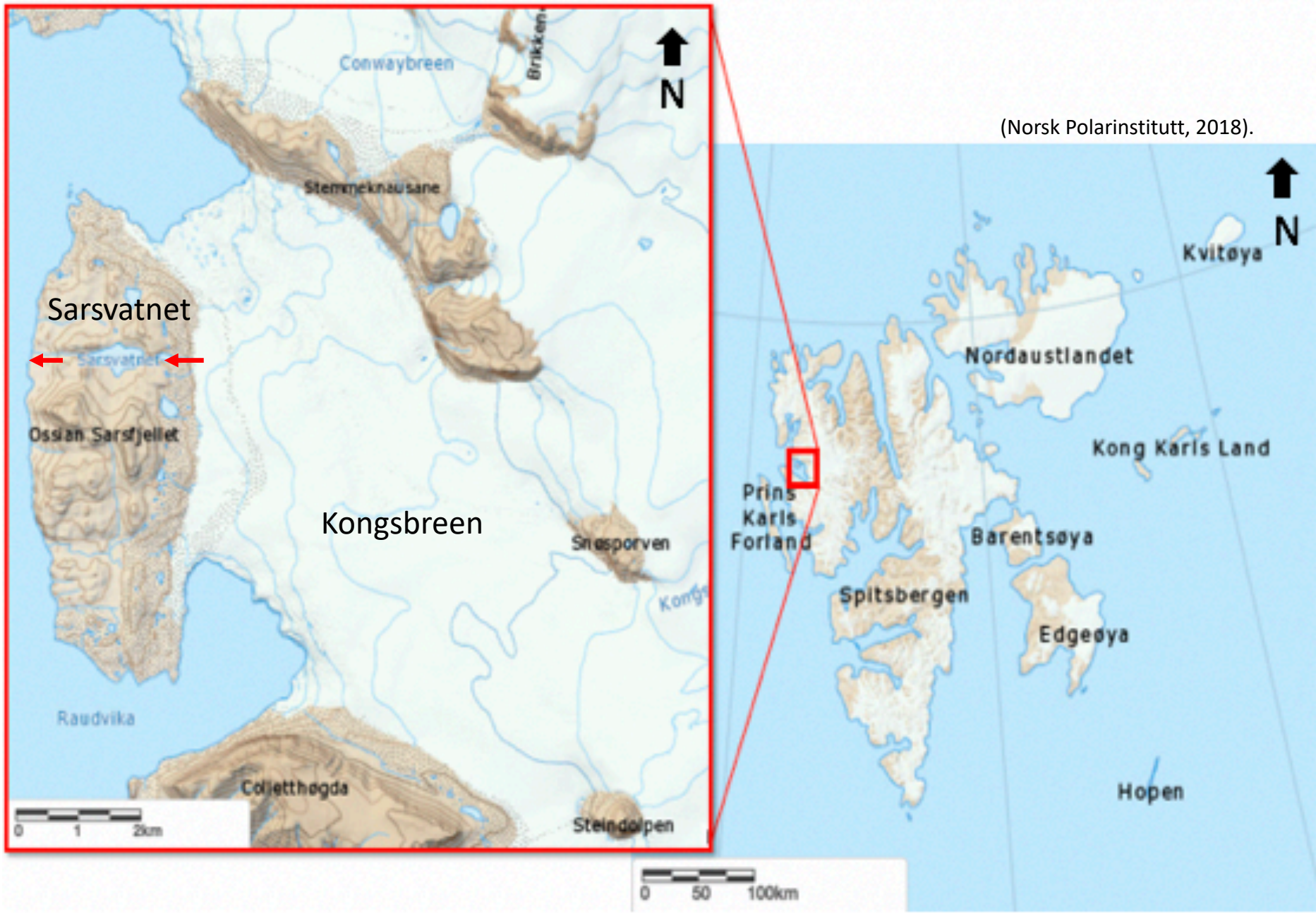
Lake Sarsvatnet is a threshold-lake that only receive glacial derived sediments when the surface of Kongsbreen crosses a local threshold. When the catchment is ice-free, lake sedimentation rate is lower and dominated by material weathered from the immediate proximity and organic-rich sediments. Based on seismic surveying seven coring sites were selected in three different sub-basins in lake Sarsvatnet. Laboratory analyses, including geochemical measurement by XRF scanning and XRD, CT scanning, grain size and measurements of magnetic proxies, were preformed in order to fingerprint the inorganic sediments.

Chronological control is based on radiometric dating (^{14}C, ^{210}Pb, and ^{10}Be). Erratics (n=3, 125-306 m a.s.l.) indicate ice-free conditions since 13.0±1.1 ka (2σ), overlapping with the oldest organic material found in the lake which is 11 860±80 cal. yr BP. Until around 7400 cal. yr BP lake Sarsvatnet is dominated by organic sedimentation. From around 7400 – 6900 cal. yr BP there is evidence for glacial input into the lake indicating the expansion of Kongsbreen and corresponding to the decline in temperature after the HTM. In the following millennia, and entering the Neoglacial period, there is evidence for mulitiple (~20) decadal to centennial-scale periods of glacier expansion, the most recent dated to AD 1650 marking the onset of glacier build-up towards the LIA maximum. This indicate that the Kongsbreen glacier had short lived expansion periods reaching LIA-like extension already during the middle Holocene, as well as multiple times during the Neoglacial.

Study Site

Kongsbreen is a situated at NV Svalbard, in Kongsbreen close to Ny-Ålesund.

Today Kogsbreen flows North and South of Ossian Sarsfjellet, but whenever the glacier is large enough to reach a local threshold at c.150 masl, meltwater from the glacier will flow west-ward into lake Sarsvatnet (red arrows).



(Norsk Polarinstitutt, 2018).

Study Site

Kongsbreen has, together with Isachsenfonna, an area of 378km^2. The glacier is mouthing in Kongsfjorden.

Lake Sarsvatnet (red circle) (0.22 km^2) is perched 100 m asl on Ossian Sarsfjellet, with a local catchment of 1.3 km^2

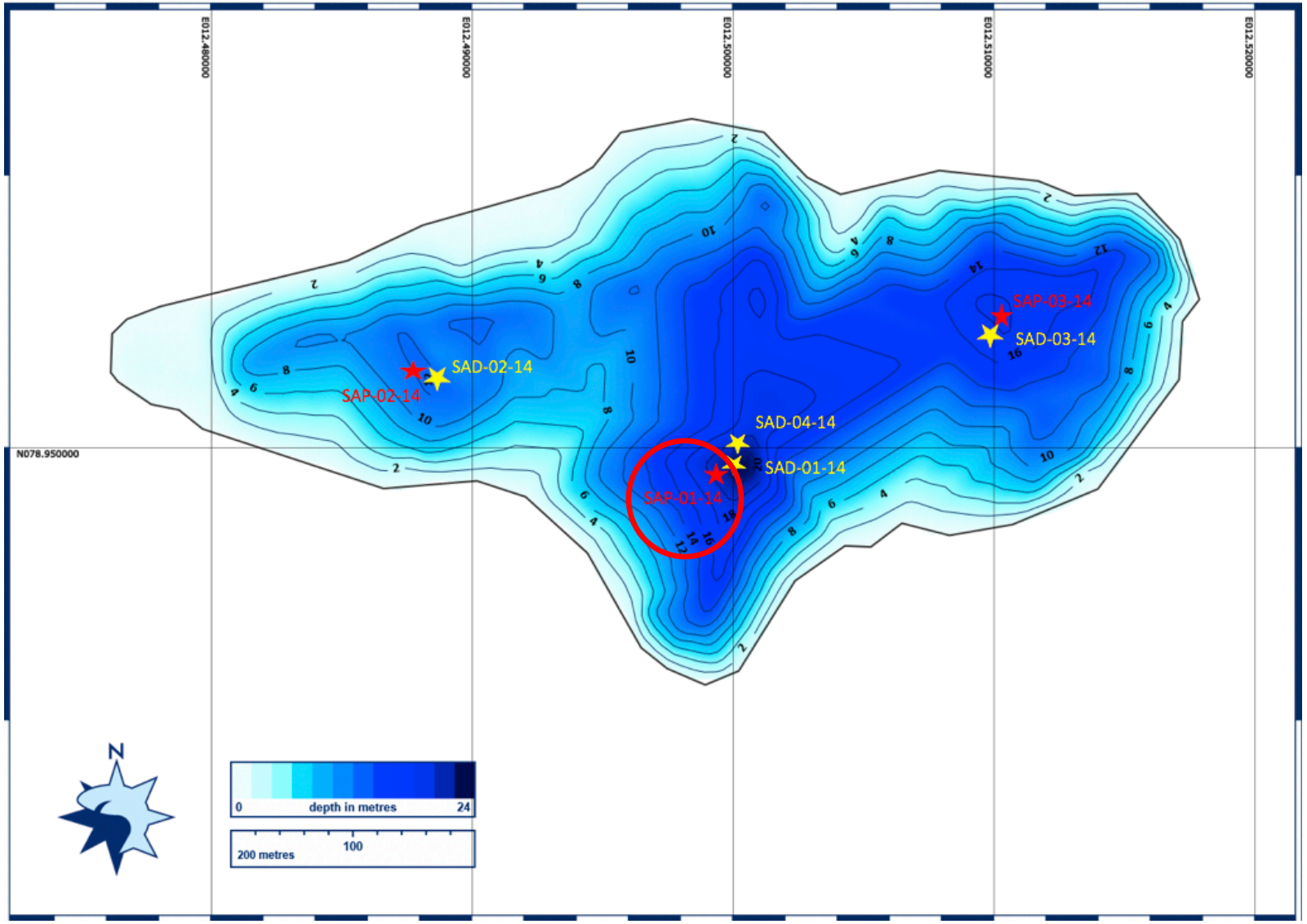
Lake Sarsvatnet, looking westward from the channel just below the threshold to Kongsbreen

Coring of Sarsvatnet in 2014. Note the dry channel entering the lake in the background.

Lake Sarsvatnet

A total of seven sediment cores was collected from Sarsvatnet in 2014. Here we present results from the 137 cm long SAP-01-14 (circled) retrieved at the deepest (22m) point in the lake.

(Photo: Sædis Olafsdottir 2014)



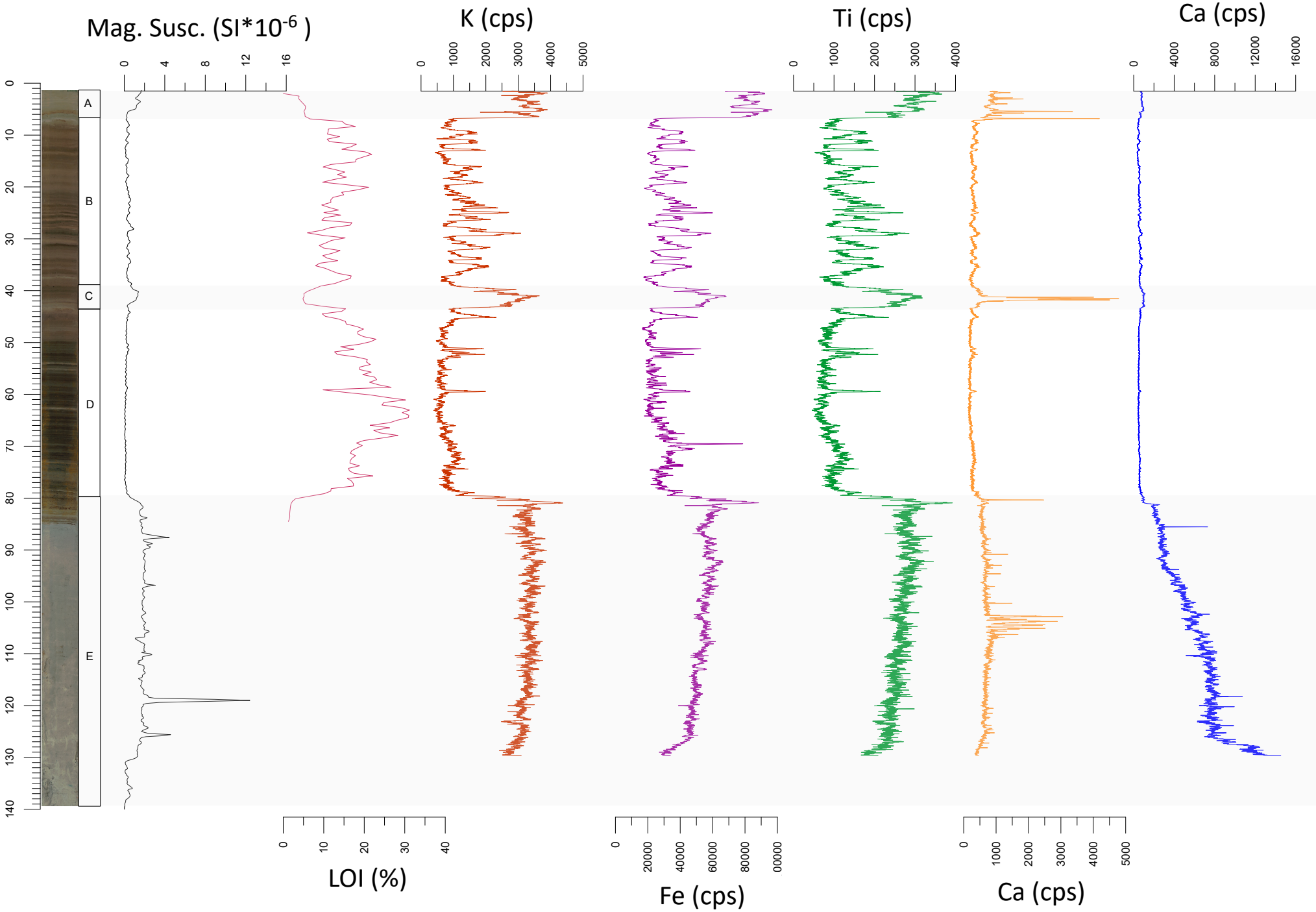
Methodology

EARTHLAB
Earth Surface Sediment Laboratory

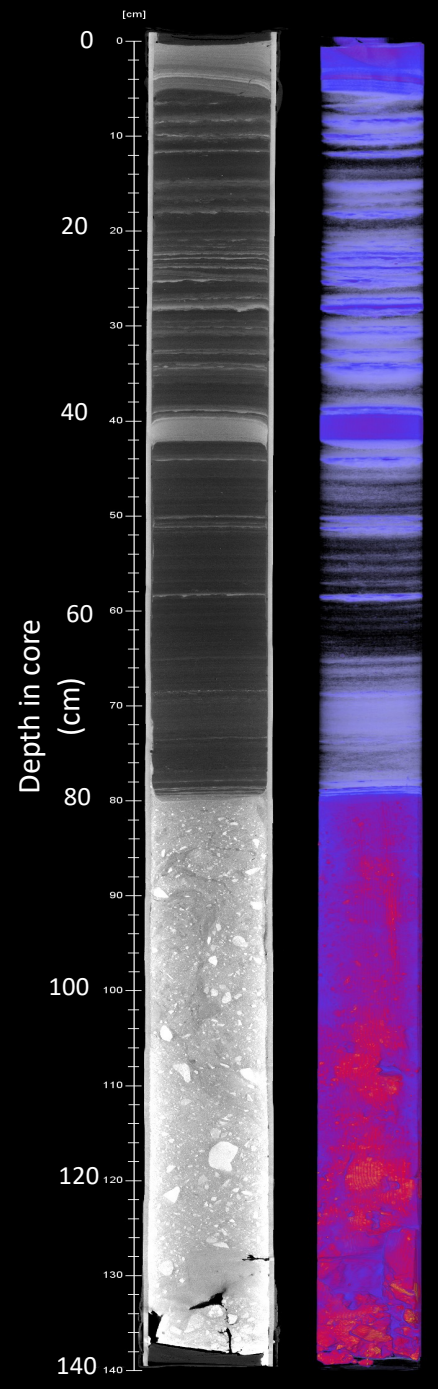
All analyses was done at EARTHLAB, University of Bergen, Norway.

- Geochemical elements measured on an ITRAX XRF core scanner with Mo-tube at 200 μm resolution at 30 Kv and 25 mA.
- CT-scanning was done using an ProCon X-Ray Alpha Core CT-scanner at 128 kV and 1100 μA, produsing D3 X-ray imagery with 50 μm voxel size.
- Magnetic Susceptibility was meassured using a GEOTEK Multi Sensor Core Logger with an Bartington MS2E point sensor at 2mm resolution.
- Loss-on-ignition was meassured according to the protocol by Dean (1974).
- Bulk density meassurements was done by meassuring dry bulk weight of volume spesific samples.
- Grain sizes was meassured on spesific layers to determine grading. Samples was treated with 35% H_2O_2 before analyzed in a Malvern Mastersizer 3000 for 20 sec. RI 1,543 , AI 0,01 and sirring speed at 2500 rpm.
- XRD analyses was done on selecte samples using an Bruker D8 ADVANCED ECO

Results
SAP-01-04



CT-SCANNING



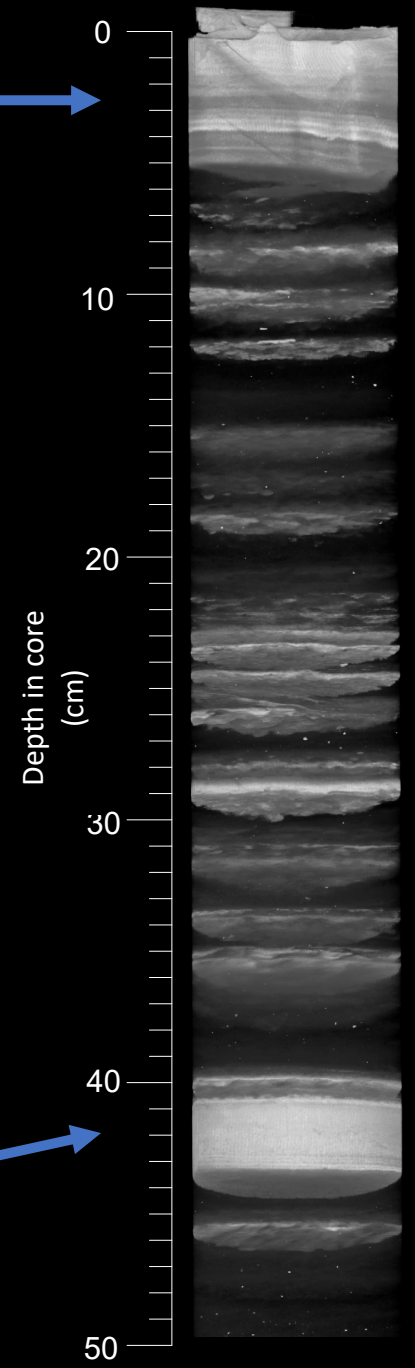
2D slice CT image (left) and high-pass filter 3D image (right) of SAP-01-14.

From 80 to 140 cm there are till. On top of this we see high density layers interbedded in organic rich gyttja.

The uppermost 5 cm has a gradual increase in density.

High-pass 3D CT image of the top 50 cm of the core. Note the undulating lower boundary of high density layeres (white).

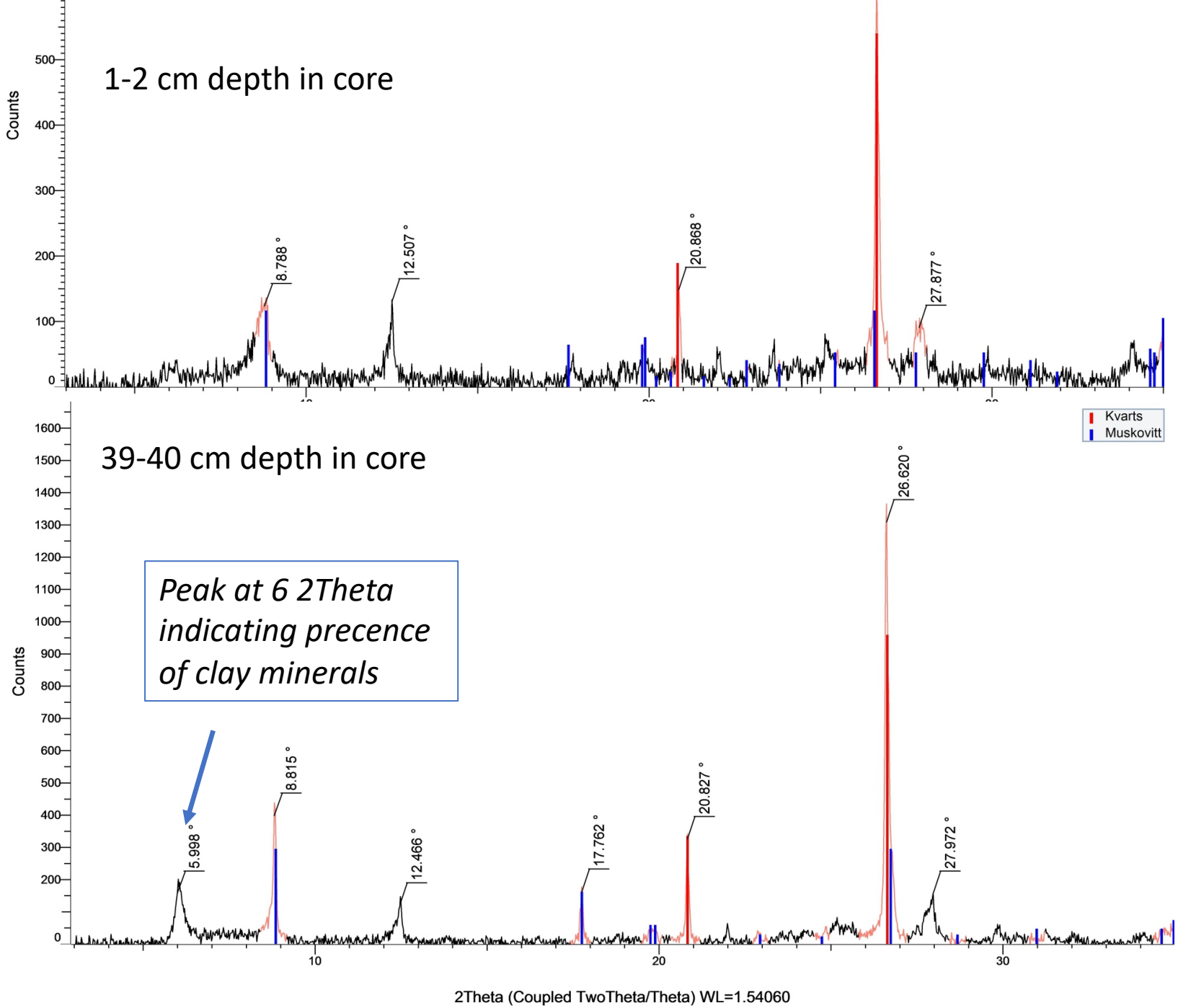
This layer has a sharp lower boundary and is remarkably thicker than the others.



XRD

XRD results of the uppermost 1-2 cm of the core (top), compared to the thick layers at 39-44 cm (bottom).

The material in both samples is mostly composed of Quartz and Muscovite. The Only difference is the peak at 6 2Theta in the 39-44 cm layer indicating in wash of wheathered catchment material.

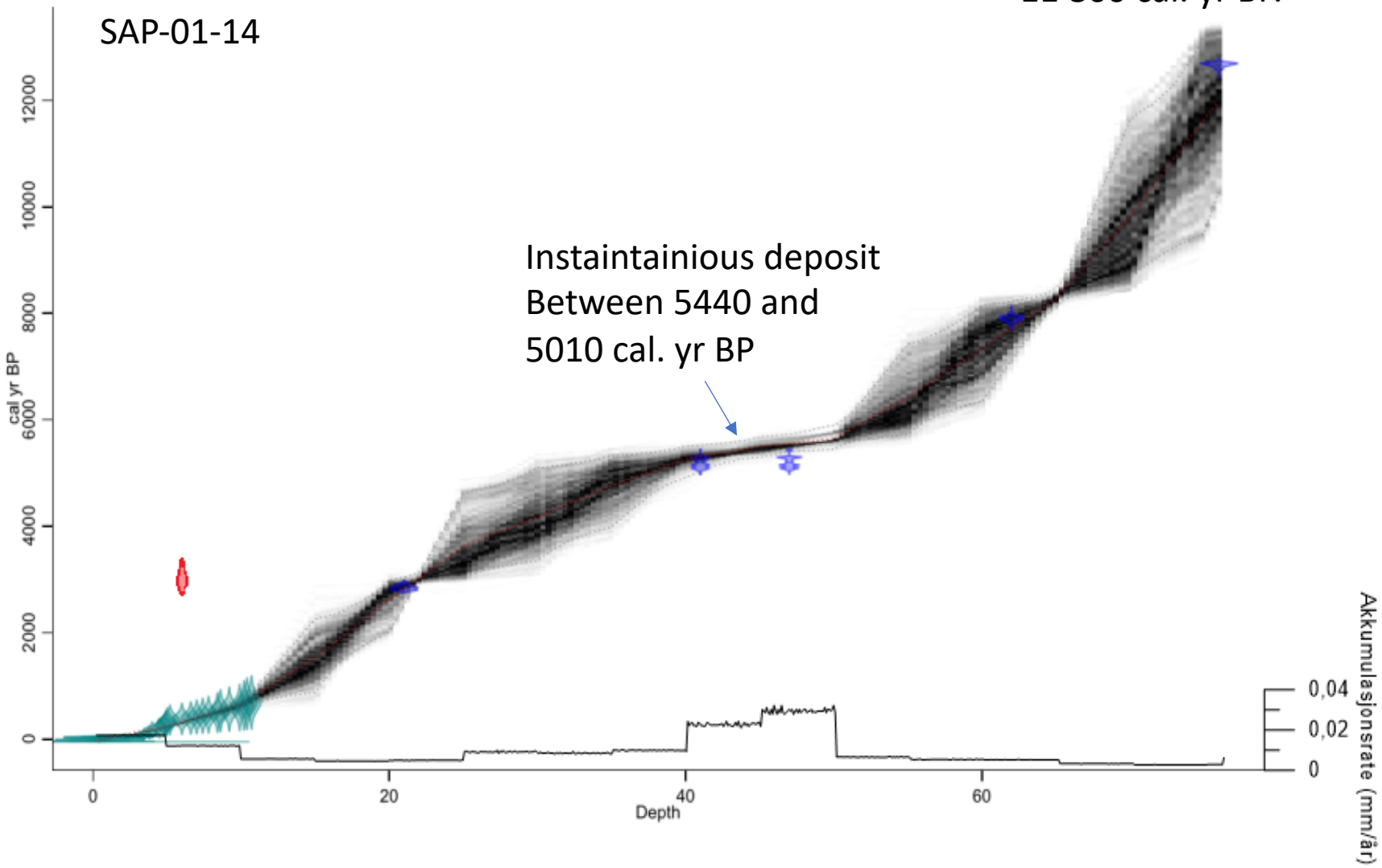


Chronology

Age-depth model is based on radiocarbon (^{14}C) dating of plant macrofossis, and lead (^{210}PB).

Note the platau in the age-depth model at 39- 44 cm depth in core, indicating that this was an slump deposit some 5440-5010 cal. yr BP.

Age at transition to till deposit at the base of the core is dated to ~11 860 cal. yr BP.

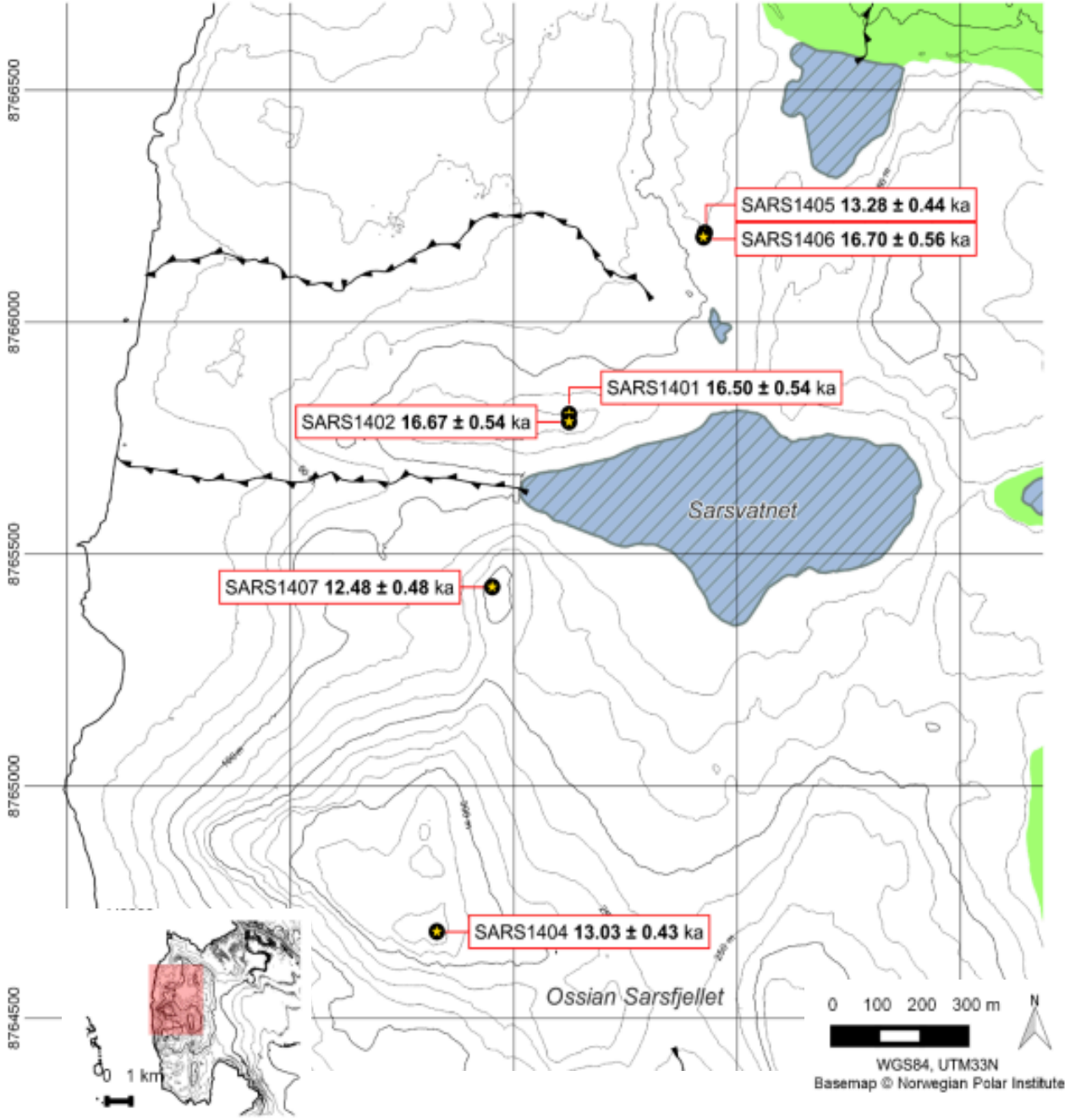


Exposure (^{10}Be) ages

Three erratics (125-306 m a.s.l.) indicate ice-free conditions since c. 13.0±1.1 ka (2σ), overlapping with the oldest organic material found in the lake which is 11 860±80 cal. yr BP.

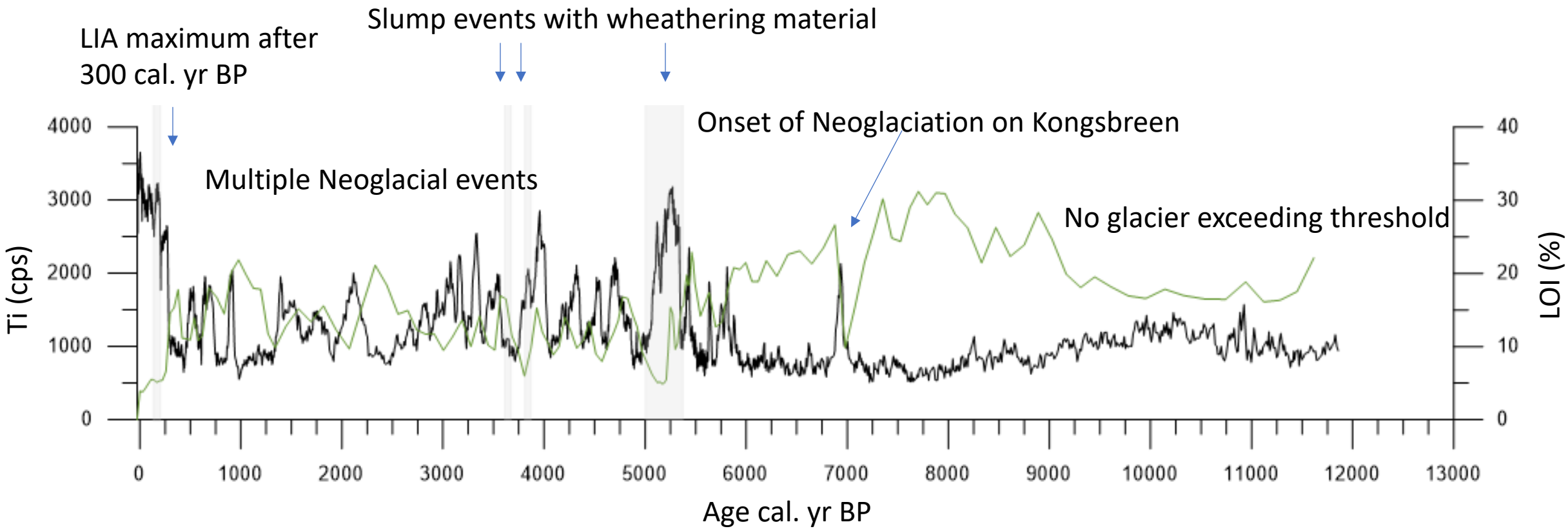
Three other erratics give older agers around 16 ka, possibly indicating supra or englacial transport of these boulders.

Figure from Grant (2016).



Glacier variability

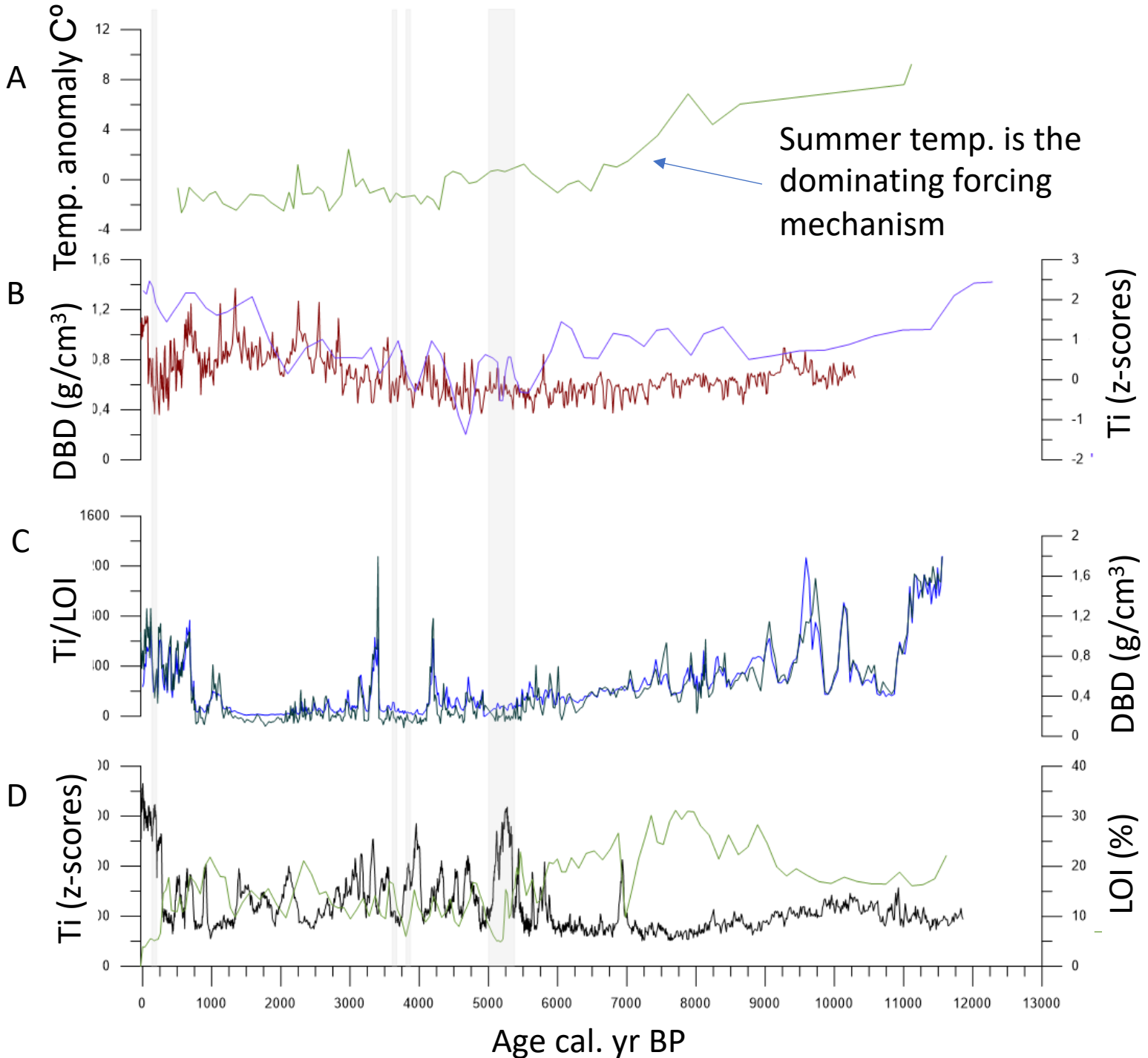
Organic gyttja indicate ice free conditios until the first glacial signal occours c. 7000 cal yr BP.
During the Neoglacial multiple centennial scale glacial advances are recorded in lake Sarsvatnet.



Early onset of neoglaciation on Kongsbreen coincide with a recorded decrease in summer temperature reconstructed from Haukluyvatnet (A) (van der Bilt et al., 2018).

Multiple Neoglacial glacier advances are also recorded in Vårfluesjøen (B) (Røthe et al 2018) and Haieren (C) (van der Bilt et al., 2016), however not as frequent and early as in Sarsvatnet (D) (this study).

This indicate that summer temperature is the dominant forcing mechanism of Holocene glacier variability on Kongsbreen.



Summary and Conclusion

- Exposure dates on erratics (n=3, 125-306 m a.s.l.) indicate ice-free conditions since 13.0±1.1 ka (2σ), overlapping with the oldest organic material found in lake Sarsvatnet which is 11 860±80 cal. yr BP.
- Until around 7400 cal. yr BP lake Sarsvatnet is dominated by organic sedimentation. From around 7400 – 6900 cal. yr BP there is evidence for glacial input into the lake indicating the expansion of Kongsbreen and corresponding to the decline in temperature after the HTM.
- In the following millennia, and entering the Neoglacial period, there is evidence for multiple (~20) decadal to centennial-scale periods of glacier expansion, the most recent dated to AD 1650 marking the onset of glacier build-up towards the LIA maximum. This indicate that the Kongsbreen glacier had short lived expansion periods reaching LIA-like extension already during the middle Holocene, as well as multiple times during the Neoglacial.