Depositional processes on the distal Scoresby Trough Mouth Fan (ODP Site 987): implications for the Pleistocene evolution of the Scoresby Sund Sector of the Greenland Ice Sheet

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Abstract

The investigation of trough mouth fans (TMFs), important paleoclimatic archives at high-latitude continental margins, has so far mainly been based on the integration of various types of acoustic data supplemented with short sediments cores. In consequence, sedimentological and chronological data about TMFs deposited prior to the Last Glacial Maximum remains sparse. Here, we re-evaluate the upper part of ODP Site 987 drilled on the distal part of the Scoresby Sund TMF on the east Greenland continental margin, monitoring the Scoresby Sund sector of the Greenland Ice Sheet. Based on a more detailed sedimentological description than previously available we find that lithological unit I deposited over the last ~2.14 Ma can be divided into two parts, a lower part dominated by glacimarine and marine deposits included some scattered, sandy turbidites and an upper part of debris flow deposits interbedded with sandy turbidites. The transition between these parts occurred at about 0.99 Ma, i.e. at the same time when the mode of ice-sheet variation changed globally, the average ice sheet size increased significantly and the periodicity of ice-volume variation increased to approximately

100 ka (the “Mid-Pleistocene Transition”). On the distal Scoresby TMF, this change appears to be reflected through a marked increase in the abundance of sandy turbidity flows accompanied by a longer run-out of some of the debris flows due to the delivery of larger sediment volumes during longer-lasting glacial maximum. This suggests that long sediment cores from trough-mouth-fans have the potential to record the major climatic trends occuring during the Pleistocene.

Key words: trough mouth fans, paleoclimatic archives, high-latitude continental margins, NE Greenland, Greenland Ice Sheet

1. Introduction

During the Pleistocene several major cooling phases occurred, and the global climate changed into glacial-interglacial cycles. First the glacial cycles showed a periodicity of ~41 kyr, but after the Mid Pleistocene Transition (MPT) between 1.2 – 0.7 Ma the periodicity changed to ~100 kyr cycles without any significant changes of the orbital forcing (e.g. Tziperman and Gildor, 2003; Lisiecki and Raymo, 2005; Clark et al., 2006). Ice sheets have left behind sedimentary evidence, which hold important information on the evolution of atmosphere-ocean-ice sheet climate system throughout the Pleistocene, including the MPT. Hence, in order to understand the evolution of the ice sheets and evaluate the climate forcing and responses it is important to locate and decode marine, continuous paleo-climatic archives. Marine palaeo-climatic archives from high-latitude continental margins that have not been affected by post-depositional mass wasting provide valuable archives to reconstruct the response of ice sheets to climate forcing in the past.

A characteristic feature of glaciated continental margins are trough mouth fans (TMFs) which are composed of thick, continuous successions of glacigenic erosional products from ice sheets. This particular group of submarine fans are located at high-latitude and glaciated continental margins beyond the terminations of shelf troughs (Vorren et al., 1989; Aksu and Hiscott, 1992; O'Brien et al., 2007). The largest TMFs are several orders of magnitude larger than the smallest (Vorren and Laberg, 1997), such as the northern high-latitude Bear Island and North Sea TMFs, that prograded into the northern and southern part of the Norwegian Sea, respectively (Fig. 1). They have low axial gradients and are in their proximal part dominated by large glacigenic debris flow deposits occurring in units (or sets; Vorren et al., 1989) separated by glacimarine and/or hemipelagic sediments (Laberg and Vorren, 1996). The same characteristics apply also for southern high-latitude trough mouth fans (Passchier et al., 2003; O'Brien et al., 2007). A unit of glacigenic debris flow deposits has been interpreted to be deposited during a glacial maximum period when an ice sheet extended to the shelf break during glacial maxima. During full glacial conditions, ice sheets included sectors of fast flow (topographically controlled ice streams) that developed within and led to deepening of cross-shelf troughs. TMFs developed beyond the terminations of the troughs because of more pronounced erosion and sediment transport beneath the ice streams (Laberg and Vorren, 1995, 1996; King et al., 1996, 1998; Nygård et al., 2007; Tripsanas and Piper, 2008). The large fans received their sediments from a large drainage basin, smaller fans corresponds to minor drainage basins (Batchelor and Dowdeswell, 2014; Rydningen et al., 2016).

Studies of the long-term evolution of the Bear Island TMF revealed that the succession deposited over during the last ~2.7 Ma, corresponding to the trough-mouth-fan part of the continental margin strata, can be separated into three main seismic units: GI (oldest) – GIII. Unit GIII, deposited over during the last ~0.7 Ma, is dominated by large glacigenic debris flow deposits, unit GII (~0.7 – 1.5 Ma) has a more complex seismic facies where irregular to chaotic intervals dominate, but where also acoustically laminated intervals and mounded facies also occur. The irregular to chaotic intervals were found inferred to represent paleo slide scars and slide deposits, whereas while the mounded signature is interpreted to reflects cross sections through glacigenic debris flow deposits. Glacigenic debris flow appeared for the first time in unit GII. Channels have also been identified within this unit. The paleo–slope morphology of unit GI (~1.5 – 2.7 Ma) shows a gentle, low-relief surface with channels (Laberg et al., 2010). This development has been assigned to an overall climate deterioration; from a temperate Barents Sea Ice Sheet with channelized meltwater flow to more polar ice conditions and a Barents Sea Ice Sheet that mainly included large ice streams, with little or no channelized meltwater flow (Laberg et al., 2010).

More recent work, e.g. by Rydningen et al. (2016) revealed that smaller fans have higher axial gradients and that some are dominated by turbidity currents inferred to result from the flow transformation of glacigenic debris flows due to the higher gradient. In addition, slide- and paleo-slide scars and corresponding slide deposits have been identified (e.g. Rydningen et al., 2015, 2016).

So far, the studies of TMFs have mainly focused on the integration of various geophysical methods with short cores documenting only the youngest fan deposits that originated during the last glacial maximum. However, very little is known about the sedimentology of TMFs predating the last glacial maximum. So far, the only TMF targeted by drilling within the Norwegian – Greenland Sea area is ODP Site 987 in the distal part of the Scoresby Sund TMF offshore east Greenland. The main focus for this site was to investigate the evolution of glaciations in the North Atlantic region in particular the Greenland Ice Sheet (Shipboard Scientific Party, 1996). The initial study of ODP 987 showed only one interval of glacigenic debris flows (lithological unit II, 305–369 m), which was interpreted to be deposited during ice sheet advances towards the shelf break around 2.58 Ma. Later interpretations then concluded that most of the eastern sector of the Greenland Ice Sheet was stable and may not have been much larger than at present during the peak Pleistocene glaciation (e.g. Butt et al., 2001). A later study based on new seismic data provided a better tie of the drill site to the proximal fan succession (Laberg et al., 2013). The seismic data showed that the Scoresby Sund sector of the Greenland Ice Sheet was more sensitive to past climatic changes than previously thought, and it expanded to the shelf break frequently during the Pleistocene (Laberg et al., 2013). In this study, the focus is on the sedimentary processes of the upper part of the Site 987 record including the MPT based on sedimentological re-logging of cores 987D and E. From this, we reinterpret the depositional environment of the distal part of a TMF and discuss the paleoclimatic implications including the potential of the fan to record the evolution of the Scoresby Sund sector of the Greenland Ice Sheet.

2. *Physiographic setting*

The Scoresby Sund Trough Mouth Fan forms a pronounced protrusion on the East Greenland margin offshore the Scoresby Sund fjord system where the shelf edge is located up to 100 km east of the coastline (Larsen, 1990; Jansen and Raymo, 1996; Dowdeswell et al., 1997; Vorren and Laberg, 1997) (Fig. 1). The shelf edge is at about 400 – 500 m water depth. Further downslope (eastwards) a prominent reduction in slope gradient occurs at a water depth of ~1500 m. Further east in the basin the sea floor shallows to about 1000 m close to the Kolbeinsey Ridge. The deepest part of the sea floor, which has a smooth relief, is interpreted to form the distal part of the fan. This part is located in a northward deepening basin, deepening from the southernmost part of the fan (Fig. 1).

The Scoresby Sund TMF is the largest trough mouth fan on the east Greenland continental margin. Smaller fans occur further south (Lykke-Andersen, 1998) and north (Bathcelor and

Dowdeswell, 2014). The Scoresby Sund fjord system, comprising the largest single ice outlet in East Greenland today (Funder et al., 1998), is ~50 km wide and more than 500 m deep at its mouth. An over-deepened trough, also more than 500 m deep, forms the fjord prolongation onto the continental shelf (Fig. 1). This fjord – trough system is inferred to have acted as one of the major drainage pathways of the eastern Greenland Ice Sheet (Solgaard et al., 2011). Based on the analyses of long-range side-scan sonar and sub-bottom profiles, Dowdeswell et al. (1997) identified glacigenic debris flow deposits on the seafloor and in the shallow sub-seafloor limited to the southern, upper part of the Scoresby Sund TMF. On the northern part of the fan, glacigenic debris flows are draped by 8 – 25 m of glacimarine sediments (Nam et al., 1995; Laberg et al., 2013), i.e. they are located too deep to be detected by the long-range side-scan sonar.

3. *Data base and methods*

In this study we have relogged lithological units I, II and the uppermost part of unit III of Hole 987D and E (Shipboard Scientific Party, 1996) based on visual inspections of the cores at the IODP repository in Bremen. Core photographs, x-rays of selected parts of the lithofacies identified and shipboard physical property measurements was made available for us by the IODP repository at Texas A&M University. In this study, we use the age model of Channell et al. (1999) and the revised time scale of Ogg et al. (2008). Our data base also includes the seismic line presented and discussed by Laberg et al. (2013).

4. *Results*

4.1 Seismic stratigraphy

The seismic stratigraphy on the distal Scoresby Sund TMF (at the drill site; corresponding to lithological unit I) is acoustically laminated and includes medium – high amplitude and continuous reflections (Fig. 2; Laberg et al., 2013). A single, acoustically transparent lens is also present. Approximately 55 km south of the core site, a transition from the acoustically laminated facies to stacked units of acoustically transparent lenses intercalating with the acoustically laminated deposits occurs. The lenses are up to 4 km wide and ~40 m thick (Fig. 2), showing that the proximal part of northern Scoresby Sund TMF comprises multiple, large glacigenic debris flow deposits. They occur in units bounded by laterally continuous and medium – high amplitude reflections and are separated by acoustically laminated intervals inferred to be glacimarine, marine and/or turbiditic deposits (Laberg et al., 2013).

An acoustically transparent lens corresponds to lithological unit II while the upper part of the unit corresponding to unit IIIA displays an irregular acoustically laminated signature of low amplitude reflections overlying a more transparent signature (Fig. 2).

4.2 Sedimentology and physical properties

Below, lithological units I, II and the uppermost part of unit III of Hole 987D and E will be described and discussed.

4.2.1 Unit I

Lithological unit I comprises three main lithofacies. Lithofacies (i) is composed of mud with sharp color changes and irregular boundaries, clay clasts/lenses, color banding is absent. These properties indicate reworking. Therefore, this facies is interpreted to represent slump and/or debris flow deposits. Mud with gradual to sharp color changes – color banding bounded by horizontal – semi-horizontal boundaries inferred to be glacimarine and marine deposits comprising Lithofacies (ii). Lithofacies (iii) is characterized by sand lamina/layers mostly comprising fine sand with sharp upper and lower boundaries, interpreted to be turbidites (Figs. 3, 4). The Shipboard Scientific Party (1996) also identified these facies, but no detailed studies of their distribution were undertaken post cruise. Sediment disturbance occurs in some intervals of all lithofacies due to disturbance during coring, and/or disturbance due to gas expansion, as reported by the Shipboard Scientific Party (1996; Figs. 3, 4).

Lithofacies (i) dominates the upper ~80 m of Unit I. It is interbedded with Lithofacies (iii) which is most abundant from ~50 – 90 m core depth, commonly occurring from ~20 – 50 m and sporadic present in the upper ~20 m (Fig. 3). A pronounced change from Lithofacies (i) to (ii) occurs at about ~80 m depth. Intercalations with sandy turbidites (Lithofacies (iii)) are most abundant between ~80 – 95 m. Lithofacies (iii) occur only sporadically further below. Scattered clasts (> 2 mm) were identified throughout most of the studied interval during the visual inspection (Fig. 3). They are interpreted as ice-rafted debris.

The lithological variations observed in lithostratigraphic unit I are not reflected by the seismic data. The latter reveal a rather uniform signature in this interval implying that the thicknesses of the distal slumps/debris flow deposits are below the vertical resolution of the seismic data (< ~4m using a P-wave velocity of 2000m/s and a signal frequency range of 20 – 250Hz) (Fig. 2).

The bulk density and porosity fluctuate frequently above ~90 m core depth, most probably reflecting the repeated lithological changes of the sand and mud deposits in this interval. Below this depth, only slight down-core increases/decreases of these properties are observed in Unit II. This reflects most probably a more uniform sediment succession, mainly deposited from suspension settling. The deposits comprising Unit II are characterized by markedly higher bulk density and lower porosity, respectively, possibly due to the higher clast content and/or remoulding during sediment reworking (see below) leading to a porosity reduction and, thus, an increasing bulk density. The shear strength increases generally down core, as a result of sediment compaction. More variable shear strength below ~90 m core depth might relate to the increased abundance of clasts, i.e. ice-rafted material, and/or variations in consolidation (Fig. 5).

The contents of Total Carbon (TC%) and Carbonate (%) increase slightly above ~90 m depth (Butt et al., 2001). This may be related to periods of higher productivity after ~0.99 Ma corresponding to longer and warmer interglacials. Deposits from these periods are interpreted to have been reworked and partly mixed with glacial deposits during glacials. However, below ~90 m depth, the productivity was probably lower and the deposits were not reworked producing more fluctuating values for the carbonate content corresponding to glacial and interglacial periods (Butt et al., 2001).

Based on the age model of Channell et al. (1999) the marked change in the abundance of sandy turbidites is at about 0.99 Ma, above which they are frequently occurring. Throughout most of this interval they are associated with muddy slumps/debris flow deposits. Thus, this part of Hole 987D is inferred to be dominated by reworked deposits. The > 0.99 Ma succession shows few indications of reworking. Predominantly thin sandy turbidites occur rarely. In a few cases, a few tens of cm thick intervals dominated by thin sand layers have been identified. This part is dominated by color-banded mud, bands vary in thickness from cm to dm, in some parts there seems to be a systematic variation in thickness and color.

4.2.2. Unit II

Unit II is a stiff, muddy diamicton with a silty clay matrix. However, compared to Unit I, the clast content, including clasts of pebble size is higher. The unit is ~67 m thick and massive except for the lowermost ~2 m where regular – irregular lamina and thin layers of varying color occur (Fig. 4e, f). High bulk density and low porosity values characterize Unit II (Shipboard Scientific Party, 1996) (Fig. 5) and in conformity with their interpretation, we find Unit II to be a debris flow deposit. The apparently laminated interval at its base (Fig. 4), mentioned, but not interpreted in the report (Shipboard Scientific Party, 1996). We suggest that it is the basal shear zone of the flow.

Unit II was probably deposited as a single event prior to 2.14 Ma (Fig. 2) according to the age model of Channell et al. (1999). Its high clast content leads us to suggest that these sediments were originally deposited as ice-proximal sediments at or near the shelf break, and were later remobilized as a large debris flow. The absence of stratification layering may indicate sediment deformation and destruction of any existing structure during flow. Its dimensions are comparable to the distal debris flows of the Trænadjupet Slide offshore Norway (Laberg et al., 2006) indicating that it may have originated from a major failure somewhere on the upper part of the continental slope.

4.2.3. Unit III

Only the uppermost part of Unit III was revisited in this study. It consists of sediments corresponding to Lithofacies ii of Unit, I inferred to be glacimarine/marine deposits (Fig. 3).

5. Discussion

5.1 Depositional environment

The revisit of the lithological sequence deposited during the past c. 2.14 Ma reveals that the sedimentation pattern on the distal part of the Scoresby Sund Trough Mouth Fan changed from glacimarine and marine deposits (including some scattered, sandy turbidites) to enhanced deposition of debris flow deposits interbedded with sandy turbidites. This transition occurred at about 0.99 Ma (Fig. 3). However, seismic data reveal that the deposition of glacigenic debris flows predominated the sedimentation pattern on the proximal fan during the time of deposition of Unit I on the distal fan (Fig. 2) (Laberg et al., 2013).

Thus, our study indicates that the lower part of lithological Unit I (~2.14 – 0.99 Ma) corresponds to a distal part of an interval of glacigenic debris flows that is not associated with turbidity flows, whereas turbidites were much more abundant in the distal realm during the last <0.99 Ma (upper part of unit I; Fig. 6). This difference probably suggests that the older debris flows were smaller and with a shorter run-out compared to the younger that formed from the release of larger volumes of sediments, possibly from a more persistent zone of basal till beneath a thicker ice sheet, a shift to a larger drainage area for this sector of the Greenland Ice Sheet and/or the longer presence of the ice sheet at the shelf break.

Alternatively, the increasing amount of turbidity flows may be related to larger input of meltwater during the presence of the ice sheet at or near the shelf break, i.e. that the turbidity currents were generated from large meltwater plumes. According to this hypothesis, the Scoresby Sund sector of the East Greenland Ice Sheet should be characterized by more meltwater over the last ~0.99 Ma as compared to the preceding period. If this assumption is correct, it would oppose observations for the East Antarctic (Rebesco et al., 2006) and Barents Sea Ice Sheets (Laberg et al., 2010) were a reduction in the occurrence of turbidites and thus the dominance of debris flow deposits was suggested to imply a transition from a predominantly warm-based ice including meltwater to a predominantly cold-based ice with little or no meltwater. This hypothesis is, therefore, considered less likely for the explanation of the development of the Scoresby Sund sector of the East Greenland Ice Sheet.

A third alternative is that this transition could be related to an increasing gradient of the fan, resulting in more profound flow transformation from debris flows to turbidity currents and channel development in the latest phase of the development of the trough mouth fan, similar to the smaller trough mouth fans offshore northern Norway (Rydningen et al., 2015). This alternative is however ruled out, as the Scoresby Sund TMF is characterized by a low axial gradient that does not show any detectable changes as the trough mouth fan developed (e.g. Larsen, 1990).

The turbidites identified at Site 987 seem to be deposited from unconfined flows as no channel systems similar to the modern systems described from further north on the NE Greenland continental slope have been identified (García et al., 2012). This indicates that the flows were 1) released in a period of high sediment input over a short time that did not allow for channels to form and 2) that they were not related to the focused release of meltwater.

In conclusion, the lithological change identified was probably related to change in sediment delivery rather than change in gradient or meltwater production within this sector of the Greenland Ice Sheet.

5.2 How did the depositional pattern on the distal Scoresby Sound TMF correlate to the evolution of the Greenland Ice Sheet?

According to the age model of Channell et al. (1999), the change from lithofacies (ii) to (i) occurred at about 0.99 Ma, i.e. the time of change from the 41 ka to the large-amplitude 100 ka climate cycles (Raymo et al., 1998), the Mid-Pleistocene Transition (or “Revolution”; Berger and Jansen, 1994). This resulted in a shift in the mode of ice-sheet variation, the average size of the ice sheets increased significantly as the periodicity of ice-volume variation increased to approximately 100 ka (Ruddiman et al., 1986; Berger and Jansen, 1994; Raymo et al., 1998). As a result, the sea-level fall during sea-level lowstands (i.e. the glacial periods) increased by 25 – 30 m, exposing larger parts of the continental shelves and upper slopes

(Raymo et al., 1997). From the above results we speculate that this shift is reflected in the distal TMF record through a marked increase in the abundance of sandy turbidites accompanied by a longer run-out of some of the debris flows due to the longer presence of larger ice sheets and/or a larger drainage area at or near the shelf break. If correct, the results presented here also show that the Scoresby Sund sector of the Greenland Ice Sheet responded to the major climatic events characterizing the Pleistocene (Jansen et al., 2000; Zachos et al., 2001) and that these changes are best identified in the distal rather that the proximal part of the fan. As these climatic changes occurred prior to the onset of the longest ice core records (e.g. Dansgaard et al., 1993), a proper decoding of the marine record to understand such large-scale changes is of paramount importance. However, this hypothesis must be supported with studies from other trough mouth fans in order to confirm whether a similar change in depositional pattern can be identified, and, if so, whether a regional response of the Scoresby Sund sector of the Greenland Ice Sheet occurred at the time of the "Mid-Pleistocene Transition".

6. *Conclusion*

The main finding of this study is summarized as follows:

1) Relogging of lithological unit I of Hole 987D and E, located on the distal Scoresby Sund trough mouth fan shows that the unit can be divided into two parts, a lower part dominated by glacimarine and marine deposits included some scattered, sandy turbidites, as well as an upper part of debris flow deposits interbedded with sandy turbidites.
2) The transition in depositional environment occurred at about 0.99 Ma, at the same time as the mode of ice-sheet variation changed globally (the Mid-Pleistocene

Transition), the average ice sheet size increases significantly and the periodicity of ice-volume variation increases to approximately 100 ka. This leads us to suggest that this shift is recorded in the distal trough-mouth-fan record through a marked increase in the abundance of sandy turbidites accompanied by a longer run-out of some of the glacigenic debris flows. If correct, the results presented here for the first time show that the Scoresby Sund sector of the Greenland Ice Sheet responded to the global cooling trend characterizing the Pleistocene.

3) It also shows that for this particular trough mouth fan it is in the distal rather that the proximal part of the fan where this change is recorded. The proximal part is dominated by glacigenic debris flows throughout the ~2.14 Ma period. Whether this is the case also for other trough mouth fans remains to be tested.

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Figure captions

Figure 1: Bathymetric map of the study area offshore the Scoresby Sund fjord system, East Greenland. The location of the seismic profile shown in Figure 2 and ODP Site 987 are shown. The bathymetry is from Jakobsson et al. (2012).

Figure 2: Single-channel seismic profile running from ODP Site 987 (right) south- and south-westwards towards the more proximal parts of the Scoresby Sund TMF (Laberg et al., 2013). The lithological units and seismic reflections R1-R4 (yellow stippled lines) follow definitions by the Shipboard Scientific Party (1996). The blue stippled line is the base lithological Unit II reflection, and the green stippled line outlines an acoustically transparent lens inferred to be a debris flow deposit similar to lithological Unit II. It should be noted that a systematic shift of the sea floor and underlying reflections was performed, because the depth to the sea floor was 2.375 sec. (twt) at ODP Site 987 (Shipboard Scientific Party, 1996) while our data revealed the seafloor depth at 2.275 sec. (twt). For location of the seismic profile, see Figure 1. The figure is slightly modified from Laberg et al. (2013).

Figure 3: Re-interpreted core log including Units I, II and the upper part of Unit III of Holes 987D and E of Ocean Drilling Program Leg 162 (Shipboard Scientific Party, 1996). Unit I comprises three main lithofacies: (i) mud with sharp color changes, irregular boundaries, clay clasts/lenses, scattered clasts and no color banding, indicating reworking of facies (ii), i.e. muddy slump/debris flow deposits; (ii) mud with color banding characterized by horizontal – semi-horizontal boundaries and scattered clasts inferred to be glacimarine and marine deposits; and (iii) sand lamina/layers mostly comprising fine sand, sharp upper and lower boundaries interpreted to be turbidites. Facies (ii) dominates the succession deposited between 2.14 – 0.99 Ma. The interval shows only few signs of reworking. Generally, thin sandy turbidites are rare, but they are occasionally more abundant in a few tens of cm thick

intervals. The abundance of sandy turbidites increases markedly about 0.99 Ma. Throughout most of the overlying interval they are associated with slumps/muddy debris-flow deposits representing facies (i) and, thus, this part of Hole 987D is inferred to be dominated by reworked deposits. Unit II is a massive, muddy diamicton inferred to be a debris flow deposit. The upper part of Unit III comprises sediments similar to facies (i) of Unit I. The age model of Channell et al. (1999) is indicated.

Figure 4: Core photographs showing the main lithological facies identified within the studied parts of Holes 987D and E of Ocean Drilling Program Leg 162 (Shipboard Scientific Party, 1996), a) Lithofacies (i), 987D core 6H/4, 0 – 60 cm, b) facies (ii), 987D 14X/3, 50 – 100 cm, c) CT-image of part of the photo in (b) showing high IRD content within the darker intervals and little IRD within the lighter, d) facies (iii), 987D 8H/5, 90 – 150 cm, and e) laminated interval at the base of Unit II showing complex cross-cutting relationships including truncation of lamina/layers (f). This is inferred to be part of the basal shear zone of the Unit II debris flow deposit and the complex cross-cutting relationships is most likely due to shear-induced erosion.

Figure 5: Lithological log of the relogged interval of Site 987 and including the bulk density (g/cc^3), porosity (%) and undrained shear strength (kPa) measured by the Shipboard Scientific Party (1996). Unit boundaries are indicated by solid lines, the stippled line shows the approximate position of the boundary between the upper and the lower part of lithological Unit I as proposed in this study.

Figure 6: Summary diagram, showing the interpreted depositional processes of the Scoresby Sund Trough Mouth Fan. In the distal part of the fan, the focus of the present study, glacimarine and/or marine deposits dominate in the lower part of lithological unit I (> 0.99 Ma) of the Shipboard Scientific Party (1996) (light green part), while in the upper part of unit

I (< 0.99 Ma) debris flows and turbidites were much more frequent in the distal realm (dark green part). These deposits do, however, have no morphological or seismic expression on the data used in this study. The proximal part of the trough mouth fan is dominated by glacigenic debris flow deposits as discussed by Laberg et al. (2013).