THE YEDOMA CLIFF OF SOBO-SISE ISLAND - INSIGHTS INTO PAST AND MODERN PERMAFROST DYNAMICS AND RELATED ORGANIC MATTER STOCK AND RELEASE

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1 The Sobo-Sise Yedoma Cliff

Syngenetic late Pleistocene **Ice Complex** of the **Yedoma** type is widespread in East Siberian lowlands and intentively studied in the **Lena Delta** and the Laptev Sea coastal in recent decades by **joint Russian-German efforts** (LENA Expedition). Diagnostic for Yedoma Ice Complex are the presence of syngenetic ice wedges, the oversaturation of the sediment with pore ice and segregated ice (excess ice) forming lenticular and reticulate cryostructures within mainly fine-grained deposits.

During a field campaign in 2018, the entire permafrost sequence of the **Sobo-Sise Yedoma cliff** has been sampled in 0.5-m vertical intervals via rope decending in three overlapping profiles (Wetterich et al., 2020; Figure 1).

The studied Yedoma cliff on Sobo-Sise Island is remarkable for its **rapid shoreline erosion** of up to 22.3 m yr^{-1} (1965-2018; Fuchs et al., 2020) over about 1.9 km length with a **mean annual retreat rate of 9.1 m yr^{-1}**.

The present study of the permafrost exposed the Sobo-Sise Yedoma cliff provides a **comprehensive cryostratigraphic and organic matter inventory**, insights into permafrost aggradation and degradation over **the last about 52 thousand years** and their climatic and morphodynamic controls on regional scale of the **Central Laptev Sea coastal region** in NE Siberia.

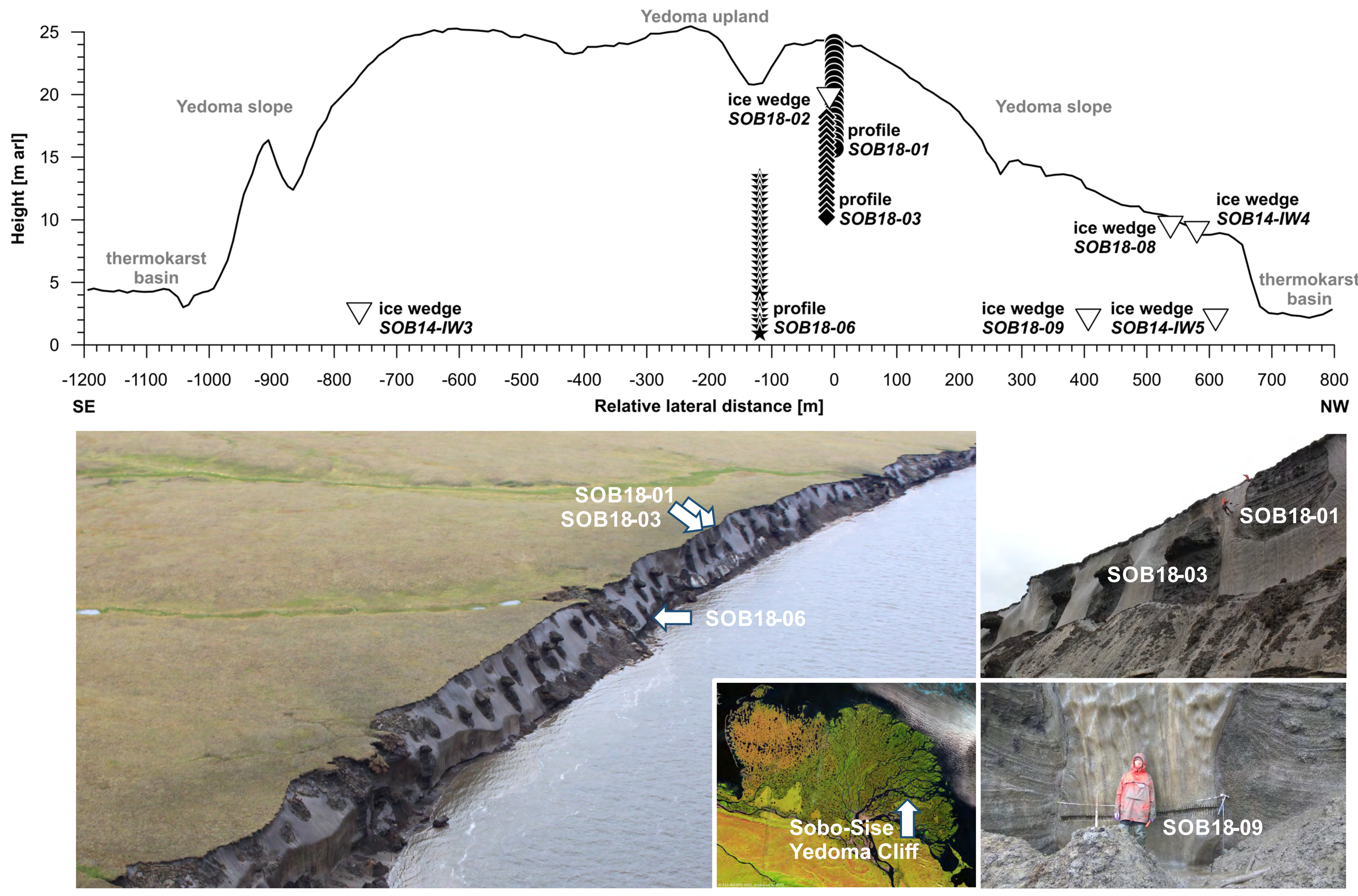

Figure 1. Profile positions of sediment profiles SOB18-01, SOB18-03 and SOB18-06 as well as ice-wedge profiles in 2014 and 2018. Lena Delta inset from ESA-BELSPO 2015, produced by VITO (ESA Earth online).

2 Geochronology and cryostratigraphy

The geochronological record of the Sobo Sise Yedoma spans the **last 52 ka cal BP** based on radiocarbon dating and age-height modelling (Figures 2, 3).

The sequence differentiates into three cryostratigraphic units that are

- **MIS 3 Yedoma IC (52–28 ka cal BP),**
- **MIS 2 Yedoma IC (28–15 ka cal BP) and**
- **MIS 1 Holocene cover (7–0 ka cal BP).**

The cryostratigraphic sequence is not continuous, but has **chronological gaps at 36–29 ka cal BP, at 20–17 ka cal BP and at 15–7 cal ka BP** (Figure 2). These gaps represent **traces of past changes in climatic conditions as well as in permafrost deposition and/or erosion regimes**. Similar observations have been made on adjacent Yedoma IC sites on Bykovsky Peninsula and Kurungnakh-Sise Island (Figure 4) and are likely related to repeated outburst floods of glacial Lake Vitim along the Lena Valley into the Arctic Ocean during MIS 3 and MIS 2 as proposed by Margold et al. (2018).

The **cryostratigraphic units** of the Yedoma cliff are built of **poorly sorted sandy silt** but differ in prevalent grain-size fractions ranging from fine silt to middle sand. The **organic matter** content is highest in the thin MIS 1 (unit C) Holocene cover (TOC of 11.3±9.9 wt%, TN of 0.6±0.3 wt%), but still substantial in MIS 3 (unit A) Yedoma IC (TOC of 4.5±2.5 wt%, TN of 0.3±0.1 wt%) and in MIS 2 (unit B) Yedoma IC (TOC of 2.1±1.3 wt%, TN of 0.2±0.1 wt%).

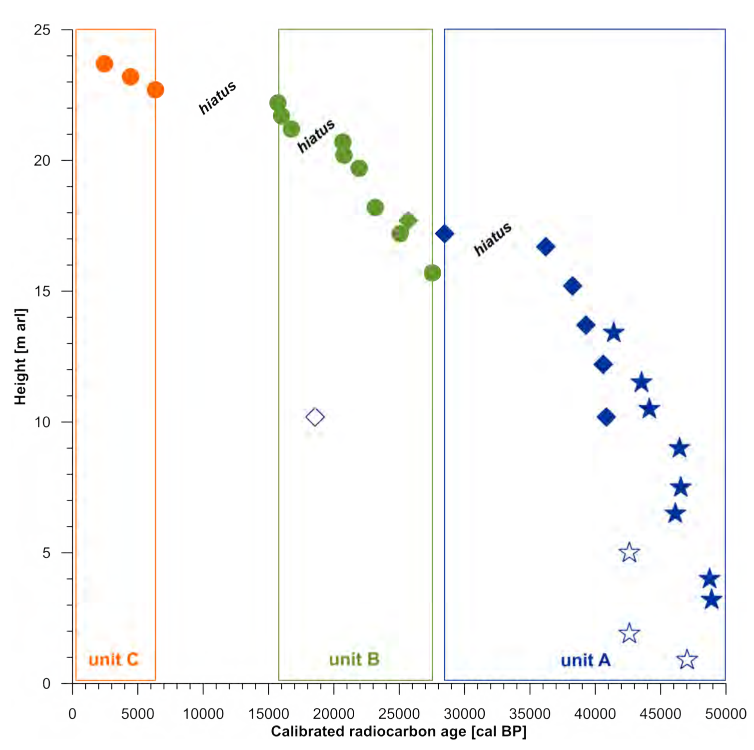

Figure 2. Age-height relation of the Sobo-Sise Yedoma cliff exposure. The hollow symbols indicate ages of redeposited material or infinite ^{14}C ages.

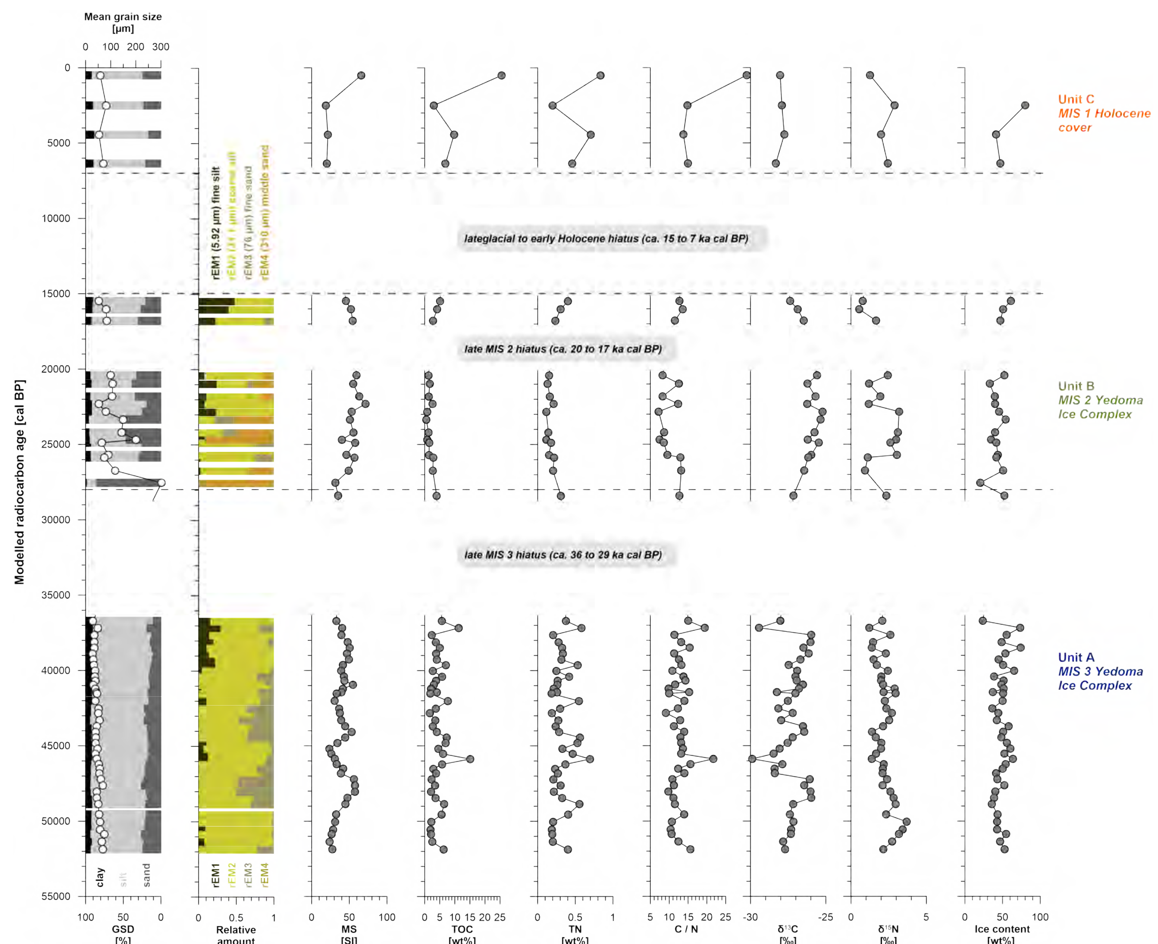

Figure 3. Sediment properties of the Sobo-Sise Yedoma record and their variations over time. Dashed horizontal lines indicate the limits of the cryostratigraphic units A, B and C.

3 Land-to-Ocean organic matter path

The **ground-ice content** including wedge ice and intrasedimental ice sums up to 88.4 vol%. High ice content and the **exposition of the cliff** towards the main Sardakhsakaya river channel promotes a **very high susceptibility to thaw and fluvial thermo-erosion**. The high mean cliff erosion rate of 15.7 m yr^{-1} (2015-2018, Fuchs et al., 2020) results in large organic quantities entering the Lena River that are:

- **5.2 ± 3.3 x 10^{6} kg organic carbon yr^{-1}**
- **0.4 ± 0.2 x 10^{6} kg nitrogen yr^{-1}** .

The Sobo-Sise Cliff is **one of the fastest eroding permafrost features in the Arctic**, releasing a significant amount of C and N on a local scale. To study rapid permafrost **shore erosion processes and resulting material fluxes** at an extraordinary location such as the Sobo-Sise Cliff is helpful to gain a **better understanding of current and future impacts of permafrost thaw**, interdependencies of permafrost erosion with runoff changes, and fluvial and marine biogeochemistry.

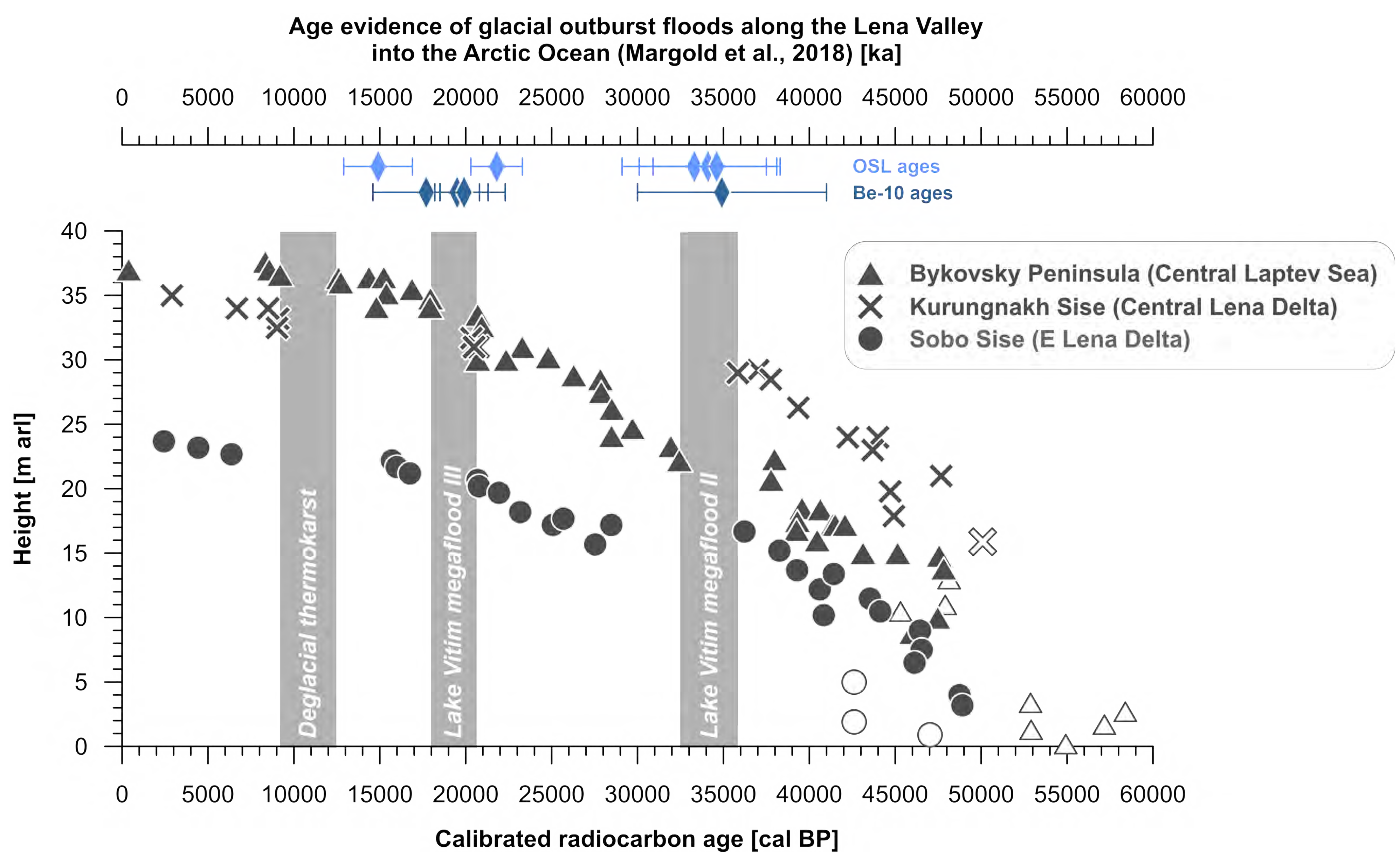

Figure 4. Comparison of interpreted chronology gaps (shown as shaded rectangles) in the Yedoma IC records from Bykovsky Peninsula, Sobo-Sise sland and Kurungnakh-Sise Island. Age evidence from OSL and Be-10 dating for repeated megafloods (namely numbers II and III) from the glacial Lake Vitim along the Lena Valley into the Arctic Ocean (Margold et al., 2018) is shown for comparison.

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References

Fuchs et al. Rapid fluvio-thermal erosion of a yedoma permafrost cliff in the Lena River Delta, Front. Earth Sci., 2020, 8, 336.
Margold et al. Repeated megafloods from glacial Lake Vitim, Siberia, to the Arctic Ocean over the past 60,000 years, Quaternary Sci. Rev., 2018, 187, 41-61.
Wetterich et al. The cryostratigraphy of the Yedoma cliff of Sobo-Sise Island (Lena Delta) reveals permafrost dynamics in the Central Laptev Sea coastal region during the last about 52 ka. TCD, under review, https://doi.org/10.5194/tc-2020-179.