The sedimentary system south of Svalbard: environmental impact of extreme glacimarine sedimentation after LGM

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Abstract

The depositional history of the Storfjorden and Kveithola trough-mouth fans (TMFs) in the NW Barents Sea has been investigated within several national and international projects in the framework of IPY Activity 367, NICE STREAMS. Sediment facies analysis allowed the distinction of depositional processes whose onset appears closely related to ice stream dynamics and oceanographic patterns in response to last climate change. On the continental margin, a several m-thick interval of glacimarine sediments consisting of laminated mud interbedded with sandy layers has been associated to rapid deposition from intense meltwater discharge deriving from fast retreat of the ice-sheet after Last Glacial Maximum. The presence of this interval has been correlated with evidences of submarine landslides on the southern Storfjorden and Kveithola TMFs. In addition, turbid meltwaters may have locally delayed the reprise of the biological activity at the beginning of interglacial MIS1.

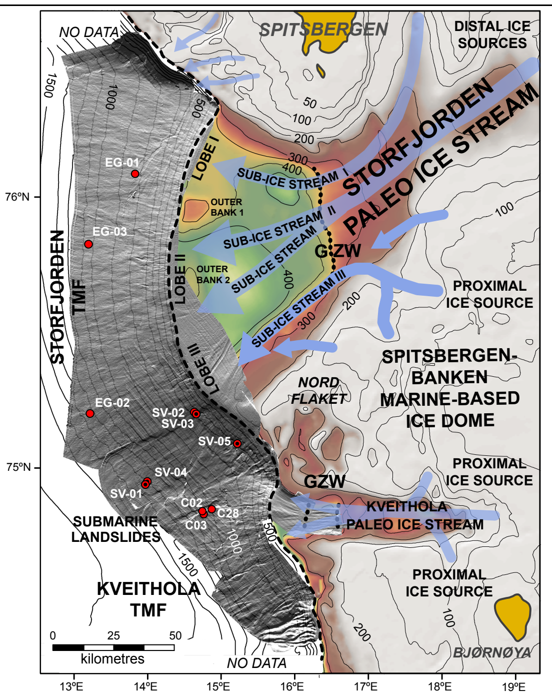

Figure 1: Map of the study area with inferred direction of the main ice streams during LGM. Red dots indicate the location of the studied cores. SV=SVAIS cores; EG= EGLACOM; C=CORIBAR; GZW=Grounding Zone Wedges.

Introduction

Ice streams are fast-flowing ice of an ice sheet, moving significantly faster than the surrounding areas. During glacials, ice streams deliver a large quantity of sediments to the outer reaches of continental shelves were they deposit forming thick piles of highly compresses unsorted sediments (Trough Mouth Fans, TMFs). During deglaciation, the ice streams melt and retreat realising to the ocean a large quantity of sediments that eroded and incorporated, along the way from its source area. These sediments are released in form of turbid meltwaters that eventually settle on the seafloor generating interlaminated deposits of alternated mud and sands (*plumites*). The horizontal distribution of plumites is in the order of a few tens-km from its melting source, whereas in more distant areas the sedimentation is characterized by vertical settling of wind and iceberg (ice-rafted debris, IRD) transported sediments and pelagic settling of bioclasts. All these types of deposits are found in TMFs that are depocentre which sedimentary

record contains the information of past climate changes.
Ten gravity and piston cores collected during the projects SVAIS (2007), EGLACOM (2008), and CORIBAR (2013) on the Storfjorden-Kveithola TMFs, were analysed for physical (radiographs, wet bulk density, magnetic susceptibility, grain size, water content, shear strength) and compositional properties (XRF core scan, Corg/Ntot, micropaleontology) for sediment facies analyses in order to reconstruct depositional processes. Stratigraphic reconstructions were assisted by 50 AMS C^{14} dating and palaeomagnetic analyses, and the areal stratigraphy was analyses through sub-bottom profiles.

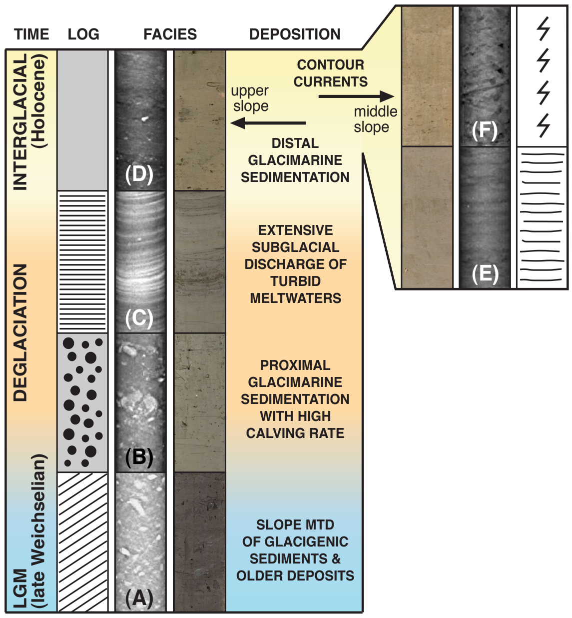

Figure 2: *Climate related depositional processes inferred from sediment facies analyses. MTD=Mass Transport Deposition (after Lucchi et al., 2015).*

Results and discussion

The base of the studied sedimentary sequence contains highly compacted glacigenic diamicton delivered to the shelf edge by ice streams during LGM (facies A, Fig. 2) and/or glacial debris flows deriving from down slope remoulding of glacigenic diamicton and older slope deposits. The diamicton is overlay by a deposit with massive, coarse-grained IRD that was related to ice sheet instability (lift-off) and collapse at the inception of deglaciation (Lucchi et al., 2013) (facies B, Fig. 2). The main phase of deglaciation is represented by a several m-think interval of interlaminated sediments (plumites, facies C, Fig. 2) that in our upper slope cores is over 4.5 m-thick, but the sub-bottom record indicate thicknesses up to 20 m in the southern part of the Storfjorden and Kveithola TMFs. According to our age model, the plumites in our cores deposited during about 130 y with a sedimentation rate exceeding 3.4 cm/y. The plumites are overlay by an interval of massive, fine-grained IRD and by bioturbated IRD-rich sediments (facies D, Fig. 2) correlated to ice-sheet collapse and distal glacimarine sedimentation. The biogenic rich crudely laminated and heavily bioturbated sediments in the upper part of the sequence (facies E and F of Fig. 2) were correlated with bottom currents transporting sediments in climatic conditions favourable to the reprise of the biological activity (interglacial MIS1).
The sub-bottom acoustic date indicates that the areal distribution of the recognized sediment facies is not uniform along the Storfjorden-Kveithola TMFs. In particular, the deposits associated to meltwater plumes have maximum thickness offshore the Storfjorden Lobe III (Fig. 1) and Kveithola with respect to the northern area. This pattern of sediment distribution was related to the local bathymetric characteristics of the area and the interplay between oceanic circulation and glacial dynamic during the deglaciation phase. The different bathymetric characteristics of the Storfjorden and Kveithola Troughs likely determined a different amplitude of the initial ice stream lift-off, with a more inland, retreated location of the north-western part of the Storfjorden grounding line with respect to that of Kveithola (location of the GZW in Fig. 1, 3). On the Storfjorden Trough a first ice sheet stabilization line (GZW, Fig. 1) was preliminarily identified at about 75 km east of the shelf break, whereas on the Kveithola Trough the two deeper GZWs are located at only 20 and 37 km east of the shelf break. Turbid meltwater plumes released at glacial terminus located some 60–70 km inland could not reach the continental slope in the northern area, depositing on the continental shelf whereas in the southern area and offshore the Kveithola Trough plumite deposition continued on the slope (Fig. 3). The oceanic path of the warm North Atlantic current may additionally contributed to a faster melting and retreat of the northern Storfjorden area, being deflected offshore

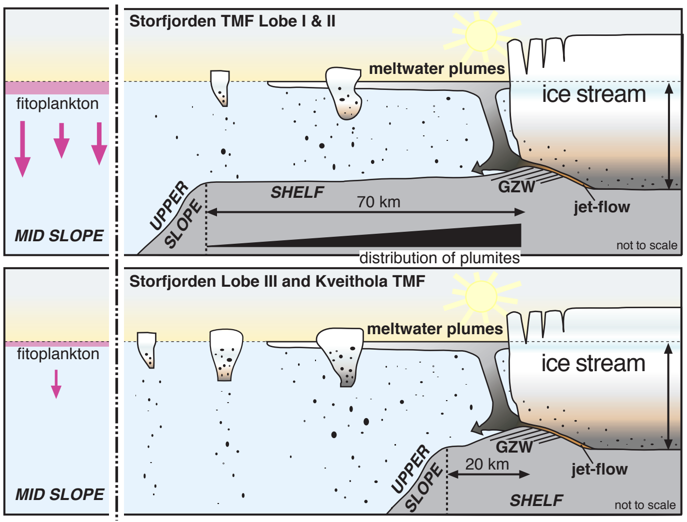

Figure 3: *Modality of ice stream retreat in the Storfjorden Lobes I and II and offshore Lobe III and Kveithola Trough.*

by the Spitsbergenbanken promontory. This is supported by little percentages of the Atlantic current related smectite in the clay mineral assemblage of the Kveithola sediments, whereas consistently higher values are recorded in the northern area sediments. Accordingly, nannofossils distribution on middle-slope sediments confirms ice-free/seasonal conditions occurred earlier in the northern area with respect to the southern part. Suspended sediments in the water column derived from meltwater plumes may have inhibit the primary productivity in the southern area (photosynthetic organism that may have been affected by turbid waters (Fig. 3). Thick plumite offshore the Storfjorden Lobe III and Kveithola Troughs were, furthermore, linked to the presence of submarine landslides that appear confined to the southern area (Fig. 1). Analysis of the sediment lithofacies distribution with respect to the extent in time and space of submarine landslides suggests that an important factor in determining slope instability is the thickness of this kind of deposits. According to our data, failure occurs preferentially along the boundary between plumites and the underlying glacigenic diamicton. Rapid loading of plumites by younger glacial diamicton is thought to result in excess pore water pressure leading to reduce effective stress preconditioning the failure (Lucchi et al., 2012; Llopart et al., 2015).

Conclusion

Ten sediment cores from the Storfjorden-Kveithola TMFs (NW Barents Sea), were studied to reconstruct the sedimentary processes occurred in the area since Last Glacial Maximum. Six main lithofacies were defined and related to deposition occurred during glacial stages with dominant mass transport deposition (highly-compacted glacigenic diamicton and glacial debris flows); the deglaciation phase that was dominated by ice streams melting and retreat (IRD-rich sediments and plumites) and the interglacial conditions when bottom currents dominated the sedimentation (crudely layered and heavily bioturbated sediments). Plumite deposits represent in the area a prominent stratigraphic feature exerting a strong control on the margin stability and reprise of the biological activity after LGM.

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