“Anomalously mild Younger Dryas summer conditions” (Björck et al. 2002) as potential solution for the stadial meltwater paradox

Frederik Schenk[a,b,c], Liva Trasune[b,c], J. Sakari Salonen[c]

[a]Department of Geological Sciences, Stockholm University, Stockholm, Sweden, frederik.schenk@geo.su.se; [b]Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden; [c]Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland

Finding first late-glacial lake sediments on Greenland

After first ice core studies from Greenland in the 1990s revealed abrupt annual temperature shifts of up to 20 degrees within ~10 to 20 years for the Younger Dryas (YD) stadial (GS-1), Svante Björck and colleagues sought to find lacustrine records on Greenland that could elucidate this event. After many unsuccessful attempts to locate and core a lake clearly pre-dating the YD (Bennike & Björck 1999), lake N14 from the Island of Angissoq in the very SW of Greenland was a match covering the period 14,4 to 10,5 ka BP. Considering the severe cooling found in nearby ice cores, the diatom-based inference of *‘anomalously mild YD summer conditions’* was clearly a surprise. Although previous studies found evidence for the presence of short-lived warm summer episodes within the YD, it was not until Björck et al. (2002) to highlight the possibility that the whole YD might have anomalously mild summers throughout - at least south of the Greenland Ice Sheet.

Widespread warm *Stadial Björck-Summers* could resolve the stadial meltwater paradox

Two decades later, it becomes clear that Svante’s study was not a local finding at all. It is echoed by reconstructions south of the Fennoscandian Ice Sheet in Europe (e.g., Schenk et al. 2018; 2020 with Svante as co-author). Toucanne et al. (2015) and Boswell et al. (2019) even found evidence for enhanced stadial ice sheet melting in Europe during some Heinrich Events. The widespread existence of warm *Stadial Björck-Summers* could resolve an apparent meltwater paradox in climate modelling: That models require most meltwater forcing during the coldest periods – to keep the AMOC off.

However, warm stadial summers are still in contradiction to most multi-proxy studies. Here we show that considering non-analogue stadial conditions may reconcile discrepancies. To define the non-analogue state, we use a direct reconstruction of the Gorczynski continentality index (CI_G) from subfossil chironomids from S-Sweden. Our reconstruction yields hyper-continental stadial climates comparable to central Siberia (CI_G 60-80%). Using continental training sets for chironomids and plant macrofossils yields stadial T_{July} >14-16°C in S-Sweden and 15-18°C in the Baltic States. Inverting the equation for CI_G allows calculating $T_{January}$ from proxies as a function of CI_G and T_{July} with stadial winters as cold as –40.5°C ± 7°C (mean –33°C ± 0.7°C). These non-analogue reconstructions confirm the qualitative diatom-based estimates by Björck et al. (2002) for mild summers with cold winters for the YD. Irrespective of regional ice sheet readvances, *Stadial Björck-Summers* appear to be much more widespread and constitute a key feature of rapid deglaciation that does not stop during stadials.

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