Sediment stratigraphy records the deglacial history of Jakobshavn Isbræ, West Greenland

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1. Introduction and background

Jakobshavn Isbræ is one of the largest ice streams of the Greenland Ice Sheet (GIS) and presently drains c. 7% of the Inland Ice. During the LGM ice in West Greenland is thought to have at least reached the outer shelf. Marine dates in Disko Bay (Fig. 1) show that ice had retreated to a bathymetric sill at the mouth of the fjord by 10-7.5 cal. ka and may have stabilised there for c. 1000 years. Here we present two types of seismic data (Sparker and Topas) in order to describe and interpret the thick sequences of deglacial sediment that accumulated in front of the retreating ice margin (Fig. 2). Sediments were deposited by suspension settling of material (from a meltwater plume) and small- and large-scale gravitational flows extruded at the ice margin when it was located at the fjord mouth (Hogan et al., *in press*).

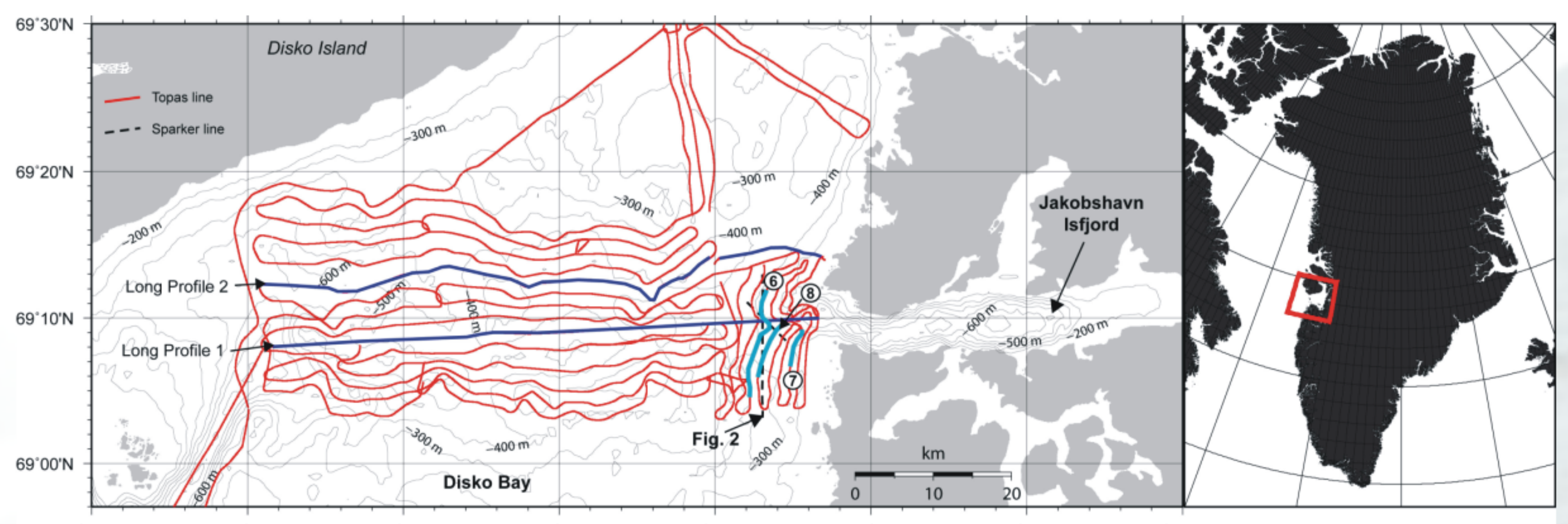

Figure1. Location of seismic datasets in Disko Bay, West Greenland. The locations of profiles in Figs. 3 and 6-8 (circles) are also shown.

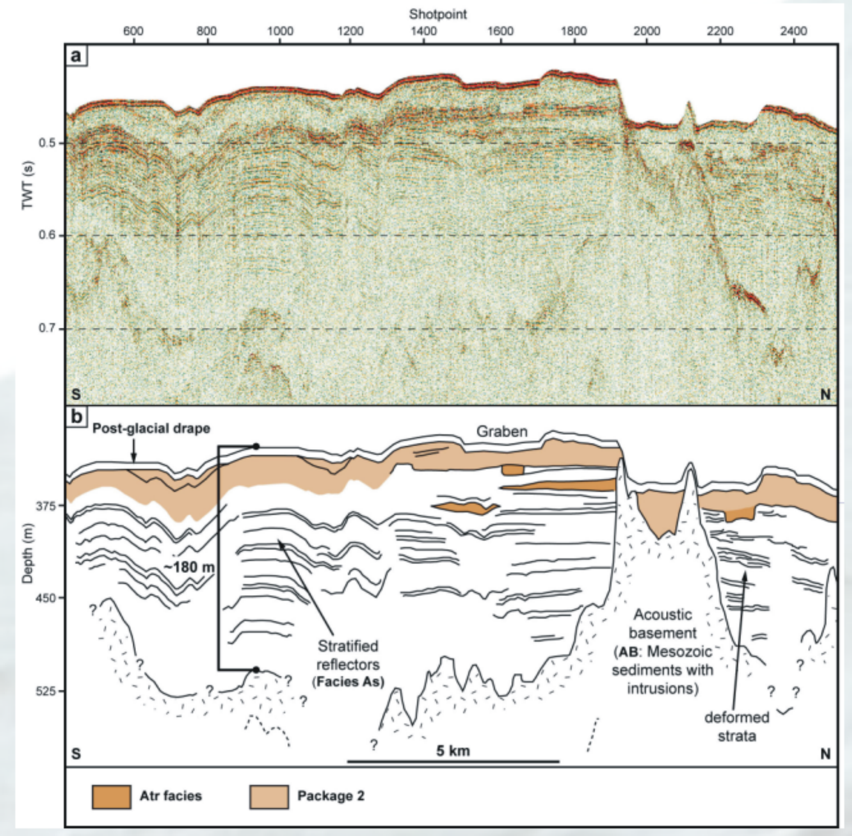

Figure 2. Regional Sparker line showing that >180 m of sediment accumulated in basins just offshore Jakobshavn Isfjord.

2. Long profiles

The nature of ice retreat (rapid vs. episodic) in Disko Bay remains relatively poorly known. Changes in foraminiferal assemblages from marine cores suggest that there may have been a stillstand in the middle part of the bay (Lloyd et al., 2005), with ice possibly stabilising at topographic pinning points. However, the distribution of sediment in Disko Bay implies that retreat was probably rapid until ice reached the fjord mouth; if multiple stillstands had occurred we would expect to see random differences in sediment thickness in basins in the middle and outer bay relating to how long any stillstand lasted at a nearby pinning point.

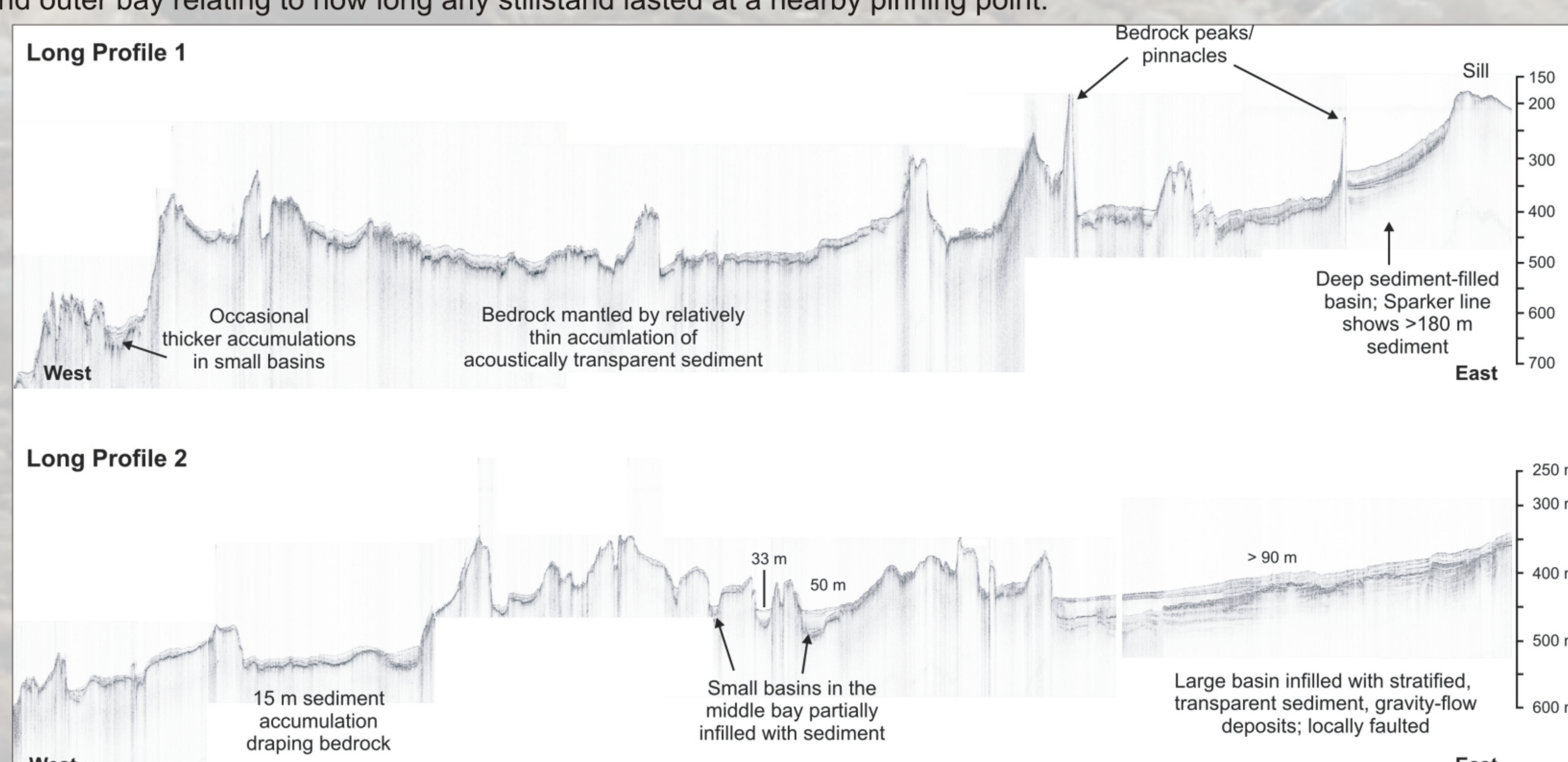

Figure 3. West-East Topas sub-bottom profiler records from Disko Bay showing 90-180 m sediment accumulation in basins close to Jakobshavn Isfjord (inner bay), small basins infilled with 20-50 m sediment in the middle bay and a thinner sediment drape in the outer bay.

3. Deglacial sediment thickness and distribution

The seafloor and the acoustic basement (interpreted as bedrock) were digitised from interpreted Topas and Sparker profiles and gridded using a kriging algorithm in Kingdom SMT. The seafloor pick showed good agreement with EM120 swath bathymetry data also acquired in 2009 (Fig. 4). An isopach map of total (unconsolidated) sediment thickness in metres was calculated using an acoustic velocity of 1500 ms^{-1} (Fig. 5). Sediment is largely confined to two basins close to fjord mouth: a N-S trending basin in the south (bedrock controlled) and more eqidimensional/circular basin in north. Maximum sediment thickness is estimated as 270 m and total sediment volume in the bay is calculated as 44.35 km^3.

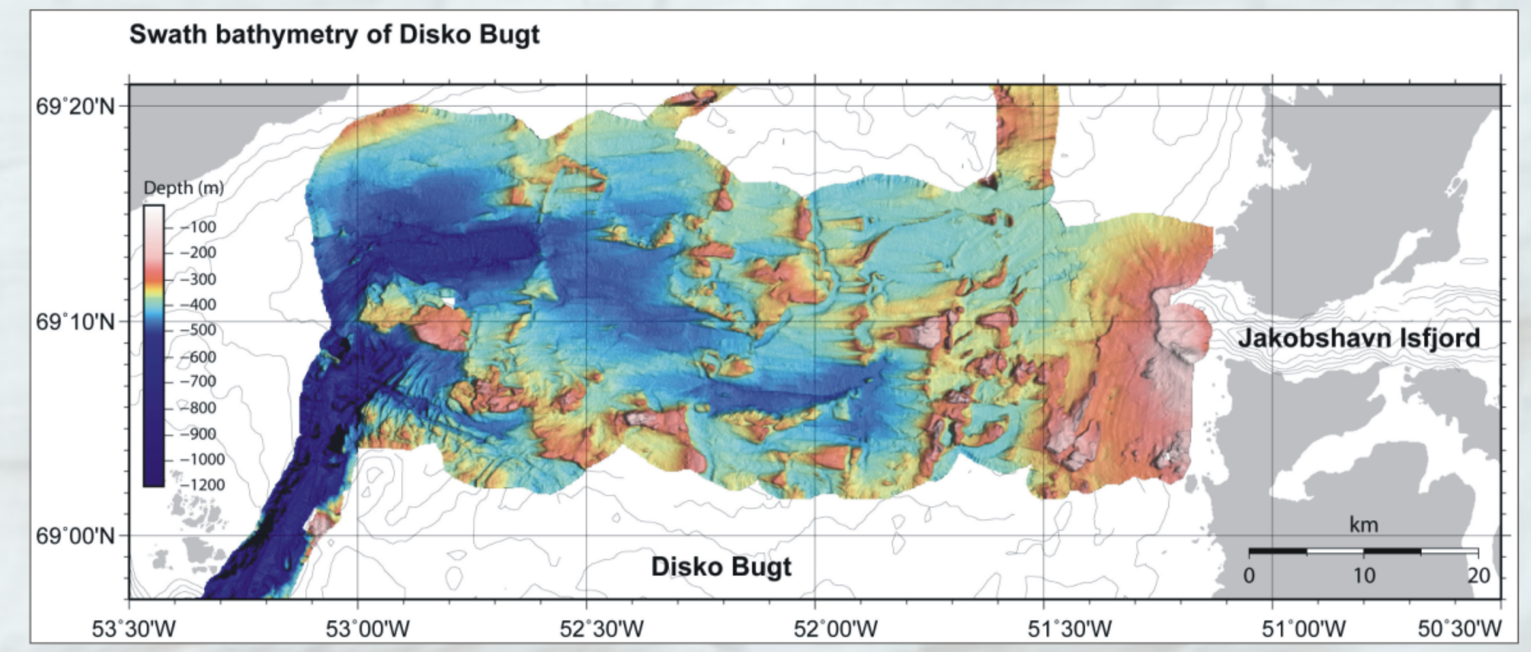

Figure 4. Disko Bay exhibits a rugged morphology with topographic peaks separated by flat or gently dipping seafloor and increasing water depths towards the west.

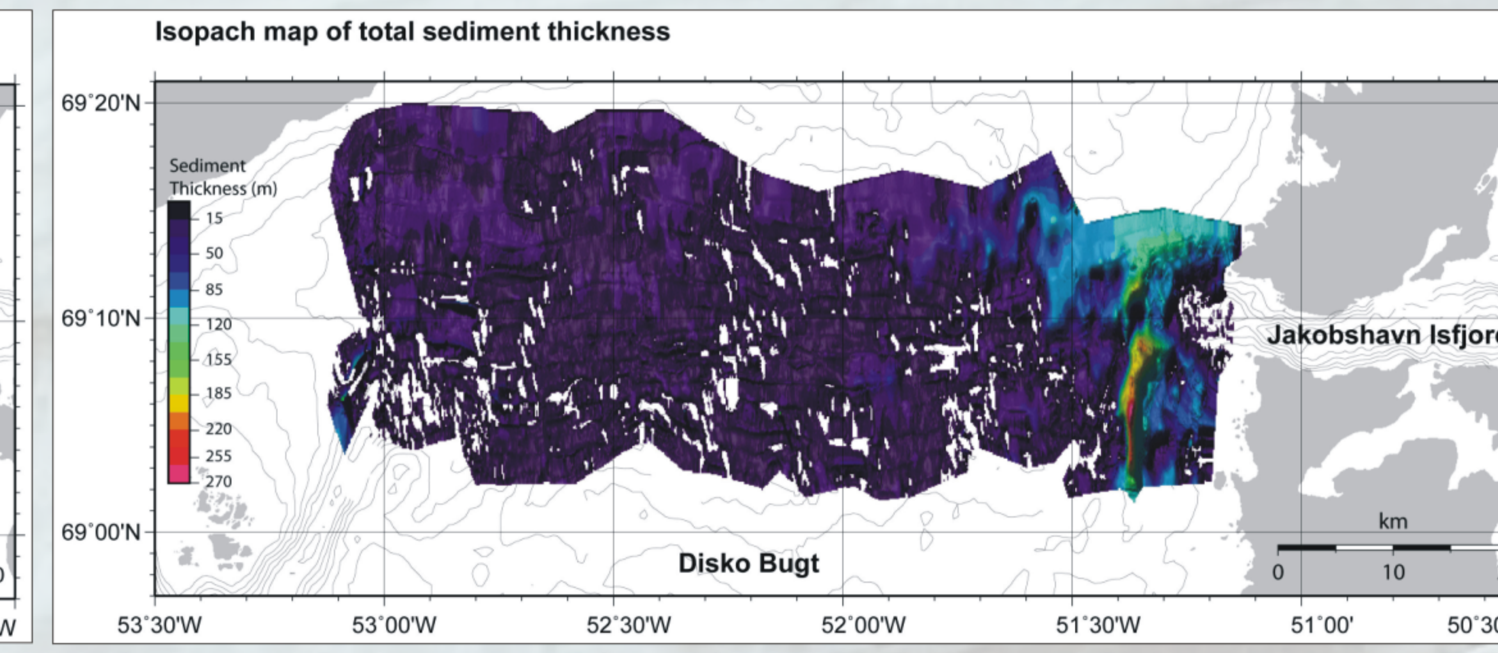

Figure 5. Deglacial sediments accumulated in basins adjacent to the fjord mouthand sediment was effectively dammed in a N-S trending basin in the south leading to thicknesses as large as 270 m.

4. Seismic stratigraphy, the nature of deglacial sediments and sedimentary processes

Based on the new Topas survey five seismic facies have been defined: acoustic basement (AB), acoustically stratified (As), acoustically transparent (Atr), chaotic (Ch), and acoustically semi-transparent (Astr). Figures 6-8 (located in Fig. 1) show examples of the acoustic facies and several other features of interest in the Topas dataset.

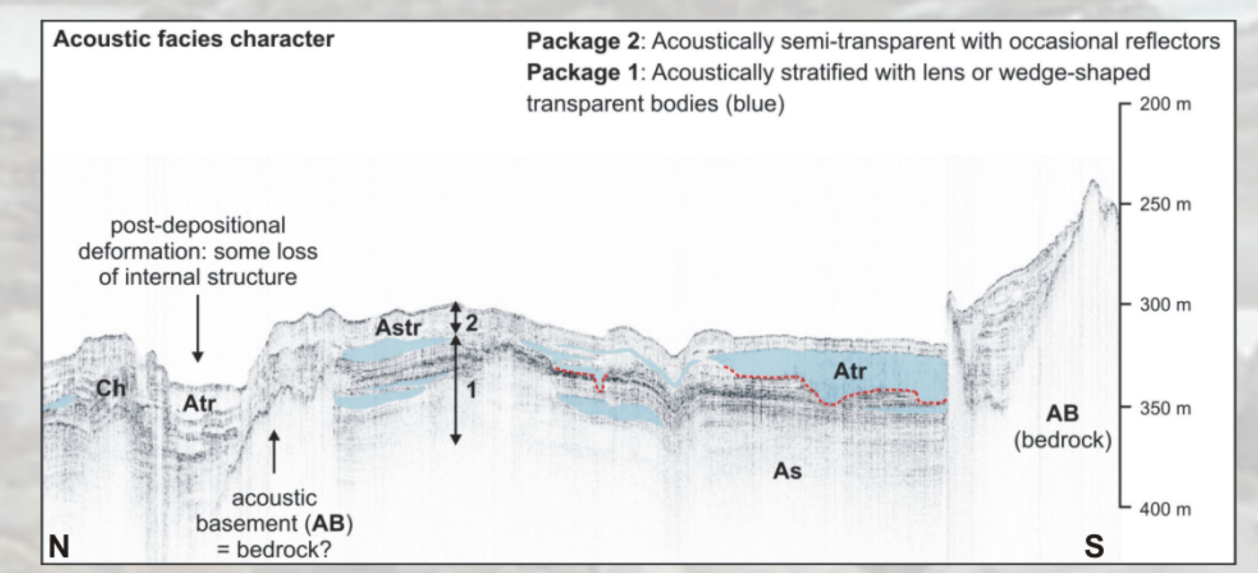

Figure 6. N-S profile showing the same seismic stratigraphy as seen in the Sparker line (Fig. 2): an older acoustically stratified package overlain by a semi-transparent package that is 20-30 m thick.

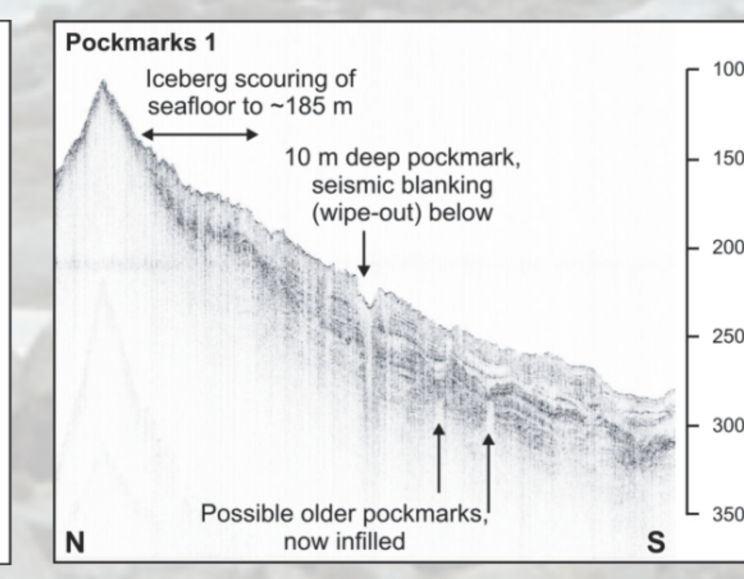

Figure 7. A N-S Topas profile showing a large pockmark with the acoustic signal wiped out below it for at least 60 m.

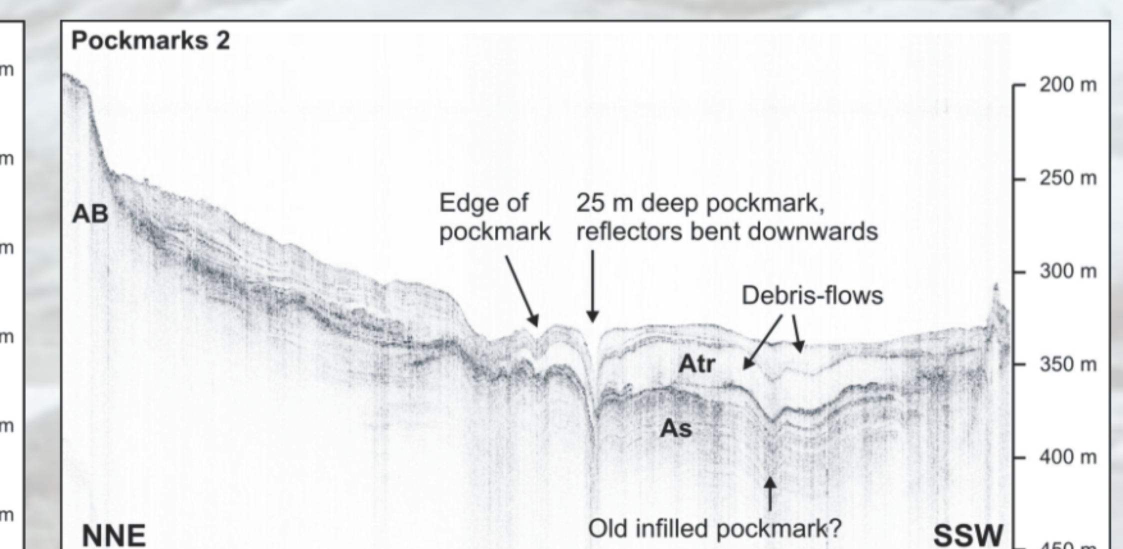

Figure 8. A large and deep pockmark that is sediment empty, further south there is an example of an older or 'relict' pockmark now infilled with sediment.

Mass-flow deposits (cf. Fig. 6) are common in the deglacial stratigraphy of Disko Bay, and are larger and more common in the upper semi-transparent unit (Package 2) than in the lower acoustically stratified unit (Package 1). This increase in gravitational activity may be related to uncoupling of grounded ice at the fjord mouth and associated instabilities around 7.6 cal. ka (Hogan et al., *in press*). The deposits can be erosive at their base and downcut into stratified reflectors or they can form positive relief features which are then draped by younger sediment (Fig. 6). Syn-depositional depressions caused by gas release (pockmarks) are observed in some profiles and are then infilled or buried by sediment. Post-depositional pockmarks are also present with little or no sedimentary infill suggesting either that these pockmarks are fairly young or that they remain empty because of continuous seeping. Syn- and post-depositional faulting and slumping has also occurred in the basins close to the fjord mouth resulting in a chaotic acoustic facies and occasionally loss of all internal structure. Mass-flow deposits, pockmarks and slumped/faulted sediments are all identified close to the fjord mouth, in the large sedimentary basins. These features are not observed in middle or outer Disko Bay. The high rates of deglacial sedimentation close to the fjord mouth resulted in rapid burial and excess pore pressures eventually causing slumping, faulting or the release of pressurised gas.

Sediment accumulation in Disko Bay was primarily controlled by proximity to the ice margin. Glacio-isostatic rebound and high sedimentation rates associated with ice-sheet retreat resulted in gravitational activity, sediment loading and a suite of related morphological/stratigraphical features (e.g. mass-flow units, pockmarks, gas chimneys). The depositional processes and products described here are similar to those observed in high-relief fjord environments during deglaciation (e.g. Lyså et al., 2010).

6. References

(1) Hogan et al. (in press). Seismic stratigraphy records the deglacial history of Jakobshavn Isbræ, West Greenland. Journal of Quaternary Science. (2) Lloyd et al. (2005). Early Holocene palaeoceanography and deglacial chronography of Disko Bugt, West Greenland. Quaternary Science Reviews, 24, 1741-1755. (3) Lyså at al. (2010). Fjord infill in a high-relief area: Rapid deposition influenced by deglacial dynamics, glacio-isostatic rebound and gravitational activity. Boreas, 39, 39-55.