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Onset and growth of Trough-Mouth Fans on the North-Western Barents Sea margin – implications for the evolution of the Barents Sea/Svalbard Ice Sheet

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ABSTRACT

The aim of this study is to discuss the onset and growth of the Bellsund, Hornsund and Storfjorden Trough-Mouth Fans (TMFs) on the North-Western Barents Sea margin. This is done on the basis of a seismo-stratigraphic analysis of new 2D seismic reflection profiles, and a new correlation between ODP Site 986 west of Spitsbergen and the seismo-stratigraphic network in the central part of the Western Barents Sea margin. We infer that reflector R4A marks the onset of both the development of the TMFs and the contourite deposition which dominate this part of the margin from this time onward. We conclude that these deposits were frequently affected by episodes of small-scale mass-wasting, focused at the mouth of the glacially eroded cross-shelf troughs. With a new interpolation between the few available constraints, we propose an age of about 1.3 Ma for the onset of both the development of the TMFs and the contourite deposition. Thus, we hypothesize, from our results and from previous studies, that the Barents Sea/Svalbard Ice Sheet expanded first beyond the coast north of Svalbard, later reaching the shelf edge at the mouth of Bjørnøyrenna and then to Storfjorden/southern Spitsbergen.

1. Introduction

At high-latitudes, continental margin sedimentation reflects past ice sheet expansions and recessions and the Trough-Mouth Fans (TMFs) have been the major depocenters (Vorren et al., 1989; Cooper et al., 1991; Kuvaas and Kristoffersen, 1991; Laberg and Vorren, 1995, 1996a; Stoker, 1995; Dowdeswell et al.,1996, , 2008; Vorren et al., 1998; Laberg et al., 2010, 2012; Ó Cofaigh et al., 2013). They are important morphologic features characterized by fan-shaped protrusions at the mouth of cross-shelf troughs that hosted fast-flowing ice streams. Major periods of shelf erosion and progradation in TMFs are associated with relatively short time intervals of ice terminating at the shelf edge during glacial maxima (Vorren and Laberg, 1996; Elverhøi et al., 1997). These intervals may be regarded as extreme events. Large quantities of sediments to the TMFs are mostly delivered by Glacigenic Debris Flow (GDF) deposits and meltwater plumes (plumites) (Alley et al., 1989; Laberg and Vorren, 1995; Stoker, 1995; King et al., 1996, 1998; Taylor et al., 2002; Wilken and Mienert, 2006; Nygård et al., 2007; Tripsanas and Piper, 2008). Thus, TMFs are very important archives for the reconstruction of palaeoclimate and ice-sheet dynamics (Vorren and Laberg, 1997).

The aims of this study are to: 1) discuss the onset and growth of the Bellsund, Hornsund and Storfjorden Trough-Mouth Fans on the North-Western Barents Sea margin on the basis of new original seismic reflection profiles (Fig. 1); 2) provide a new correlation between ODP Site 986 west of Spitsbergen and the seismo-stratigraphic network in the central part of the western Barents Sea margin; 3) review the seismo-stratigraphy of the margin; 4) discuss the onset and evolution of the Barents Sea/Svalbard Ice Sheet.

2. Regional setting

Several fans that developed on the north-western margin of the Barents Sea at the mouth of cross-shelf troughs are still clearly visible in the morphology (Fig. 1). They were fed during glacial times by ice streams draining the Svalbard/Barents Sea Ice Sheet

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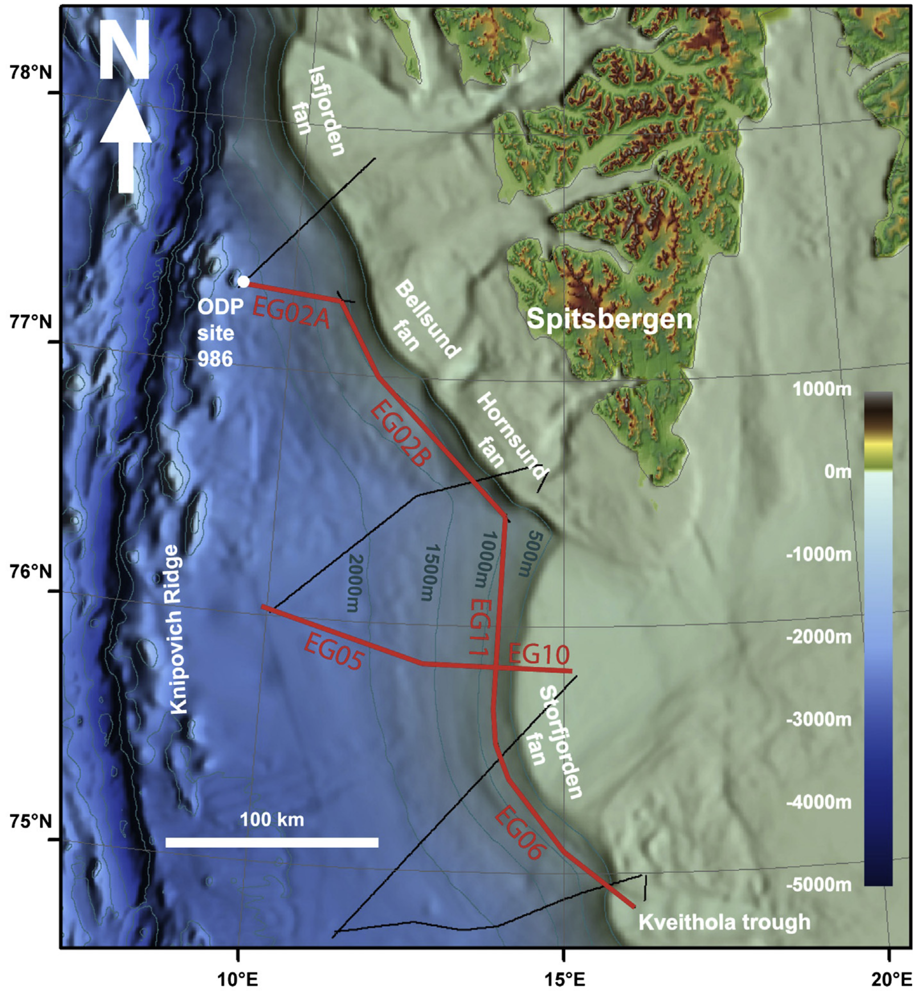

Fig. 1. Bathymetry map (from Jakobsson et al., 2012) of the NW margin of the Barents Sea showing the location of TMFs. Position of multichannel (EGLACOM) seismic reflection profiles is shown in black and the figured profiles are highlighted in red and labelled. The position of ODP Site 986 is shown in white. Contour interval is 500 m. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Vorren, 2003; Ottesen et al., 2005). The area of these TMFs is roughly proportional to the area of the feeding cross shelf troughs, which is also roughly proportional to the size of the paleo-ice stream drainage area.

Seven regional seismic reflectors, R7 (oldest) to R1 were correlated along the entire western Barents Sea/Svalbard continental margin by Faleide et al. (1996). R7 was inferred to mark the onset of glacially-dominated deposition. A change from erosion to sediment accumulation and aggradation of the outer shelf was observed at times corresponding to reflection R5, R3, and R1 adjacent to Svalbard, the Storfjorden and Bjørnøyrenna troughs, respectively.

On the basis of multichannel seismic lines, the sediments of the Storfjorden TMF have been divided by Hjelstuen et al. (1996) into four major sequences inferred to reflect two types of depositional environments. The central sequences GI and GII (between R7 and R1) were inferred to be dominated by sediment focussing on the Storfjorden TMF, whereas before and afterwards (sequences G0 and GIII) sediments were more evenly distributed over the entire margin. An average erosion rate of 0.037 mm/a was estimated for the preglacial period, whereas an increased average rate of 0.63 mm/a was attributed to the intense glacial erosion during the following period.

Both Faleide et al. (1996) and Hjelstuen et al. (1996) concluded that transport in a subglacially deforming till layer is the most likely high capacity mechanism for transporting these sediments from Svalbard and the Barents Sea to the margin. Laberg and Vorren (1996b) showed that the Storfjorden TMF during the Middle-Late Pleistocene had an evolution very similar to the Bear Island TMF, with periodic high sediment input dominated by GDF deposits delivered by an ice sheet grounded at the shelf edge during the glacial maxima.

The Ocean Drilling Program (ODP) drilling of Site 986 (Fig. 1) during Leg 162 (Shipboard Scientific Party, 1996; Raymo et al., 1999) derived some constraints for the R7-R1 seismostratigraphic network and introduced reflector R4A between R5 and R4 that indicates a distinct upward change in seismic character (from very strong to low-amplitude reflectors) and a major change in depositional style detected in the physical properties of the sediments (from larger to smaller GDF) at Site 986.

Analyses of samples from Site 986 lead Forsberg et al. (1999) and Butt et al. (2000) to conclude that the Plio-Pleistocene development of the Svalbard Margin took place in at least three distinct phases: there was an initial glacial growth during the R7–R6 sequence (inferred to be between 2.3 and 1.6 Ma) when glaciofluvial drainage (recorded through a greater increase in the deposition of sand than clasts) was the main sediment transport mechanism to the coast, and downslope transport was as GDFs and turbidites; there was further glacial expansion during the R6–R5