Deglaciation of the Ardencaple Fjord and adjacent shelf environment, Northeast Greenland

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Background & Motivation

Recent studies have presented isochron-based reconstructions of the circum-Greenlandic, grounded ice margin since the last deglaciation[1]. However, crucial knowledge gaps regarding the timing and dynamics of this ice retreat still exist, particularly in offshore Northeast Greenland, where fjords and cross-shelf trough systems hosted past fast-flowing ice. This study intends to fill in these data gaps by reconstructing the deglaciation and paleoenvironmental development of the Ardencaple Fjord and the adjacent cross-shelf trough in Northeast Greenland (Fig.1)

Methods

Our environmental reconstruction integrates marine geophysical datasets (multibeam bathymetry and subbottom profiling and analyses of four marine sediment cores that constitute a transect along Ardencaple Fjord and the adjacent cross-shelf trough. The core data includes computed tomography scans and derived first-order density estimations[2] as well as segmentation of large sediment grains. Benthic foraminiferal assemblage analyses have been conducted at various resolutions, and assemblage successions are presented based on selected species of well-established environmental preferences. The chronological framework for the study area primarily relies on radiocarbon dating of foraminiferal aliquots, supplemented by preliminary paleomagnetic secular variation records.

Results

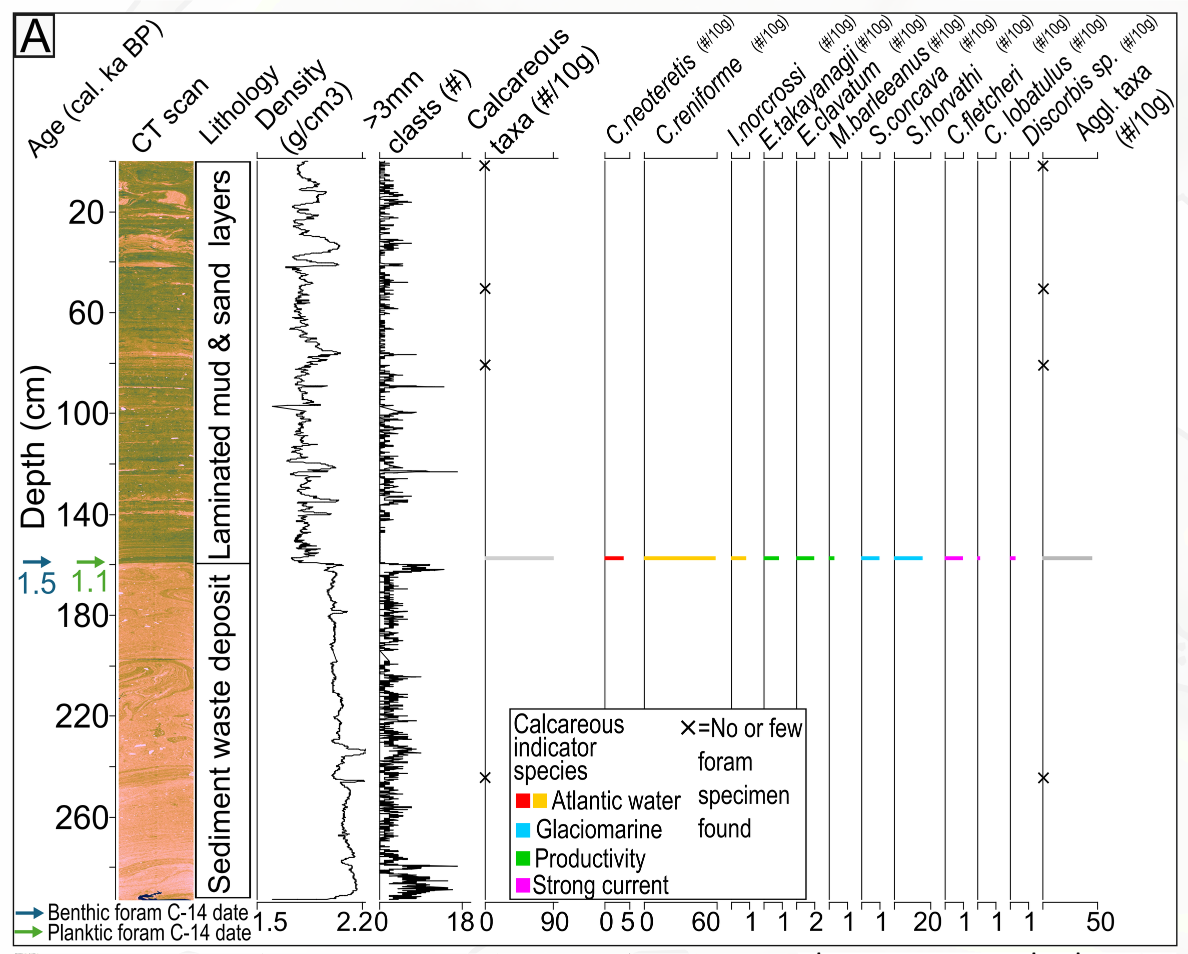
Glacial landforms are observed within the multibeam survey area (Fig.2-5), including glacial lineations, small grounding zone wedges, a group of crevasse squeeze ridges, possible sporadic crag and tails, and iceberg ploughmarks. The Last Glacial Maximum and deglaciation are constrained by two sediment cores and accompanying seismic profiles from the inner to middle shelf trough (Fig.6-7), while the two cores and seismic profiles from the Ardencaple Fjord capture the Late Holocene at high resolution (Fig.8-9).

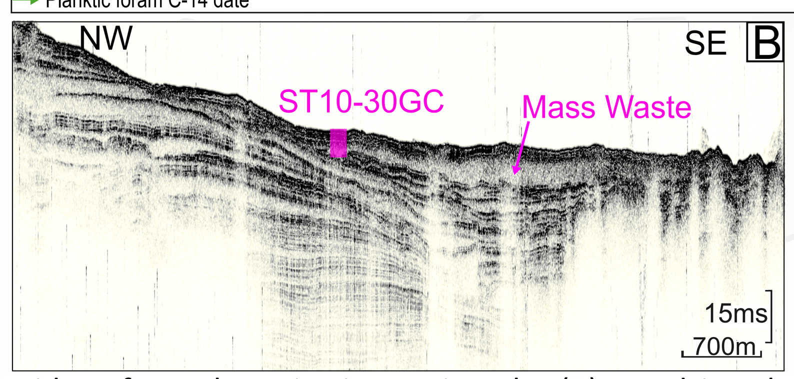
Conclusions

The sediment core and seismic profile from the middle trough show the presence of grounded ice during the LGM. Sediment deformation structures in this area display the ability of substrate deformation by overriding ice, while also not being able to completely remove deposits of previous glacial stages. The concurrence of glacial lineations and grounding-zone wedges indicates rapid yet stable ice retreat during deglaciation. Sedimentological and benthic foraminiferal evidence from the trough cores indicates the presence of a floating ice shelf during the retreat. The presence of a floating ice shelf is backed by double-keeled iceberg ploughmarks, pointing to the calving of large tabular icebergs. The fjord cores indicate a late deglaciation of the fjord side and recurring mass wasting events in the proximity of the modern-day marine-terminating glacier.

Fig.1: Background map of Ardencaple Fjord and shelf

Fig.9: MSM110-10-30GC





The core spans the last 1.5 ka at high resolution (A) and is located close to the modern-day marine outlet of the Ejnar Mikkelsen glacier. The deposits characterize a proximal glaciomarine environment with high-density gravity flow deposits (A), reflecting recurring mass wasting events, also evident from the seismic stratigraphy (B), and interbedded laminated mud and sand layer deposits, reflecting deposition from buoyant sediment plumes and turbidity currents. A single benthic foraminiferal assemblage analysis from the laminated plume shows species compositions similar to the shelf compositions, indicative of oceanographic conditions on the shelf being able to affect the fjord, including the advection of Atlantic-derived water masses.

References

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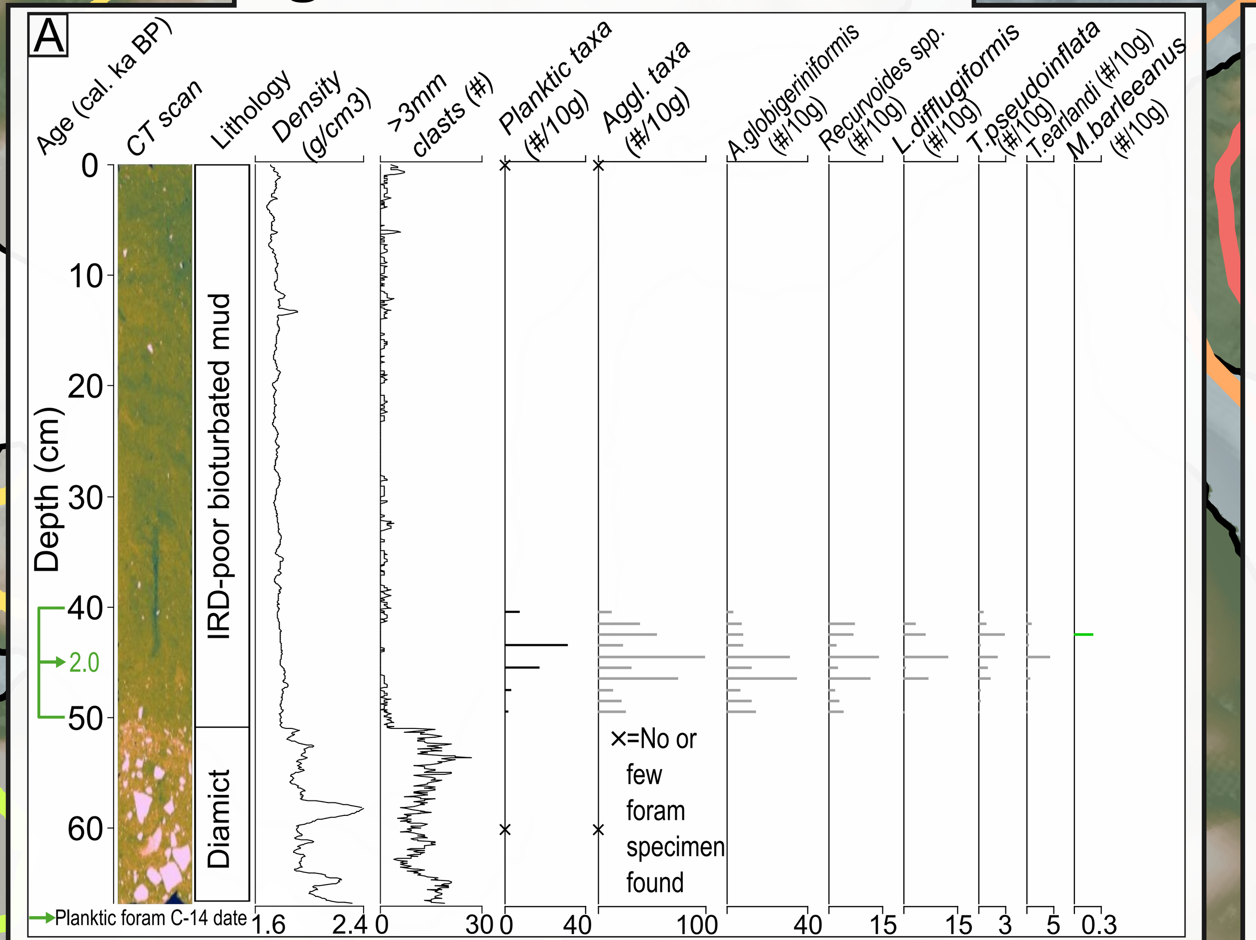
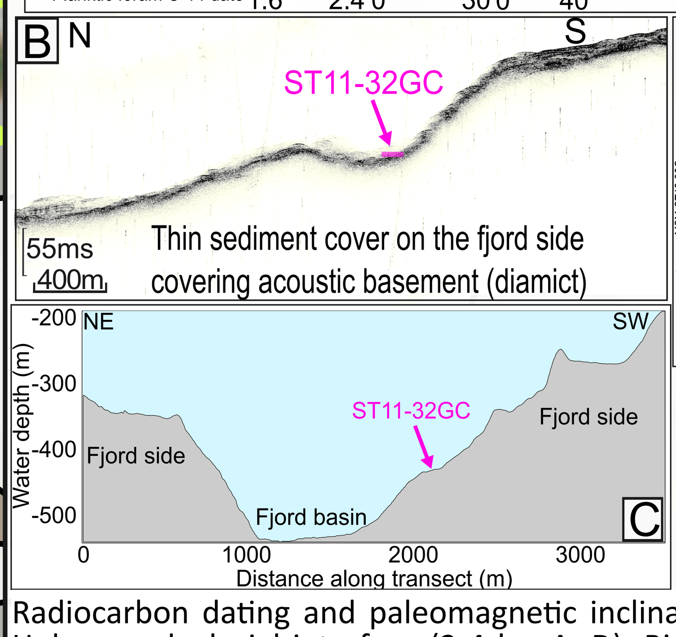
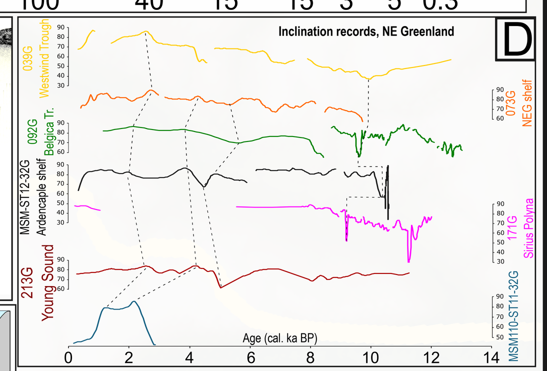
6. Unpublished paleomagnetic secular variation record data

Fig.8: MSM110-11-32GC



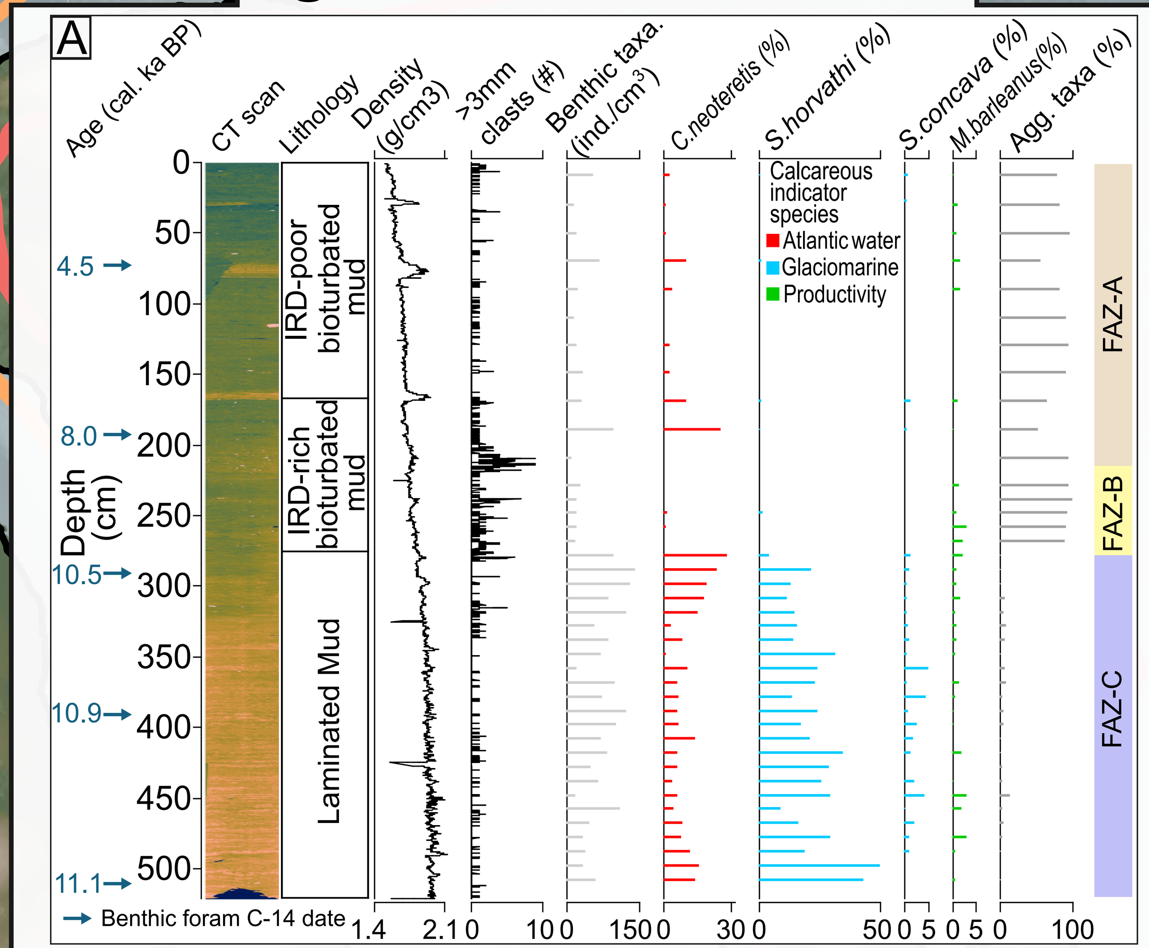


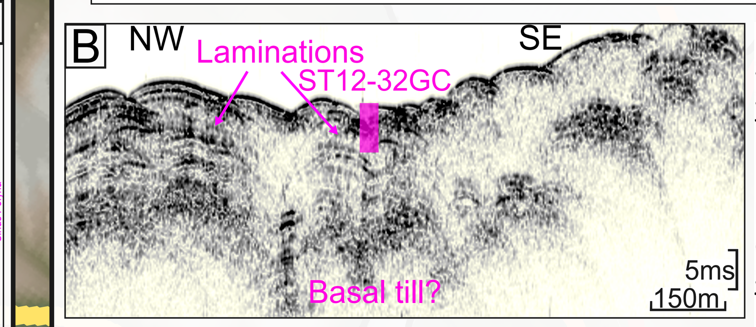


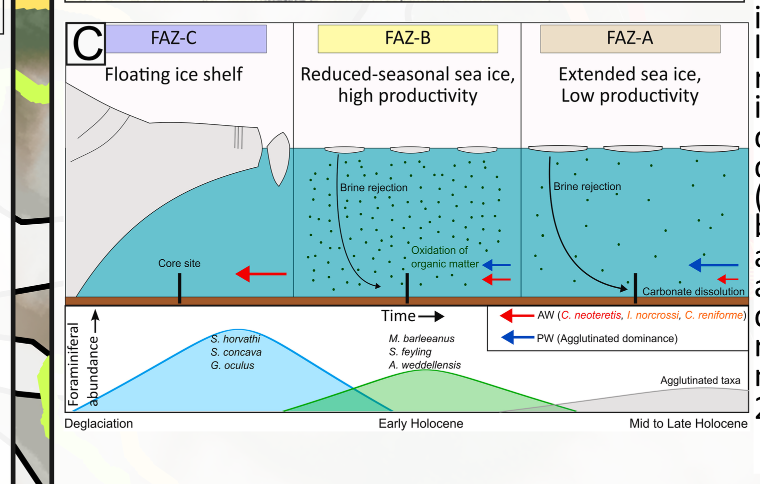
The matrix-dominated diamict (A) ties to the chaotic boundary of the acoustic basement (B) and possibly reflects a basal till deposit, and thus potentially captures the deglaciation of the core site, situated on the fjord side (C).

Radiocarbon dating and paleomagnetic inclination[5-6] records point toward a Late Holocene deglacial interface (2-4 ka; A, D). Bioturbated mud overlies the diamict (A), exhibiting a stable, low content of large clasts, which does not suggest the presence of a floating ice shelf, and thus may suggest its collapse prior to the deglaciation of the core site. Agglutinated foraminifera predominate the benthic assemblage. and may relate to the prevalence of suboxic and/or turbid water conditions.

Fig.7: MSM110-12-32GC

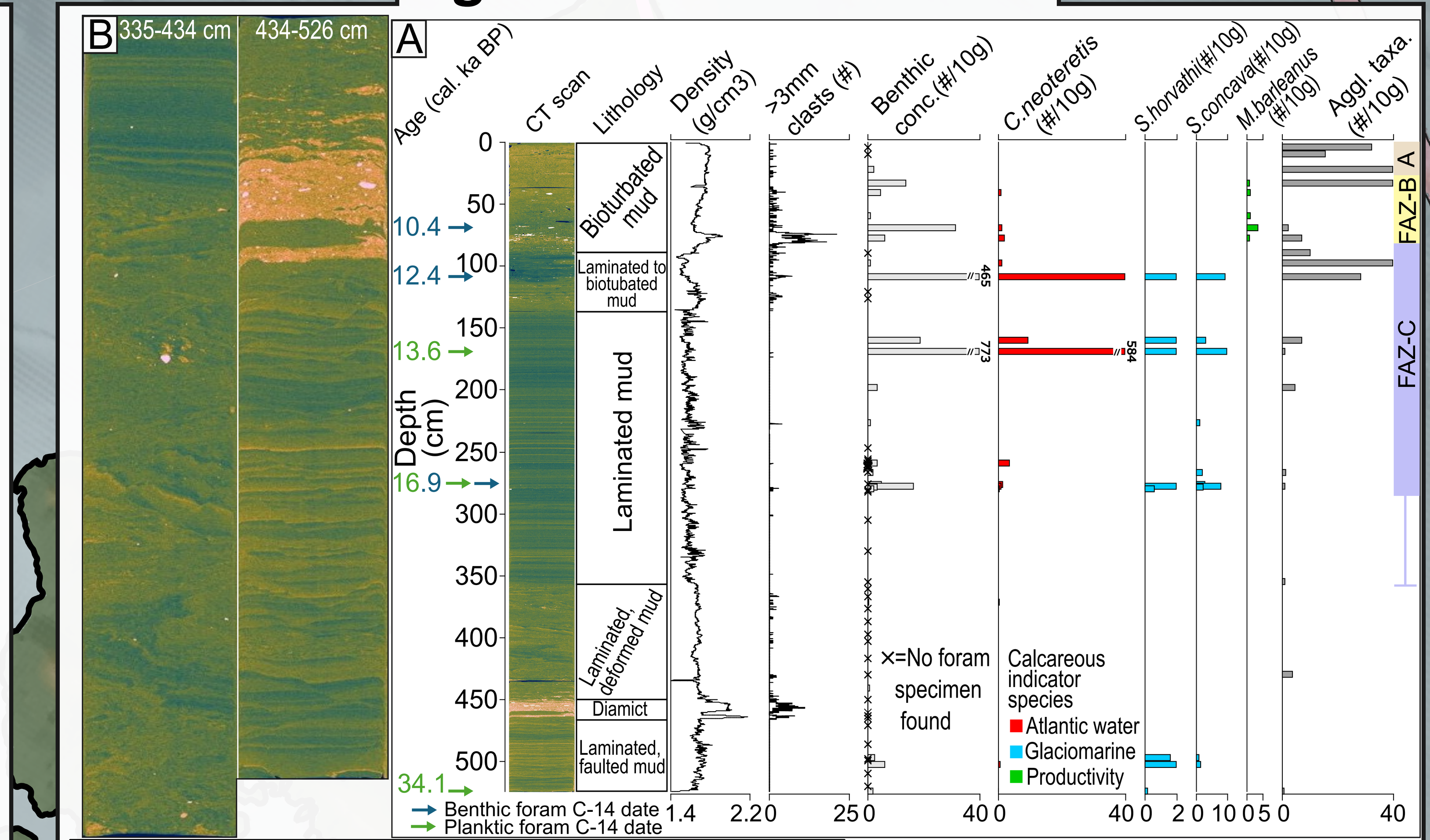


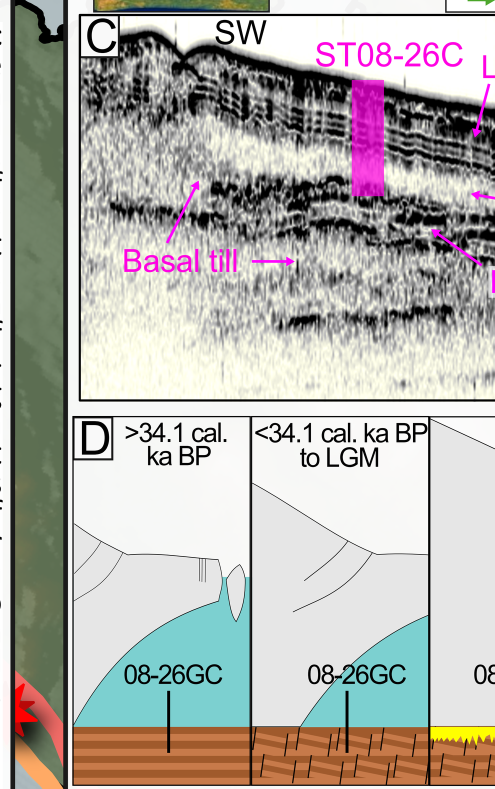




Laminated muds and seismic stratigraphy indicate the core spanning the deglaciation, with the basal till likely situated well below the core bottom (A,B). Laminations and low content of large clasts (A) indicate a depositional environment situated below a floating ice shelf. The retreat of the floating margin is marked by increasing content of large clasts, deposited as ice-rafted debris from calving icebergs, transitioning towards a distal glaciomarine environment dominated by bioturbated muds (A). The sustained presence of benthic foraminifera (A) allows for a detailed assemblage succession analysis of ecosystem response to deglaciation, consistent with recently established conceptual models[4] (C; Stoltenberg et al., 2025).

Fig.6: MSM110-08-26GC





Sediment faulting in the bottom core deposits (A,B) indicates the presence of grounded ice advancing towards its LGM position, faulting preexisting sub-shelf laminated sediments (D). As the core site was overridden, deposition of a thin diamict (A, D) possibly reflect a basal till deposit, when considering the seismic stratigraphy of the core site (C). Deformed muds (A,B) were likely rapidly deposited upon initial deglaciation of the core site, spilling out from the grounding line (D). With increasing distance to the grounding line, the environment turned into a stable sub-shelf setting with deposition of laminated muds (A,D). Abrupt increase in large clasts and transition towards bioturbated muds near the core top (A) exhibit the passage of the retreating floating ice margin and transition to a distal glaciomarine environment (D). Despite the scarce occurrences of benthic foraminifera (A), the assemblage data is indicative of a benthic ecosystem response to deglaciation, consistent with recently established conceptual models[4] (Fig.7C), supporting the use of benthic foraminifera as a proxy for recognizing deglacial stages.