IODP Proposal Cover Sheet

909 - Full 2

NW Greenland Glaciated Margin

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Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Proponents	Paul Knutz, Calvin Campbell, Paul Bierman, Anne de Vernal, Mads Huuse, Anne Jennings, David Cox, Rob DeConto, Karsten Gohl, Kelly Hogan, John Hopper, Benjamin Keisling, Andrew Newton, Lara Perez, Janne Rebschläger, Kasia Sliwinska, Elizabeth Thomas, Eske Willerslev, Chuang Xuan, Joseph Stoner
Keywords	Arctic, climate, interglacial, ocean circulation
Area	Baffin Bay

Proponent Information

Proponent	Paul Knutz
Affiliation	Geological survey of Denmark and Greenland
Country	Denmark

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Abstract

Understanding the long-term history of the Greenland Ice Sheet (GrIS) is key to understanding northern hemisphere glaciation, to elucidating mechanisms underlying amplification of glacial cycles since the late Pliocene and to predicting how the GrIS will respond to modern climate warming. To address current knowledge gaps in the evolution and variability of the GrIS and its role in Earth's climate system, we propose to drill along a transect across the northwest Greenland margin extending from the shelf to Baffin Bay where thick Cenozoic sedimentary successions primarily reflect the evolution of the northern GrIS (NGrIS). The mission strategy is to retrieve a composite stratigraphic succession representing the Late Cenozoic era from Oligocene/early Miocene to Holocene. The proposed drill sites will specifically target high-accumulation-rate deposits associated with contourite drifts and potential interglacial deposits within a trough-mouth-fan system including proximal shelf deposits, all densely covered by excellent quality 2-D and 3-D seismic data. We seek to test if the NGRIS underwent near-complete deglaciations in the Pleistocene and assess recent models for the change in orbital cyclicities through the Mid-Pleistocene transition. Moreover, the proposal will examine a possible linkage between the general decrease in atmospheric CO2 from the Oligocene to the early Miocene and arrival of cold and possibly glacially-dominated environments in northwest Greenland and establish the timing for tectonic margin adjustments inferred from the seismic record. Finally, records will be produced that can test hypothesis that glacial expansion of the NGrIS is linked with intensification of northern hemisphere glaciations (3.3-2.8 Ma) and unravel marine heat transport through the western North Atlantic and Baffin Bay as a potential cause for the Pliocene high Arctic warmth. The detailed information obtained from these paleoclimate archives will be of great value for predictive models addressing how the GrIS may respond to global warming in the near future. The overall aim is to investigate the full range of forcing and feedbacks - oceanic, atmospheric, orbital, tectonic - that influence the GrIS over a range of time scales, as well as conditions prevailing at the time of glacial inception and deglacial to interglacial periods. The scientific objectives of this proposal are of key significance in addressing the challenges "How do ice sheets and sea level respond to a warming climate?" and "How does Earth's climate system respond to elevated levels of atmospheric CO2?" under the Climate and Ocean Change theme of the IODP science plan.

909 - Full 2

Scientific Objectives

1. Test the hypothesis that the northern Greenland Ice Sheet (NGrIS) underwent significant deglaciation at intervals within the frequency range of orbital eccentricity (~100-400 ka).
2. Test the hypothesis that the general decrease in pCO2 from the early-middle Oligocene to the early Miocene is linked to cold and possibly glacially-dominated environments in northwest Greenland.
3. Provide information on timing, sedimentary processes and changes in NGrIS erosion related to tectonic adjustments inferred from the seismic record.
4. Test the hypothesis that major glacial expansion of the NGrIS is linked with intensification of NHG (3.3-2.8 Ma).
5. Assess recent models for the change in orbital cycles through the MPT, by analyzing sediment maturity and regolith history.
6. Test the hypothesis that the high Arctic warmth of the early-mid Pliocene is related to heat advection through the western North Atlantic Ocean and Baffin Bay.

Non-standard measurements technology needed to achieve the proposed scientific objectives

909 - Full 2

Proposed Sites (Total proposed sites: 18; pri: 7; alt: 11; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
MB-01C (Primary)	73.0001 -63.0065	1809	473	0	473	Recover a high-resolution paleoceanographic record of a early/middle-late Pleistocene sediment drift system corresponding to the most recent part of the trough-mouth-fan history (scientific objectives 1 and 5). Site MB-1C is targeting expanded intervals of units 9, 10 and 11 and overlaps stratigraphically with the strata drilled at site MB-2C. Site was moved from 1B position to avoid amplitude anomaly at target depth. MB-1C is located 3.9 km from nearest crossing line to provide optimal coverage of units 9, 10 and 11.
MB-20A (Alternate)	72.9118 -63.0642	1928	464	0	464	Recover a high-resolution paleoceanographic record of a middle-late Pleistocene sediment drift system corresponding to the most recent part of the trough-mouth-fan history (scientific objectives 1 and 5). Site MB-20A targets expanded intervals of units 9, 10 and 11 and overlaps stratigraphically with the strata drilled at site MB-2C. The site is located ~1.2 km NW of nearest crossing line to avoid strong reflections at target depth (e.g. channel sands).
MB-02C (Primary)	73.1150 -63.7904	1957	537	0	537	Recover a high-resolution paleoceanographic record of a early/middle-late Pleistocene sediment drift system corresponding to the most recent part of the trough-mouth-fan history (scientific objectives 1 and 5). Site MB-2C targets an expanded interval of unit 8 and overlaps stratigraphically with the strata drilled at site MB-1C. The site is located ~1 km off the nearest crossline to obtain optimal stratigraphic coverage of unit 8 (beween horizons 7-8) and avoid amplitude anomaly at the base of this unit.
MB-22A (Alternate)	73.1388 -63.6402	1850	611	0	611	Recover a high-resolution paleoceanographic record of a early/middle-late Pleistocene sediment drift system corresponding to the most recent part of the trough-mouth-fan history (scientific objectives 1 and 5). Site MB-22A targets an expanded interval of unit 8 and overlaps stratigraphically with the strata drilled at site MB-1C.The site is located ~1 km off the nearest crossline to obtain optimal stratigraphic coverage of unit 8 (beween horizons 7-8) and avoid drilling into strong reflections (e.g. channel sands).
MB-21A (Alternate)	73.6439 -64.8251	1954	751	0	751	Recover a high-resolution paleoceanographic record of a early/middle-late Pleistocene sediment drift system corresponding to the most recent part of the trough-mouth-fan history (scientific objectives 1 and 5). Site MB-2C targets an expanded interval of unit 8 and overlaps stratigraphically with the strata drilled at site MB-1C. Moreover, the site has potential for recovering stratified sediments of units 5-7. The site is located 3.8 km off nearest crossing line to optimize stratigraphic coverage and avoid intervals of slope re-deposition (e.g slumps). Requires drilling through ~150 m of younger fan/slope sediments.
MB-08A (Primary)	73.4870 -62.2682	497	370	0	370	Recover deglacial and interglacial intervals of potentially early-middle Pleistocene age within top-set strata of the trough-mouth fan. High priority for scientific objectives 1 and 5. Site MB-8A penetrates a package of flat-lying, semi-continuous reflections that onlap glacial unconformities of units 6, 7, 8 and 9 (target depth is a positive reflection above horizon 6). The site is ~1 km offset from the nearest crossline to optimize recovery of the identified onlapping reflections.
MB-03B (Alternate)	73.5032 -62.4861	498	375	0	375	Recover deglacial and interglacial intervals of potentially early-middle Pleistocene age within top-set strata of the trough-mouth fan. High priority for scientific objectives 1 and 5. Site MB-3B penetrates a package of flat-lying, semi-continuous reflections that onlap glacial unconformities of units 6, 7, 8 and 9 (TD = top unit 6). The site is placed ~2.7 km off the nearest crossline to optimize recovery of onlapping reflections.
MB-04B (Primary)	73.8711 -62.0342	630	340	0	340	Recover deglacial and interglacial intervals of potentially early Pleistocene age within top-set strata of the trough-mouth fan (scientific objectives 1 and 5). MB-4B penetrates a package of flat-lying, semi-continuous reflections that onlap a major glacial unconformity (horizon 3). Depth target is a positive-phase horizon within an upper slope front segment of unit 3. MB-4B is offset ~2.5 km from nearest crossline to achieve optimal stratigraphic overage of units 3-4. The site is a primary location due to well-defined onlapping reflections reachable within ~300 mbsf.

Proposed Sites (Continued; total proposed sites: 18; pri: 7; alt: 11; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
MB-09A (Alternate)	73.9650 -61.4959	580	270	0	270	Recover deglacial and interglacial intervals of potentially early Pleistocene age within top-set strata of the trough-mouth fan (scientific objectives 1 and 5). The site targets strata that onlap horizon 1 (top of oldest prograding unit). Site MB-09A is alternate to MB-4B due to reduced imaging quality of reflection onlaps and stratigraphic coverage. The site is located ~1 km offset from nearest crossing line to achieve optimal penetration of onlapping deposits.
MB-05B (Primary)	74.2116 -61.3397	704	520	0	520	(1) Capture a thin wedge of progradational deposits that may correspond to the earliest shelf-based glaciations in NW Greenland; (2) Recover Neogene contourite drift sediments of likely Pliocene age that can elucidate paleoceanographic conditions prior to the major basinward expansion of the Greenland Ice Sheet (scientific objectives 3, 4 and 6). MB-5B targets the stratigraphically younger interval of the drift deposit that overlaps with the section drilled at site MB-6C. The site is located within the ANU-3D cube. Selected as primary site due to most optimal recovery of the youngest sediments.
MB-13A (Alternate)	74.2118 -61.3958	707	540	0	540	(1) Capture a thin wedge of progradational deposits that may correspond to the earliest shelf-based glaciations in NW Greenland; (2) Recover Neogene contourite drift sediments of likely Pliocene age that can elucidate paleoceanographic conditions prior to the major basinward expansion of the Greenland Ice Sheet (scientific objectives 3, 4 and 6). Site MB-13A (alternate for 5B) targets the stratigraphically younger interval of the drift deposit that overlaps with the section drilled at site MB-6C. The site is located within the ANU-3D cube.
MB-14A (Alternate)	74.2109 -61.2704	663	510	0	510	(1) Capture a thin wedge of progradational deposits that may correspond to the earliest shelf-based glaciations in NW Greenland; (2) Recover Neogene contourite drift sediments of likely Pliocene age that can elucidate paleoceanographic conditions prior to the major basinward expansion of the Greenland Ice Sheet (scientific objectives 3, 4 and 6). Site MB-14A (alternate for 5B) targets the stratigraphically younger interval of the drift deposit that overlaps with the section drilled at site MB-6C. The site is located within the ANU-3D cube.
MB-06C (Primary)	74.1254 -60.9510	609	620	0	620	Recover Neogene contourite drift sediments of likely Pliocene age that can elucidate paleoceanographic conditions prior to the major basinward expansion of the Greenland Ice Sheet (scientific objectives 3, 4 and 6). Site MB-6C overlaps stratigraphically with the lowermost section drilled at site MB-5B (and alternates 13A and 14A). The main target is an expanded section of the drift deposit that may contain a high-resolution early Pliocene record. TD is placed 30 ms below a prominent reflection draping over a slide scar. MB-6C is located within the ANU-3D cube.
MB-15A (Alternate)	74.1217 -60.9909	605	625	0	625	Recover Neogene contourite drift sediments of likely Pliocene age that can elucidate paleoceanographic conditions prior to the major basinward expansion of the Greenland Ice Sheet (scientific objectives 3, 4 and 6). Site MB-15A overlaps stratigraphically with the lowermost section drilled at site MB-5B (and alternates 13A and 14A). The main target is an expanded section of the drift deposit that may contain a high-resolution early Pliocene record. TD is placed 30 ms below a prominent reflection draping over a slide scar. High priority for scientific objectives 3, 4 and 6. MB-15A is located within the ANU-3D cube.
MB-07A (Primary)	74.5136 -60.6792	737	1173	0	1173	Recover an upper Miocene interval and continue coring through the Middle Miocene horizon (d1) with TD at horizon d2 of possible Oligocene age. The scope is to elucidate past ocean and terrestrial climates in NE Baffin Bay/Greenland and the onset of ephemeral glaciation in NW Greenland (scientific objectives 2 and 3). Located within PITU-3D high-res cube. Site 7A is selected as the primary site on the basis of a better stratigraphic coverage in the topmost section.
MB-11A (Alternate)	74.4283 -60.4086	747	1170	0	1170	Recover an upper Miocene interval and continue coring through the Middle Miocene horizon (d1) with TD at horizon d2 of possible Oligocene age. The scope is to elucidate past ocean and terrestrial climates in NE Baffin Bay/Greenland and the onset of ephemeral glaciation in NW Greenland (scientific objectives 2 and 3). Located within PITU-3D high-res cube.
MB-12A (Alternate)	74.4597 -60.5049	739	1145	0	1145	Recover an upper Miocene interval and continue coring through the Middle Miocene horizon (d1) with TD at horizon d2 of possible Oligocene age. The scope is to elucidate past ocean and terrestrial climates in NE Baffin Bay/Greenland and the onset of ephemeral glaciation in NW Greenland (scientific objectives 2 and 3). Alternate site for 7A. Located within PITU-3D high-res cube.

Proposed Sites (Continued; total proposed sites: 18; pri: 7; alt: 11; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
MB-10A (Alternate)	74.4584 -61.1792	698	1206	0	1206	Recover an upper Miocene interval and continue coring through the Middle Miocene horizon (d1) with TD at horizon d2 of possible Oligocene age. The scope is to elucidate past ocean and terrestrial climates in NE Baffin Bay/Greenland and the onset of ephemeral glaciation in NW Greenland (scientific objectives 2 and 3). MB-10A is located on the edge of the PITU-3D seismic data. Alternate position to site MB-07A.

909 - Full 2

Contact Information

Contact Person:	Paul Knutz
Department:	Geophysics
Organization:	Geological Survey of Denmark and Greenland
Address:	Øster Voldgade 10 Copenhagen Denmark 001350 Denmark
E-mail/Phone:	pkn@geus.dk; Phone: +45 91333925

Proponent List

First Name	Last Name	Affiliation	Country	Role	Expertise
Paul	Knutz	Geological survey of Denmark and Greenland	Denmark	Principal Lead	Marine geology, sedimentology, paleoceanography
Calvin	Campbell	Geological Survey of Canada	Canada	Data Lead	Marine geoscience, sedimentology
Paul	Bierman	University of Vermont	United States	Other Lead	Cosmogenic geochemistry and geomorphology
Anne	de Vernal	GEOTOP, Université du Québec à Montréal	Canada	Other Lead	Biostratigraphy, paleoceanography
Mads	Huuse	University of Manchester	United Kingdom	Other Lead	Marine geology, sedimentary basins, fluid flow
Anne	Jennings	INSTAAR, University of Colorado	United States	Other Lead	Paleoclimate, paleoceanography, biostratigraphy
David	Cox	Manchester University	United Kingdom	Other Proponent	Marine Geophysics; Subsurface Geohazards
Rob	DeConto	University of Massachusetts	United States	Other Proponent	Earth system modeling
Karsten	Gohl	Alfred Wegener Institute	Germany	Other Proponent	Marine Geophysics; Co-chief scientist Exp. 379
Kelly	Hogan	British Antarctic Survey	United Kingdom	Other Proponent	Marine Geophysics; Sedimentology
John	Hopper	Geological Survey of Denmark and Greenland	Denmark	Other Proponent	Marine geophysics, Arctic basin tectonics
Benjamin	Keisling	University of Massachusetts	United States	Other Proponent	Ice Sheet/Climate Modelling
Andrew	Newton	Queen's University Belfast	United Kingdom	Other Proponent	Marine Geophysics; Quaternary Science
Lara	Perez	British Antarctic Survey	United Kingdom	Other Proponent	Marine Geophysics
Janne	Rebschläger	Max-Planck-Institut für Chemie, Mainz	Germany	Other Proponent	Foraminifera, Mg/Ca, alkenones
Kasia	Sliwinska	Geological Survey of Denmark and Greenland	Denmark	Other Proponent	Micropaleontology; Oligocene-Miocene Paleoclimate
Elizabeth	Thomas	University of Buffalo	United States	Other Proponent	Organic geochemistry, biomarkers, stable isotopes
Eske	Willerslev	University of Copenhagen	Denmark	Other Proponent	geogenetics

Proponent List (Continued)

First Name	Last Name	Affiliation	Country	Role	Expertise
Chuang	Xuan	University of Southampton	United Kingdom	Other Proponent	Paleomagnetics, stratigraphy
Joseph	Stoner	Oregon State University	United States	Other Proponent	Sedimentology; Paleomagnetics

Cenozoic Evolution of the Northern Greenland ICE sheet exposed by transect drilling in northeast Baffin Bay (CENICE)

1 Rationale

The Greenland ice sheet (GrIS) holds a large amount of freshwater, equivalent to ~7.4 m of global sea level (Bamber *et al.* 2013). Recent studies have highlighted the sensitivity of the GrIS to climate warming and the potential impact on sea-level rise and Atlantic Meridional Ocean Circulation (AMOC) (Alley *et al.* 2010; Khan *et al.* 2010; Hansen *et al.* 2016). Documenting the full range of **forcing and feedbacks - oceanic, atmospheric, orbital, tectonic – that influence GrIS over a range of time scales**, is crucial for making robust predictions of future climate and sea-level change. We need information from long-term archives of proximal ice-sheet history to understand how the GrIS will respond to warming in the near future and how this response may affect other components of the Earth system. Therefore, we propose to drill along a transect crossing the Greenland margin in northeast Baffin Bay to retrieve a composite stratigraphic succession of Oligocene to Holocene sediments (Figs. 1-2). The aims and objectives of this proposal directly addresses the challenges "How do ice sheets and sea level respond to a warming climate?" and "How does Earth's climate system respond to elevated levels of atmospheric CO_2?" under the Climate and Ocean Change theme of the IODP science plan.

The northwest Greenland margin contains extensive, thick Cenozoic sedimentary successions primarily reflecting the evolution of the northern GrIS (NGrIS). Geophysical data and shallow core studies demonstrate the presence of fast-flowing ice streams that reached the shelf margin during Late Pleistocene (Ó Cofaigh *et al.* 2013; Dowdeswell *et al.* 2014; Slabon *et al.* 2016; Newton *et al.* 2017). However, the ice sheet response to major climate transitions, such as the Pleistocene terminations, is poorly known. The last glacial retreat from outer shelf grounding positions to fjord outlets in northwest Greenland probably occurred in discrete steps controlled by reverse-bed gradients associated with shelf over-deepening (Patton *et al.* 2016; Newton *et al.* 2017) and enhanced marine ablation linked to the West Greenland Current (Jennings *et al.* 2017). During glacial maxima, surface waters in Baffin Bay likely cooled sufficiently to allow formation of

buttressing ice shelves that stabilized ice domes in Greenland (Hulbe *et al.* 2004). Glacial variability during previous climate cycles was possibly controlled by similar ice-ocean-atmosphere couplings and ice-topographic interactions. A better understanding of the boundary conditions and forcings determining long-term ice sheet evolution requires information only attainable by offshore drilling. However, long sedimentary records specifically illuminating NGrIS history are lacking. Previous drilled sites in the North Atlantic recovered sediment shed from elevated terrains in southern and eastern Greenland margins (Thiede *et al.* 2011; Reyes *et al.* 2014) influenced by semi-permanent alpine glaciers since late Miocene (Bierman *et al.* 2016) (Fig. 1a). The only deep core site in Baffin Bay (645; Fig. 1a) was drilled during the early phase of the Ocean Drilling Program (ODP) and its contribution to understanding GrIS history is limited due to its location on the Canadian margin, poor recovery and age uncertainties (Baldauf *et al.* 1989).

The sensitivity of the GrIS to ocean warming (Holland *et al.* 2008; Yin *et al.* 2011) emphasizes the need for long-term high-resolution records near the major glacial outlets of eastern Baffin Bay. Important advances in drilling techniques, dating methodologies, and proxy approaches make new drilling key for advancing understanding of past GrIS dynamics and ice-ocean-climate interactions, which so far have only been addressed by seabed mapping, shallow cores (Jennings *et al.* 2017; Jennings *et al.* 2018), and seismic stratigraphy correlated to exploration wells (Hofmann *et al.* 2016). There are several reasons for choosing northeast Baffin Bay for documenting the Cenozoic evolution of the NGrIS (Fig. 1b). (**1**) The area covers a large trough-mouth fan (TMF) system primarily constructed by glacial drainage over millions of years. (**2**) It contains a succession of gently-dipping strata, where a composite sequence of Oligocene-Quaternary deposits may be drilled at relatively shallow depths (Knutz *et al.* 2015)(Fig. 2). (**3**) It has extensive coverage of high-quality 2D and 3D seismic data (Fig. 1b), with outstanding imaging of glaciogenic sediment progradation, marine deposits formed by along-slope currents and hemi-pelagic basin-infilling sediments (Figs. 3-5). (**4**) A detailed seismic stratigraphy tied to well/borehole information illuminates the sediment transport dynamics from the NGrIS (Figs. 6-7; (Knutz *et al.* In review). (**5**) The western Greenland margin is accessible due to amenable ocean temperatures and reduced sea-ice associated with the northbound West Greenland Current (Holland *et al.* 2008). (**6**) Expedition 344S in 2012 demonstrated that *JOIDES Resolution* can successfully operate in northeast Baffin Bay, a region that

is crossed by icebergs but lacking pack ice.

2 Scientific Objectives

Complete seismic imaging, from deep basin to inner shelf, guides drilling and stratigraphic correlation to better understand the long-term evolution of the NGrIS. Based on a transect-drilling strategy, we have developed multi-proxy and chronological templates for constraining different phases of ice extent and regional climate regimes (Table 1 and 2). These templates provide a methodological basis to test hypotheses that are crucial for understanding GrIS history.

2.1 How did the NGrIS respond to extreme interglacial warmth?

Marine paleoclimate records of past interglacial stages are critical for reconstructing ocean-climate interactions and boundary conditions that constrain future predictions. Previous research has focused on marine isotope stage (MIS) 5e and the "super-interglacial" MIS 11 (Loutre 2003; Reyes *et al.* 2014). During MIS 5e sea level may have been 4-6 meters higher than present (Dutton & Lambeck 2012), of which the GrIS may have contributed 10-20 % (Dahl-Jensen *et al.* 2013). In contrast, global sea-level during MIS 11c estimated to 6-13 m (Dutton *et al.* 2015) imply a significant or near-complete elimination of the GrIS (Willerslev *et al.* 2007; de Vernal & Hillaire-Marcel 2008; Reyes *et al.* 2014), consistent with the cosmogenic nuclide concentrations in GISP2 bedrock (Schaefer *et al.* 2016). Compelling evidence for hemispheric scale warming comes from the Lake El' gygytgyn in the western Siberian Arctic, with MIS 11c characterized by summer temperature 4 - 5 °C warmer, and annual precipitation ~300 mm higher than the present interglacial (Melles *et al.* 2012). Since super-interglacials are not readily explained by forcing related to orbital parameters or elevated pCO_2, they require strong interhemispheric ice-ocean couplings and non-linear feedbacks (Berger *et al.* 2016).

High-quality seismic data covering the proposed drilling transect on the northwest Greenland margin show eleven prograding sedimentary units reflecting major glacial advance cycles (Fig. 2)(Knutz *et al.* In Review). Erosional unconformities topping each unit demarcate 10 paleo-trajectories of shelf break grounding zones that prograded seaward with sediment supplied by

successive advances of the NGrIS onto the outer shelf and slope. Between the two, modern cross-shelf troughs (Melville Bugt and Upernavik TMFs) (Fig. 1b), topset strata of prograding units and associated shelf breaks are extremely well preserved due to high sediment input from paleo-ice streams and basin subsidence over older rift structures (Fig. 2). Beyond the shelf break, the horizons can be traced along clinoformal reflections to the basin strata resulting in a complete "pseudo-3D" mapping of the continental margin architecture. An age model for the depositional evolution of the TMF was reconstructed by correlating the seismic horizons to nearby wells/boreholes (Fig. 6-7) (Knutz *et al.* In review). The youngest depositional sequence, comprising units 8-11 of likely middle-late Pleistocene age, form a series of contourites intersected by channel deposits on the lower slope (Fig. 3a and 6). Thus, drilling these contourites will allow high-resolution paleoceanographic reconstructions back to, and possibly through, the Mid-Pleistocene transition. Within the aggradational topset package, seismic reflections phase reversed from seabed onlap the glacial erosion surfaces or infill intra-shelf depressions (Fig. 3b-c). These reflections, with stratal thicknesses of >20-30 m, may represent marine muddy sediments deposited during periods of grounding line retreat and rising sea level, interrupting the glacial advance mega-cycles. Based on the preliminary age model it is hypothesised that the stratal onlaps, succeeding major shifts in ice stream configuration, may have formed during super-interglacials (Fig. 7) (Knutz *et al.* In review).

Cosmogenic nuclides in sub-ice bedrock show that central Greenland was almost completely deglaciated at some time in the last 1.1 Ma (Schaefer *et al.* 2016). The long-term depositional record on the margin of northeast Baffin Bay contains a unique glaciation history that can be used to infer when such extreme mass loss occurred. This connection between the seismic-stratigraphy of the shelf margin and the sub-glacial bedrock archive (Schaefer *et al.* 2016) is compelling and raises critical questions: (1) What forcings drove near-complete collapse of the GrIS during the Pleistocene? and (2) how did the ice sheet reconfigure to a state of "normal" glacial-interglacial conditions? By drilling high-accumulation sites in the basin (MB-1, MB-2) and on the shelf margin (MB-8, MB-4, MB-5) (Figs. 3-4) targeting potential interglacial deposits, **we intend to test the hypothesis that the NGrIS underwent substantial deglaciation on one or more occasions during the Pleistocene**. Parameters for identifying warm interglacial periods will be derived from multiple qualitative and quantitative proxies that constrain ice sheet response and environmental conditions

in both marine and terrestrial/atmospheric areas (Table 1). Key evidence for glacial-interglacial dynamics may come from allochthonous organic components (e.g. pollen, biomarkers) and cosmogenic isotopes contained in coarse-grained sediments, providing integrated paleo-environmental and exposure/erosion histories (Bierman *et al.* 2016). These data will provide targets for long-term ice sheet modelling simulations and will also be integrated with ice-sheet models to link recovered sedimentary archives with spatially integrated physically processes (i.e. sub-ice sheet basal conditions, meltwater/sediment transport, and NGrIs mass balance).

2.2 When did glacial inception occur in NW Greenland and how did the NGrIS evolve during the Oligocene–Miocene, late Pliocene and Mid-Pleistocene transitions?

The question of when glaciations began on Greenland and the temporal and spatial variability of the GrIS has been addressed mainly through the quantification of ice-rafted debris extracted from ODP/IODP cores. The late Pliocene (3.5-2.7 Ma) increase in benthic $\delta^{18}O$, is attributed to intensification of Northern Hemisphere glaciations (NHG) (Shackleton *et al.* 1984) and contemporaneous with major GrIS growth (Jansen *et al.* 2000; St John & Krissek 2002) (Fig. 8a). However, ephemeral marine-based glaciers may have existed in East Greenland since the middle Miocene (~18 Ma) (Thiede *et al.* 2011) and even the late Eocene (Eldrett *et al.* 2007; St John 2008; Tripati *et al.* 2008), implying an earlier onset of NHG than previously thought, possibly coeval with East Antarctic ice sheet growth (Tripati & Darby 2018). Conversely, ice sheet modelling results indicate that northern hemisphere ice sheet growth would have been restricted until at least the early Miocene, in response to decreasing atmospheric pCO_2 (DeConto *et al.* 2008). Thus, the timing and extent of primeval GrIS development and the implications for interhemispheric teleconnections is controversial.

Cenozoic climate experienced significant changes in atmospheric greenhouse gas concentrations, notably linked to pCO_2 (Pearson & Palmer 2000; Zachos *et al.* 2008; Pagani 2014). Studies spanning the last 25 Ma reveal complex linkages or even decoupling between pCO_2 and global ice volume (Raymo *et al.* 1996; Tripati *et al.* 2009) (Fig. 8a), highlighting the importance of evaluating all multiple potential forcings in the earth system. A key factor complicating the relationship between long-term

pCO_2 records and ice volume history involves tectonic base-level adjustments and snowline lowering that may trigger glaciations (Foster *et al.* 2010). In this context, the post-Eocene tectonic history of West Greenland has implications for the onset of ice sheet growth (Solgaard *et al.* 2013). Moreover, the configuration of shallow oceanic passageways such as Davis Strait and Nares Strait controls the meridional heat fluxes into Baffin Bay (Nielsen *et al.* 2011; Knutz *et al.* 2015) (section 2.3). A late Miocene unconformity associated with extensive submarine landslides along the northwest Greenland margin (Fig. 2 and 4) points to a regional tectonic adjustment that predates the first shelf edge advances (Knutz *et al.* 2015). This erosional event may be linked to hinterland uplift (Japsen *et al.* 2006) but a more concise understanding of its origin requires recovery of Neogene sediments. Following glacial inception, physical weathering would redistribute mass from the Greenland craton to the continental slope, and consequently accelerate hinterland uplift by isostatic compensation (Berger *et al.* 2008; Medvedev *et al.* 2013), prompting the question: Did active tectonics play a role in the development of the GrIS, or are the late Neogene basin adjustments along the West Greenland margin a response to mass-redistribution caused by glacial erosion? (Ruddiman & Kutzbach 1989; Molnar & England 1990).

Understanding the evolution of the NGrIS holds the key to the origin of NHG, including possibly the mechanisms of gradual amplification of glacial cycles since the late Pliocene (Raymo & Huybers 2008) evident in benthic $\delta^{18}O$ (Fig. 7a). Orbital insolation cycles in the 20-100 ka band have been considered the primary forcing factor for Pleistocene climate variability linked to waxing and waning of continental ice sheets (Hays *et al.* 1976). However, the mechanism(s) by which subtle shifts in insolation results in abrupt reductions in global ice volumes is not well understood (Raymo & Huybers 2008) and global climate records show that correspondence between global ice volume and orbital obliquity (~41 ka periodicity) is only apparent for the late Pliocene-Early Pleistocene (Naish *et al.* 2009). Most perplexing is the Mid-Pleistocene transition (MPT) between 1.1-0.7 Ma when glacial-interglacial cycles changed from 40 to 100 ka (Hodell & Channell 2016). Explanations for the MPT include fast feedback interactions involving ice albedo, insolation, and CO_2 reservoir exchanges (Ruddiman 2006; Yin & Berger 2010), forced climate synchronization and antiphase relationships in interhemispheric ice volumes (Raymo *et al.* 2006; Rial *et al.* 2013), tectonic base-level adjustments (Crowley 2002), and changes in ice sheet dynamics related to bedrock/regolith

cover (Clark & Pollard 1998; Clark *et al.* 2006; Abe-Ouchi *et al.* 2013). The lack of consensus reflects knowledge gaps in understanding the complexity of ice sheet dynamics in the earth system, hence emphasizing the importance of retrieving long-term records from glaciated margins.

The depositional development of the Melville Bay TMF points to a major reorganisation in the ice flow that drains the NGrIS during the MPT as shown from elongate progradation along the entire shelf front to crescent-shaped fan build-out between units 7-8 (Fig. 6) (Knutz *et al.* In review). Drilling the proposed transect will provide information on what caused the marked change in paleo ice stream configuration from spatially homogenous advance rates to fast-flowing, deeply grounded ice streams. Ultimately, this will provide new insights into the dynamic ice behaviour of the NGrIS through the MPT.

Local and regional evidence suggests that major changes in the size, erosivity, and responsiveness of the GrIS occurred through the late Cenozoic (Bierman *et al.* 2016; Schaefer *et al.* 2016). By drilling at all the proposed sites, we will collect sediment necessary to better understand GrIS evolution, especially as it relates to the major transitions/phases that are key for understanding the late Cenozoic climate.

(1) Early development of land-based glaciation: **We will test the hypotheses that the decrease in pCO_2 from early-middle Oligocene (>600 ppm) to early Miocene (<300 ppm) coincides with cold and possibly glacial environments in northwest Greenland** (Fig. 8a). This is achievable by retrieving a 1180 m long climate record from Oligocene-Miocene strata (site 7A; Fig. 5) and the application of the multi-proxy template (Table 1). Drilling of middle Miocene and late Miocene/early Pliocene seismic horizons (d1 and c1; Fig. 2) will **provide information on timing, sedimentary processes and changes in denudation rates related to tectonic margin adjustments inferred from the seismic record**. Neogene changes in shelf margin configuration induced by glacial weathering and large-scale redistribution of sediments in Greenland should be detectable from the glaciogenic imprint on the composition of late Miocene sediments (full-interglacial ice; Table 1). Conversely, if hinterland topography was influenced by tectonics prior to major glacial inception in West

Greenland we expect to find evidence of "slow" coastal regression through the late Miocene succession, with gradual increase in reworked material from older strata and regolith. A quantitative approach for unravelling glacial vs non-glacial denudation rates will be based on long-lived (^{10}Be), and if measurable about radiogenic background, a stable cosmogenic ^{21}Ne (Shakun *et al.* 2018) as part of the post-cruise programme (Table 1).

(2) Advance of marine-based GrIS glaciers onto the northwest Greenland margin: Drilling through the initial clinoforms of the first prograding unit and further into marine contourite sediments of probable Pliocene age (sites MB-5; MB-6) **will test the hypothesis that glacial expansion of the NGrIS is linked with intensification of NHG (3.3-2.8 Ma)**. Paleoclimate and sedimentological proxies (Table 1) will be used to infer ice extent before, during, and after the first shelf-based glacial advance. A new ^{10}Be record from ODP 645 (P. Bierman) suggests that limited glaciation on/around Baffin Bay may have started as early as 7 Ma (Fig. 8b), corresponding to glaciation of southeast Greenland (Larsen *et al.* 1994). Application of cosmogenic isotopes at sites MB-5, 6 and 7 will provide direct evidence of a GrIS response during the late Neogene.

(3) The Mid-Pleistocene transition: Little is known about GrIS response to the change from 40 to 100 ka cycles at the MPT but new results associate this time interval with a major change in NGrIS flow dynamics (Knutz *et al.* In review). **By drilling seismic units 7, 8 and 9 at the deep-water sites (MB-1, MB-2) and on the shelf (MB-8), we will test recent models for the change in orbital cycles through the Mid-Pleistocene.** The regolith hypothesis by Clarke and Pollard (1998) associates the MPT with increased basal shear stresses due to changes in sub-glacial bed material that allowed more ice to remain above the ablation zone, eventually leading to larger and thicker ice sheets that were less responsive to obliquity forcing. Evaluation of this model for the NGrIS will be based on measuring the geochemical maturity of sediments of differing ages. Analysis of multiple cosmogenic nuclides (^{21}Ne, meteoric and in situ ^{10}Be, and ^{26}Al) post-cruise will provide further insights into the GrIS erosion and regolith history and perhaps the regolith hypothesis (Bierman *et al.* 2016).

2.3 What was the role of the West Greenland/Irminger boundary current in AMOC related heat transport during the Pliocene and Early Pleistocene?

The early-mid Pliocene was characterized by relatively warm and humid forest tundra conditions in the high Arctic of Canada (Fyles *et al.* 1994; Csank *et al.* 2011) and Greenland (Bennike *et al.* 2002). A similar environment was inferred from early Pleistocene interglacial deposits in northern Greenland (Funder *et al.* 2001), when southern Greenland appears to have been forested (de Vernal & Mudie 1989). These warm Arctic conditions occurred under modest pCO_2 levels (~400 ppm), implying a high sensitivity of the Pliocene Arctic climate to pCO_2 or the influence of other forcing factors (Fig. 8a). In the late Neogene, presumably latest Miocene and Pliocene, the West Greenland-Baffin Bay margin was influenced by contour currents that deposited extensive sedimentary drifts (Knutz *et al.* 2015). The establishment of persistent oceanic gradients strong enough to maintain a geostrophic boundary current over millions of years is intriguing and may be linked with enhanced Pliocene AMOC. Past configurations of Arctic gateways, e.g. Davis Strait, Nares Strait and Bering Strait, could have played a key role for poleward heat exchange during the the Pliocene (Hu *et al.* 2015; Keisling *et al.* 2017), however, the tectonic history of these topographic thresholds are poorly known. The contourite deposits of mega-unit B (Fig. 4), presently exposed at shallow depths below the glacial troughs, can illuminate the environmental conditions of this paleo-current system that appear to have existed prior to the expansion of the NGrIS.

The main purpose of drilling sites MB-5 and MB-6 is to test the hypothesis that the high Arctic warmth of the early-mid Pliocene is related to heat advection through the western North Atlantic and Baffin Bay. To date, only one well-dated Pliocene oceanographic data point constrains reconstructions in the entire western North Atlantic region (Dowsett *et al.* 2016), so the proposed drilling will place key constraints on climate development of Baffin Bay before the onset of major NHG. Reconstruction of paleoceanographic conditions will rely on micropaleontological and sedimentological analyses (Table 1). Water mass properties, e.g., temperature and salinity, as well as changes in productivity and Atlantic warm water inflow will be reconstructed using microfossil assemblages, stable isotopes, and trace element analyses on benthic and planktic foraminifera. Dinocysts, diatoms, and algal biomarkers can construct sea surface conditions, especially in intervals of low biogenic carbonate (Aksu 1983; De Vernal *et al.* 1992a; Gibb *et al.* 2015). Pollen/spores,

organic biomarkers, and DNA analyses (Willerslev *et al.* 2007) may provide clues on terrestrial vegetation cover and climate conditions.

2.4 Summary of scientific objectives

1. Test the hypothesis that the NGrIS underwent significant deglaciation at intervals within the frequency range of orbital eccentricity (~100-400 ka).
2. Test the hypothesis that the general decrease in pCO_2 from the early-middle Oligocene to the early Miocene is linked to cold and possibly glacially-dominated environments in northwest Greenland.
3. Provide information on timing, sedimentary processes and changes in NGrIS erosion related to tectonic adjustments inferred from the seismic record.
4. Test the hypothesis that major glacial expansion of the NGrIS is linked with intensification of NHG (3.3-2.8 Ma).
5. Assess recent models for the change in orbital cycles through the MPT, by analyzing sediment maturity and regolith history.
6. Test the hypothesis that the high Arctic warmth of the early-mid Pliocene is related to heat advection through the western North Atlantic Ocean and Baffin Bay.

3 Drilling strategy and archive quality

We will recover chronostratigraphic records by drilling a composite Neogene and Quaternary succession representing contourite drifts, glacial-marine sediments, and marine hemipelagic deposits along a margin transect. The drifts and prograding sequences show pronounced lateral variations in sedimentation rates, indicated by juxtaposed depocentres. With excellent seismic data, we can focus on areas and intervals that show expanded sedimentary sections. Seven primary sites have been identified based on 2D and 3D industry seismic data that capture Cenozoic intervals critical for addressing the scientific objectives (Figs. 1-5; see Table 3 for drilling/logging schedule). The selection criteria are based on (i) stratigraphic recovery, (ii) reflection homogeneity/clarity, and (iii) the seabed/sub-seabed/overburden character. Eleven alternate sites, targeting same or similar intervals as primary, has been selected in case of iceberg presence or encountering drilling

impediments. All sites have been assigned priority aimed at maximizing recovery and balancing risks (Table 4). For time-depth conversion, an average seawater velocity of 1.48 km/s was assumed while various functions were used for sediment velocities depending on the anticipated lithologies, seismic processing parameters, and information from exploration wells.

Primary sites MB-1 and MB-2; Alternate sites, 20, 21 and 22 (Objectives 1 and 5).

Sites MB-1 and MB-2 capture a mounded-channelized drift system located on the continental rise between the Melville Bugt and Upernavik TMFs (Figs. 2 and 3a). These locations will provide high-resolution records of the middle-late Pleistocene interval (targeting horizon 7). Similar types of glacially-influenced deep-sea environments have been drilled on continental rise settings with recovery typically >70 %, e.g. sites 1095-1096, Antarctic margin (Barker *et al.* 2002); U1305-06-07, Eirik Drift (Channell *et al.* 2006); and U1417-U1418, Alaskan Margin (Jaeger *et al.* 2014). The drift sites are elevated 150-170 m above a series of incised channel systems that appear to have been active at least since deposition of unit 8 (Fig. 3a). Seismic reflection geometries suggest that the sites received fine-grained sediments winnowed from downslope channel systems and carried southward by geostrophic bottom-currents, with additional input from hemipelagic sources and IRD. Lateral migration of channel thalwegs occurs throughout the succession. Bright anomalies and reflection disturbances that flank the channels (e.g. slumps), were avoided for identifying suitable drilling targets.

Limited preservation of biogenic carbonate due to carbonate dissolution could influence the archive quality. Poor fauna preservation characterized the Pliocene-Early Pleistocene section (Unit IIIA) of ODP Site 645 (Srivastava *et al.* 1987; Kaminski *et al.* 1989). However, carbonate preservation and microfossil recovery will likely be better at our proposed deep-water sites: (1) Site 645 was drilled on part of the lower slope influenced by mass-transport, which is clear from new seismic data (Knutz *et al.* 2015). With the new, high-quality seismic data, sites have been selected that avoid large-scale slope mass transport deposits. (2) Whereas Site 645 is located in the pathway of the cold Baffin Current, our sites are located in eastern Baffin Bay under the influence of the West Greenland Current, where there is a better chance of recovering well-preserved biogenic carbonate and abundant microfossils, as demonstrated from Holocene records (Perner *et al.* 2011; Ouellet-Bernier

et al. 2014).

Both proposed sites include the same stratal succession above unit 7, but with different accumulation rates at different intervals (Fig. 3a). MB-1 includes a thick and evenly stratified interval of units 9-11 while site MB-2 captures an expanded section of unit 8, likely encompassing the MPT (Fig. 7). At these sedimentary drift sites, rapid drilling is expected (>150 m/day). The plan is to use triple-hole APC/XCB (advanced piston core/extended core barrel) coring to horizon target depths (TD) at 450-550 m. For MB-2, the upper ~200 m may be washed and then resume with XCB coring to TD (Hole B-C). An average sediment velocity of 1800 m/s was used to convert TWT depths to meters, consistent with time-depth results from ODP 645 and Greenland margin exploration wells.

Primary sites MB-8 and MB-4; Alternate sites MB-3 and MB-9 (Objectives 1 and 5).

Sites MB-3 and MB-8 target marine sediments of early–middle Pleistocene age that onlap the glacial erosion surface within the aggradational top set strata (Fig. 3b-c). In addition, these sites may record ice grounding and major ice sheet retreat that provide additional age control on the seismic horizons. The sites offer a unique opportunity to study early Pleistocene climate at a proximal location to the NGrIS that may be reached by drilling to 250-350 m.

To recover inter-stratified muddy sediments, requires drilling through sub-glacial deposits such as compacted diamictons and clast-rich muds. Previous ODP/IODP drilling in high-latitude glaciated shelf margins resulted in core recoveries of 30% or less, e.g. U1420, Bering Trough (Jaeger *et al.* 2014); sites 739-742, East Antarctic margin (Barron *et al.* 1989); and Antarctic Peninsula Leg 178 (Barker *et al.* 1999). Recent RCB drilling on the Ross Sea shelf (U1521A/Leg 374 (McKay *et al.* 2018)) show more promising results with a recovery of 63% (interlayered diatomites, muds and diamictite). Sites U110/U100, 344S, north of the Melville Bay Trough yielded RCB recoveries of 15-30 % drilling through ~125 m compact diamictite (Acton *et al.* 2012), although these sites were characterized by massive till beds without seismic inter-stratification. We plan to start with RCB coring which may lose sandy intervals but recover muddy marine intervals compacted by ice loading. In case of sparse recovery through desired muddy intervals the strategy is to trip out, offset, and drill using an APC/XCB bit without coring and then resume coring at the depth of interest. Drilling the shelf margin

is the most risky element of proposal 909 but it will deliver the greatest reward if marine interglacial deposits are recovered. Our strategy of allocating 6 days to drill the stratified shelf margin deposits is a balance between risk and potential for achievement. In case of delay at sites MB-8 or MB-7, Site 4 may be drilled to a shallower depth or omitted. For time-depth conversion of the shelf margin sites, a sediment velocity function of Vp [m/s] = 2100 + 0.5*TWT was assumed based on velocities in aggradational strata drilled south of the proposed sites (Delta-1, Fig. 1a).

Primary sites MB-5 and MB-6; Alternate sites MB-13, MB-14 and MB-15 (Objectives 3, 4 and 6).
We aim to recover an 800-m composite stratigraphic section in mega-unit B, which forms the youngest part of a thick Neogene succession on the West Greenland-Baffin Bay margin (Figs. 2 and 4). The site locations are selected to provide high-resolution records of potential late Miocene-Pliocene age that capture ice-ocean interaction prior to the major NHG. The sites sample juxtaposed expanded contourite intervals with an additional 50-80 m section of clinoform strata (MB-5), which may represent the earliest signature of mid-shelf glaciation (Seismic Unit 1; Figs. 4 and 6). Site MB-6 includes an expanded mounded section at the base of mega-unit B, presumably an intact lower Pliocene record. The contourite intervals likely consist of fine-grained, homogenous and semi-consolidated mudstone. Due to glacigenic compaction it is most probable that the sites will be RCB drilled with expected recovery of >70%. This is acceptable for reaching our objectives since sedimentation rates are likely high (>15 cm ka^{-1}). In the topmost interval of MB-5, coarse-grained deposits may potentially slow the drilling progress but these sediments will be valuable for cosmogenic work. The target depths of 500-600 m are based on an average sediment V*p* of 1900 m/s.

Primary site MB-7; alternate sites MB-10, MB-11, MB-12 (Objectives 2 and 3).
The goal is to obtain a continuous succession through the thick Miocene packages that are exhumed on the inner shelf (Figs. 2 and 5a). The strategy is to drill to 1180 m with TD above the flank of Melville Bay Ridge; a remnant of the Cretaceous rifting and modified by compression during late Eocene (Gregersen *et al.* 2013). The sites in this area are covered by 3D PSDM seismic data, allowing detailed risk analyses to guide site selection (Fig. 5b).

MB-7A and the corresponding alternate sites penetrate a late Miocene sediment prism related to a deep shelf environment that covers large parts of the West Greenland margin. MB-7 is the primary site since it displays the best stratigraphic recovery, and most even reflection geometries. Thicknesses are up to 1000 m (mu-C; Knutz *et al.* (2015)). The sites cross horizon d1, a middle Miocene marker that separates the late Miocene shelf prism from an Oligocene to early Miocene succession interpreted as hemipelagic mudstone (mu-D). The unit is intersected by layer-bound faults related to dewatering of smectite-rich claystone. Deposits of early Miocene age recovered at ODP Site 645E (Fig. 1a) are characterized by muddy sandstone and silty mudstone with occasional laminae related to current sorting (Srivastava *et al.* 1987) while smectite dominates the clay fraction (Thiébault *et al.* 1989). Dinocyst assemblages suggest a nearshore environment while warm to temperate deciduous forest vegetation is inferred for Baffin Island (Head *et al.* 1989). The lower Miocene has not been drilled along West Greenland, but the seismic data indicate km-scale thick muddy basin fills. Thus, paleo-water depth at our proposed site was likely deeper, with more oceanic conditions than on the Canadian margin.

The top of the drilled section, in combination with the base of MB-6, will constrain the timing of the major basinward erosional phase along horizon c1 (Fig. 2). The base of the MB-7 sites includes potential Oligocene deposits that onlap the Melville Bay Ridge. By drilling into this stratigraphic level targeting horizon d2, new insights will be gained on climate conditions in Greenland during the end of the early Cenozoic greenhouse period (Fig. 8a). The plan is to RCB drill one hole with casing set in the upper 300-400 m. Depth conversion is based on the PITU-3D PSDM cube.

4 Ship-board analyses and methodologies

4.1 Chronology

The strategy for obtaining high-resolution chronologies through the sequences drilled will follow a template that designates what methods may be applied through different time intervals and depositional environments (Table 2). Magnetic stratigraphy and biostratigraphy will be combined with other methods, including high-resolution seismic stratigraphy where possible, to achieve a composite age model for the entire margin transect (i.e. from Oligocene to Holocene).

Paleomagnetism

A primary chronology of the composite sedimentary succession will be constructed based on shipboard paleomagnetic analyses of the sediment samples. Natural remanent magnetization (NRM) of all archive-half core sections will be measured before and after nondestructive stepwise alternating field (AF) demagnetization. NRM measurement of the core-sections will be collected at 2 to 5 cm interval resolution depending on the speed of core flow through the shipboard superconducting rock magnetometer station. Discrete cube samples will be taken from working-half core-sections (one sample per core-section) and used for NRM analyses before and after complete AF demagnetisation.

NRM directions including inclinations and declinations will be used to derive magnetic polarity stratigraphy for the cores. The polarity pattern of the sediment sequences will be compared to a geomagnetic polarity time scale (i.e. GPTS2012, Ogg (2012)). Most reversals back to Oligocene in GPTS2012 have been calibrated using astrochronology and have relatively small age uncertainties (<20 ka).

Well-documented geomagnetic excursions (Laj & Channell 2015) and relative paleointensity (RPI) records (Channell *et al.* 2009; Simon *et al.* 2012) collected during the last few decades provide opportunity for high resolution stratigraphic correlation and dating within polarity chrons. High accumulation rates at the proposed drill sites improve the chance that sediments record excursions providing additional chronological constraints. Preliminary RPI estimates from the cores will be constructed by normalizing NRM intensity using magnetic susceptibility. For key intervals of the cored sediment sequences, more robust RPI estimates will be obtained based on detailed shore-based paleomagnetic analyses. RPI data will then be correlated to well-dated RPI reference curves to provide detailed stratigraphic constraints of the sediments.

Biostratigraphy

Shipboard microscopic analyses will be conducted on benthic and planktonic foraminifera, coccoliths, diatoms and organic-walled microfossils. Palynology is useful in epicontinental seas such

as Baffin Bay as organic-walled microfossils are well preserved and have affinities for nearshore to offshore settings. Well constrained Cenozoic biostratigraphic schemes of dinocysts and acritarchs have been developed at the scale of the North Atlantic, especially for the Pliocene (De Schepper & Head 2008; De Schepper *et al.* 2017). For the Quaternary, dinocysts will allow the identification of interglacial periods by correlation with the Labrador Sea reference biostratigraphy and ecostratigraphy (de Vernal *et al.* 1992b; de Vernal & Mudie 1992).

Because our sites are shallower and closer to the Greenland margin and thus experienced increased sedimentation rates and more Atlantic Water compared to ODP Site 645, we expect better preservation of carbonate and siliceous microfossils (Ouellet-Bernier *et al.* 2014; Gibb *et al.* 2015; Jennings *et al.* 2017). Our proposed sites lie along the path of the West Greenland Current, allowing direct correlation with the Labrador Sea biostratigraphy (IODP 1307) and possible new sites on the Davis Strait and Eirik Drift (proposal 814).

4.2 Paleo-environmental analyses

Assemblages of foraminifers, diatoms, dinocysts and molluscs will provide ecological clues on ocean conditions in response to the opening the Canadian Arctic Archipelago gateways and the onset of major Greenland glaciations as well as glacial/interglacial cycles. Planktonic foraminifera may trace movements in the polar frontal system, northward advection of subtropical waters (Berggren & Schnitker 1983; Cronin *et al.* 2014), and the properties of the West Greenland Current. Benthic foraminiferal assemblages (calcareous and agglutinated) will provide clues on biological productivity, calcium carbonate preservation and the bottom water conditions that can drive ice retreat from the shelf during deglaciations (Jennings *et al.* 2017). The benthic fauna could also help constrain water depth in the Pleistocene shelf deposits (Sites MB-8 and MB-4). Dinocysts will be used for sea-surface reconstructions (salinity, temperature, sea-ice cover and productivity) (de Vernal *et al.* 2001; de Vernal *et al.* 2013; Gibb *et al.* 2014; Ouellet-Bernier *et al.* 2014). Pollen and spores will be used to assess terrestrial vegetation and climate on Greenland and to make direct land-sea correlations (de Vernal & Mudie 1989; de Vernal & Hillaire-Marcel 2008). The occurrence of older, reworked palynomorphs of Paleozoic-Mesozoic age may also provide complementary information on erosion.

4.3 Sedimentology, geochemistry and physical properties

With the different continental margin settings along the transect, we will encounter a range of sedimentary facies that will be important for the first-order environmental interpretation (Table 1). The lithofacies description of the cores will use a scheme appropriate for deep-marine, near-shore marine, and glacial-marine environments (Reading 1996). Samples will be taken for smear-slide microscopy, XRD mineralogy and grain size analyses, supporting lithofacies description and depositional interpretation. Mud-encased or "floating" clasts >1 cm will be counted within suitable intervals (e.g. every 50 cm of core section) as a proxy for IRD abundance.

Total organic carbon, inorganic carbon, and sulphur will be measured at regular intervals. The organo-chemistry results will be important for ascertaining changes in biogenic paleoproductivity (Muller & Suess 1979), marine vs freshwater conditions, and bottom-water oxygen levels (Raiswell *et al.* 1988). Headspace gas will be closely monitored. Routine core scanning (e.g. photometric analyses, magnetic susceptibility, gamma-ray) will facilitate the paleo-environmental reconstruction. Physical properties (sediment density, porosity, discrete magnetic susceptibility) will be done at regular intervals to support lithofacies identification.

4.4 Wire-line logging and seismic-borehole correlation

Since variable recovery rates are expected (>80 % in hemipelagic and contourite drift intervals and <50 % for the sites drilling the aggradational shelf wedge), a full wireline logging suite (spectral GR, sonic, resistivity, density, porosity, magnetic susceptibility, formation imager) will be important for determining actual depths and to capture the lithological signature of the entire succession. If hole conditions are amenable, the formation imager tool should enable a complete understanding of sections with poor recovery, preferably on all sites, but most importantly on the shelf margin sites (MB-8 and MB-4). In case of hole instability, the anticipated poor recovery sites would also benefit from deployment of logging-while drilling tool string with a basic logging suite as was done in Antarctica (O'Brien *et al.* 2001; Barker *et al.* 2002). To enable accurate borehole to seismic data ties, check-shot vertical seismic profiles will be required on sites MB-1, MB-8, MB-6 and MB-7.

5 Expected scientific outcome and post-cruise work

The proposed scientific drilling of the northwest Greenland margin will have immediate outcomes highly relevant for understanding the role of the GrIS in past and future climates:

- A detailed composite stratigraphic record will be produced illuminating the timing of NGrIS advances and retreats and interaction with the oceanic heat transport through the Arctic gateways.
- Key seismic horizons with only inferred ages will be dated.
- Sedimentary records will generate information on the past dynamic regimes of the NGrIS and shed light on the Mid-Pleistocene transition.
- Data will reveal the ice sheet response to extreme interglacial climates, e.g. MIS 5e, 11c, and 31, from continuous deep-sea archives and from proximal deposits on the shelf.
- Drilling will provide information on the boundary conditions of NGrIS variability over extended time periods crucial for understanding long-term cryospheric evolution in the Northern Hemisphere. The last decade has seen a major progress in paleo-ice sheet modelling, but model verification requires a detailed stratigraphy of ice sheet history from the proposed drilling area.

5.1 Integrated post-cruise analytical programme

An integrated post-cruise analytical program will provide both a robust chronologic framework and the greatest likelihood of identifying periods of significant ice volume change in northwest Greenland (Table 1). We use an integrated approach because we fully cognizant of the difficulties and assumptions inherent to analytical methods used for deciphering paleoclimate, interpreting paleo ice-volume, and establishing chronology in complex depositional environments such as the ones of Baffin Bay.

<u>Paleoceanographic proxies: Microfossil assemblages, stable isotopes, Mg/Ca and biomarkers.</u>

Intervals with well-preserved biogenic carbonates will be analysed for benthic and planktic foraminifer assemblages and measurements of shell $\delta^{18}O$, $\delta^{13}C$ and Mg/Ca will be performed

(Kristjansdottir *et al.* 2007; Groeneveld & Filipsson 2013; Hasenfratz *et al.* 2017). Organic-walled microfossils such as dinocysts and acritarchs (de Vernal *et al.* 2013; De Schepper *et al.* 2017) and biomarkers, including alkenone $IP_{25,}$ TEX-86 and highly branched isoprenoid proxies (Ho *et al.* 2014; Belt *et al.* 2015; Stein *et al.* 2016; Köseoğlu *et al.* 2018) will be analysed. The combination of the various proxies will be used to: (1) reconstruct surface, subsurface, and deep ocean conditions at the deeper hemipelagic sites; (2) constrain Atlantic water inflow, stratification, salinity, sea-ice cover and seasonal gradient of sea-surface temperature; and (3) differentiate glacial meltwater spikes and other freshwater sources from temperature–related isotopic changes (Hillaire-Marcel *et al.* 2001; Bartoli *et al.* 2006; Knutz *et al.* 2011; Repschläger *et al.* 2015; Moros *et al.* 2016).

Organic biomarkers and pollen and spores as proxy for land-sea correlations

Preliminary results from glacial and interglacial sediments at ODP Site 646 demonstrate that leaf waxes and alkenones are abundant enough to obtain reliable measurements (E. Thomas, pers. comm.). For efficient use of material, multiple organic biomarkers will be measured in the same sample extracts. Leaf wax hydrogen isotopes, δ^2H_{wax}, will constrain changes in terrestrial summer precipitation δ^2H and aridity (Sachse *et al.* 2012; Thomas *et al.* 2016) and surface ocean salinity (Sachs *et al.* 2018). Branched and isoprenoid glycerol dialkyl glycerol tetraethers will constrain terrestrial and marine production and land or ocean temperature (Tierney & Tingley 2014; De Jonge *et al.* 2016; Hopmans *et al.* 2016). Ancient DNA, if preserved, may provide insights into terrestrial and marine ecosystem changes (Willerslev *et al.* 2007; Boere *et al.* 2011). Moreover, pollen and spores from terrestrial plants, which are abundant in pre-Mid-Late Quaternary deposits of Baffin Bay (de Vernal & Mudie 1989), relate to inputs from land through both atmospheric and hydrologic processes. Hence, they reflect the vegetation of the nearest adjacent land and their analyses will permit inference about Greenland vegetation and climate.

Cosmogenic isotopes

In Greenland, cosmogenic isotopes (mostly ^{10}Be and ^{26}Al) have been applied on land (Sinclair *et al.* 2016), in sediment and rock sourced from and under the ice (Bierman *et al.* 2014; Nelson *et al.* 2014; Schaefer *et al.* 2016; Graly *et al.* 2018) and in offshore marine sediment (Bierman *et al.* 2016). Most relevant to the cores collected here is the paired analysis of ^{10}Be and ^{26}Al in marine sediment, which

allows inferences about the depth of regolith erosion, the duration of ice cover, and the extent and duration of interglacial exposure. Detection limits of these nuclides have steadily fallen such that with optimized samples and laboratory processing, reliable detection of ^{10}Be in later Miocene samples from marine sediment is practical (Shakun *et al.* 2018).

^{10}Be analysis of 7 Ma sediment from ODP site 645 as a proof of concept demonstrates the utility of this method in Baffin Bay; the drop of ^{10}Be concentration through the Miocene and Pliocene is consistent with early, limited glaciation in the area progressively excavating pre-existing Tertiary regolith as postulated by Bierman et al. (2016) for East Greenland (Figure 8b).

Measurement of stable ^{21}Ne, when paired with the long-lived radionuclide ^{10}Be, could extend the window of understanding back >10 Ma; however, radiogenic production of ^{21}Ne in old crustal rocks that underlie much of the GrIS mandates such an approach be tested before application. Similarly, measurement of ^{10}Be adhered to sediment grains in glacial shelf sediment may be useful for tracking erosion since sediment was minimally exposed to the water column during deposition (Bierman *et al.* 2014; Graly *et al.* 2018).

The drilling strategy proposed here – paired cores to increase recovery and sample mass available for analysis as well as drilling of glacial sediment on the shelf – will provide the larger samples needed for optimized cosmogenic analysis. Testing glacial sediment from site U0110 just north of proposed drilling sites (Fig. 1b) shows that sufficient material for high precision ^{10}Be/^{26}Al analysis can be obtained from only 20 cm of halved core.

<u>Additional methods</u>

- High-resolution coarse-fraction analyses using automated image analyses in order to refine the IRD record from sites MB-1 and MB-2.
- High-resolution sediment properties, including sedimentary magnetism and XRF geochemistry, can be measured rapidly and will be valuable for site correlation and environmental interpretation (Stoner *et al.* 2000; Carlson *et al.* 2008; Hatfield *et al.* 2017).
- Silt analyses (10-63 um) to determine changes in current flow speed which may be

particularly relevant for the contourite drift sites (McCave *et al.* 2017).

- Application of radiogenic isotopes, e.g. U-Pb and $^{40}Ar/^{39}Ar$, measured on specific mineral components (zircon, rutile, amphibole, feldspar) to infer provenance of coarse-clastic sediments (Knutz *et al.* 2013; White *et al.* 2016).

6 Site survey data

Seismic data

The drill sites (Fig. 1b) are located using 2D seismic data collected by TGS (four regional seismic surveys, 2007–2010) and two 3D data volumes: Cairn-PITU-3D-2011 and Shell-ANU-3D-2012. TGS BB07-BB08 are released whereas BB09-BB10 are expected to be released in 2019. Both 3D surveys were utilized in a recent compilation of seabed geomorphology (Newton *et al.* 2017) and for further refining drill site locations and hazard assessments (Fig. 7). A high-resolution 3D Cube from Cairn-PITU-3D-2011 was used to constrain the deep coring sites 7, 11 and 12. Alternate sites for MB-5 and MB-6 were constrained using the Shell-ANU-3D-2012 data. Further analyses using Shell's 3D survey will be performed to identify additional sites capturing early-middle Pleistocene marine onlaps (objectives 1 and 5).

Shallow site survey data

Multibeam and high-resolution sub-bottom profiler (ParaSound) data were collected in 2017 (AWI expedition MSM66). The data cover an area of 900 km^2 and envelop deep water sites MB-1 and MB-2 and a transect over site MB-3 (Dorschel 2017). Depending on the outcome of Danish shiptime proposal, high-resolution seismic data and gravity cores may be collected in the study area in 2019, which can provide enhanced imaging of the drilling targets within the upper 0.3-0.5 s interval.

7 Requirements, logistics and relations to other proposals

The proposed transect crosses petroleum license areas that were surrendered in 2018. None of the proposed sites lie within major prospects but headspace gas will be closely monitored following procedures established during expedition 344S. Based on the experience from expedition 344S

(Fournier *et al.* 2013) the iceberg flux is expected to be low at the proposed sites compared to 344S, although icebergs require contingency plans for drilling at nearby alternate sites. As a result, more alternate sites are proposed here compared to 909-Full1 (Table 4). The mission will require ice observers with ice track modelling expertise. Due to the subarctic location and the presence of drifting icebergs, the time window for this mission is limited to July, August and September. The time plan includes 1.5 days of WOI (Table 3). Transfer time of 13 days assumes St. John's as the nearest port-call but this would be reduced by about 2/3 if the mission could be operated out of Nuuk.

The scientific scope of drilling a presently glaciated is closely linked with Exp. 379 (Amundsen Sea; Gohl *et al*.) scheduled early 2019. In parallel with Exp. 379 we intend to obtain middle-late Cenozoic records so combining the results may lead to new understandings of synchronicities/asynchronicities in bipolar glaciation (2.2: Obj. 2 and 4). Proposal 909 likewise carries a strong thematic affiliation with current proposal 814 (Erik Drift and southwest Greenland; Stoner *et al*.). The scope of drilling Neogene drifts in both proposals will provide a detailed regional database that is valuable for paleoclimate reconstruction of the Pliocene system (2.3: Obj. 6). Furthermore, proposal 909 is related to the recently completed expeditions 341, Southern Alaska Margin (Jaeger *et al.* 2014) and 374, Ross Sea (McKay *et al.* 2018). It also aligns with the Newfoundland Sediment Drifts proposal 874 (Friedrich *et al.*) and the German-Canadian ArcTrain project planning to use the MeBo in southern Baffin Bay.

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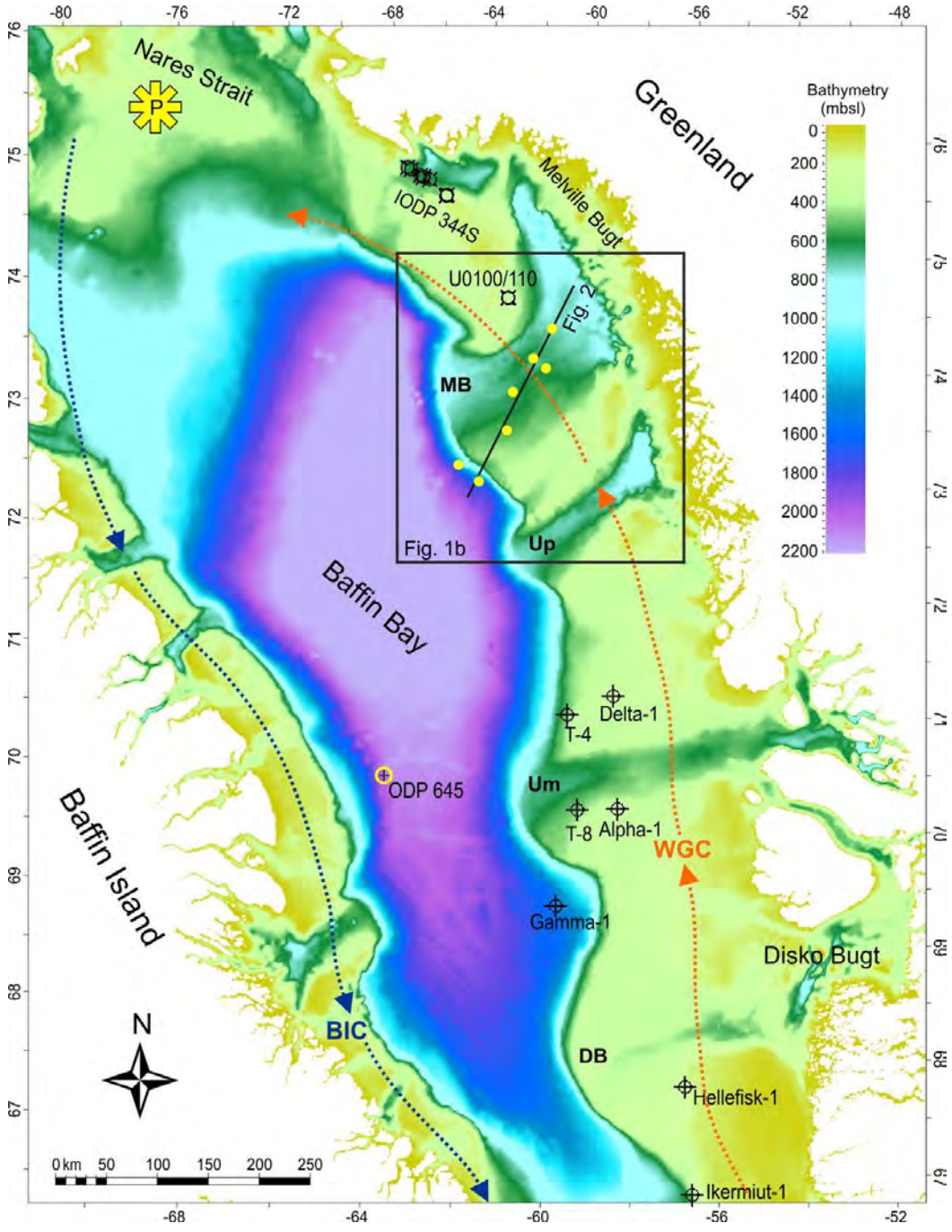


Figure 1a. Bathymetric map (IBCAO v3; Jakobsson *et al*. 2012) showing study area of proposal 909 and the main ocean current systems in Baffin Bay. WGC = West Greenland Current. BC = Baffin Island Current. Yellow star demarks the area of the North Water Polynia. Proposed sites along key transect (yellow) and existing wells/boreholes are indicated. West Greenland trough-mouth fans; Melville Bay (MB), Upernavik (Up), Umiivik (Um) and Disko Bay (DB), are shown.

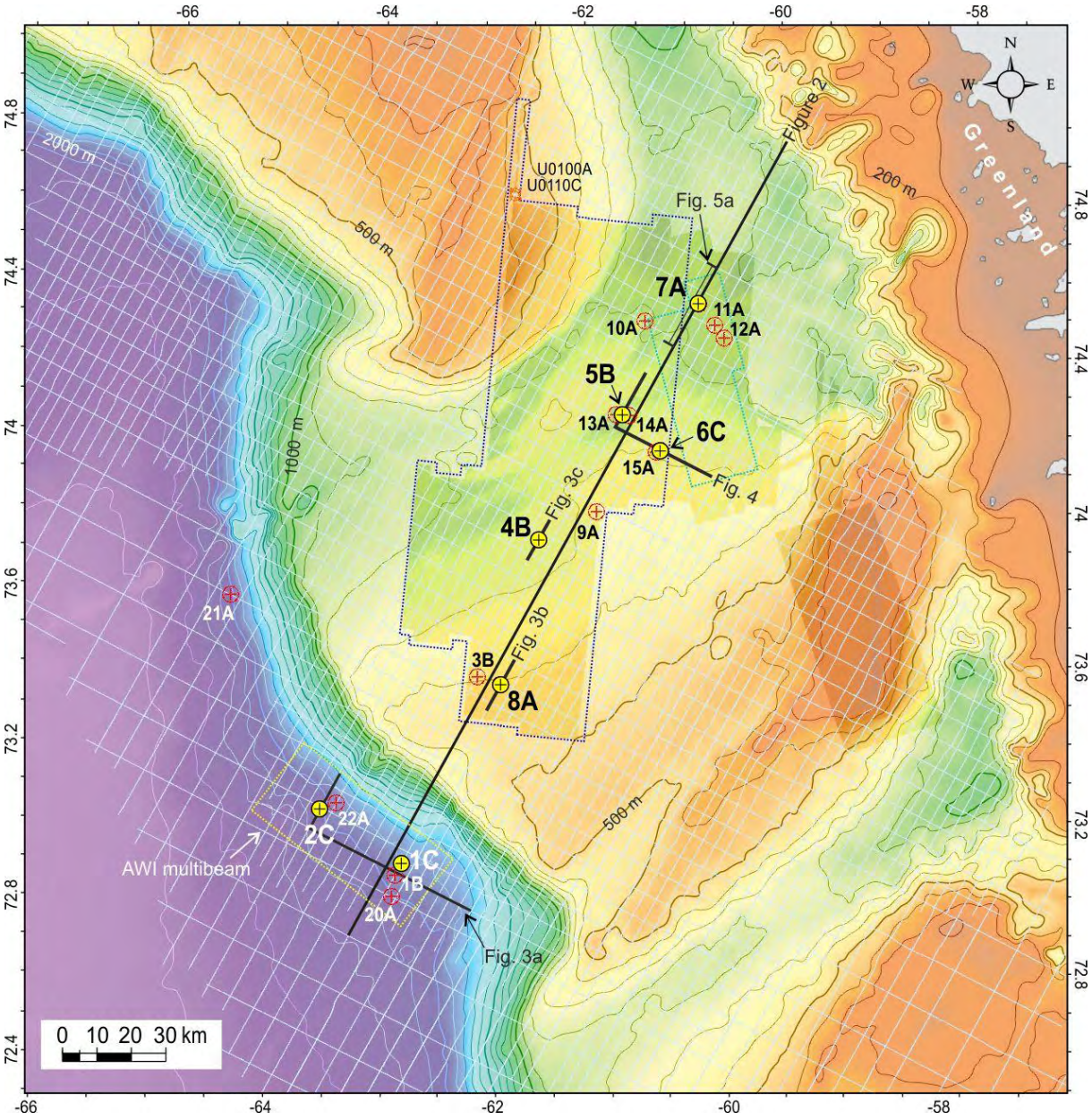


Figure 1b. Map of the proposed drilling transect across the Melville Bay Trough Mouth Fan with position of seismic profiles (Figs. 2-5) and proposed drilling sites (primary sites in yellow; alternate sites in red). The 2D seismic grid is TGS Baffin Bay surveys 2007, 2008, 2009 and 2010 (minimum spacing is about 3.75 km). Polygons demarcate 3D surveys Shell-ANU-2012 (blue) and Cairn-PITU-2011 (turquoise). Bathymetry is based on IBCAO v3 (Jakobsson *et al*. 2012) with contours shown at 100 m depth intervals. Detailed shelf bathymetry is based on industry multibeam data combined with 3D seismic imaging (Newton *et al*. 2017). Detailed bathymetry on the continental rise is from multibeam data collected by Alfred Wegener Institute (Dorschel 2017). Positions of sites U0100/110 drilled during Expedition 344S (Acton *et al*. 2012) are also indicated.

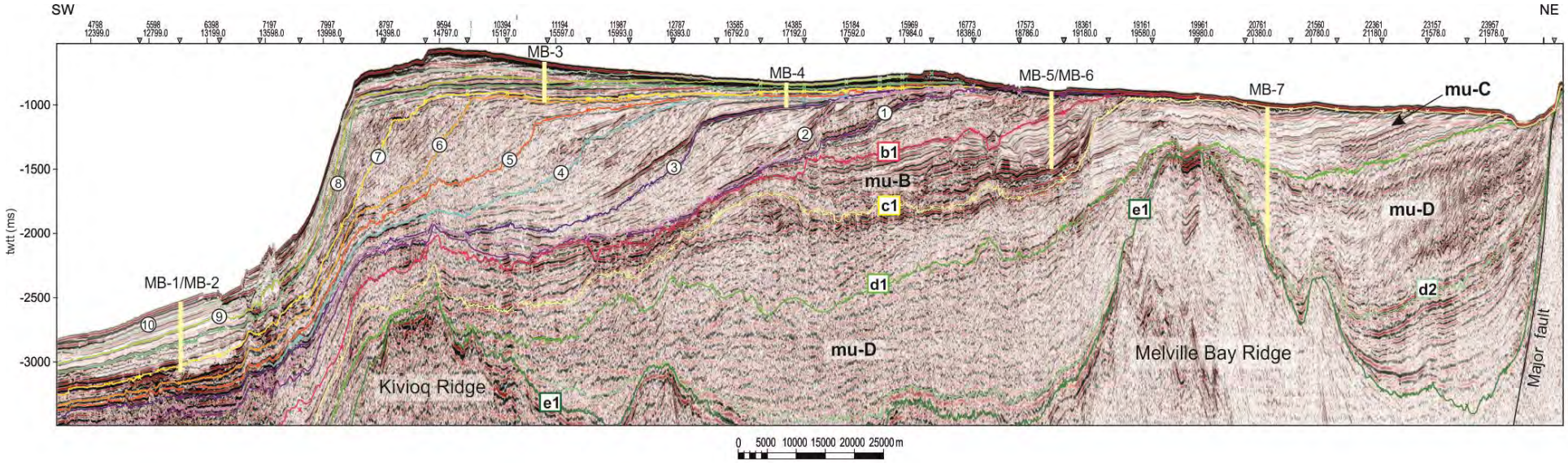


Figure 2. Key seismic transect (BB08-50575) with interpreted horizons and projected sites MB 1-7. Positions of crossing display profiles are shown with triangles. The prograding sequence forming part of the Melville Bugt - Upernavik trough-mouth fan (TMF) system is dissected by 10 horisons defined by slightly dipping erosional surfaces (high-amplitude reflections in topset strata) with abrupt shelf breaks. The pre-TMF horizons b1 (c. late Pliocene) and c1 (c. late Miocene) define a package of wave-form contourites displaying two-way time (twt) thicknesses of 600-700 ms within a prominent slide scar truncating the c1 horizon (Knutz et al. 2015). Horizon d1, of likely middle Miocene age, define the base of a late Neogene drift prism forming part of mega-unit C. The age of horizon d2 is not constrained by well-ties but it is possibly late Oligocene. The sequence between d1 and d2 is interpreted as mainly fine-grained sediments filling in the remnant space of older rift basins. The Melville Bay Ridge represents a prominent tectonic element from the Mesozoic rift phase that was modified by compression associated with strike-slip tectonics during late Eocene-early Oligocene (Gregersen et al. 2013).

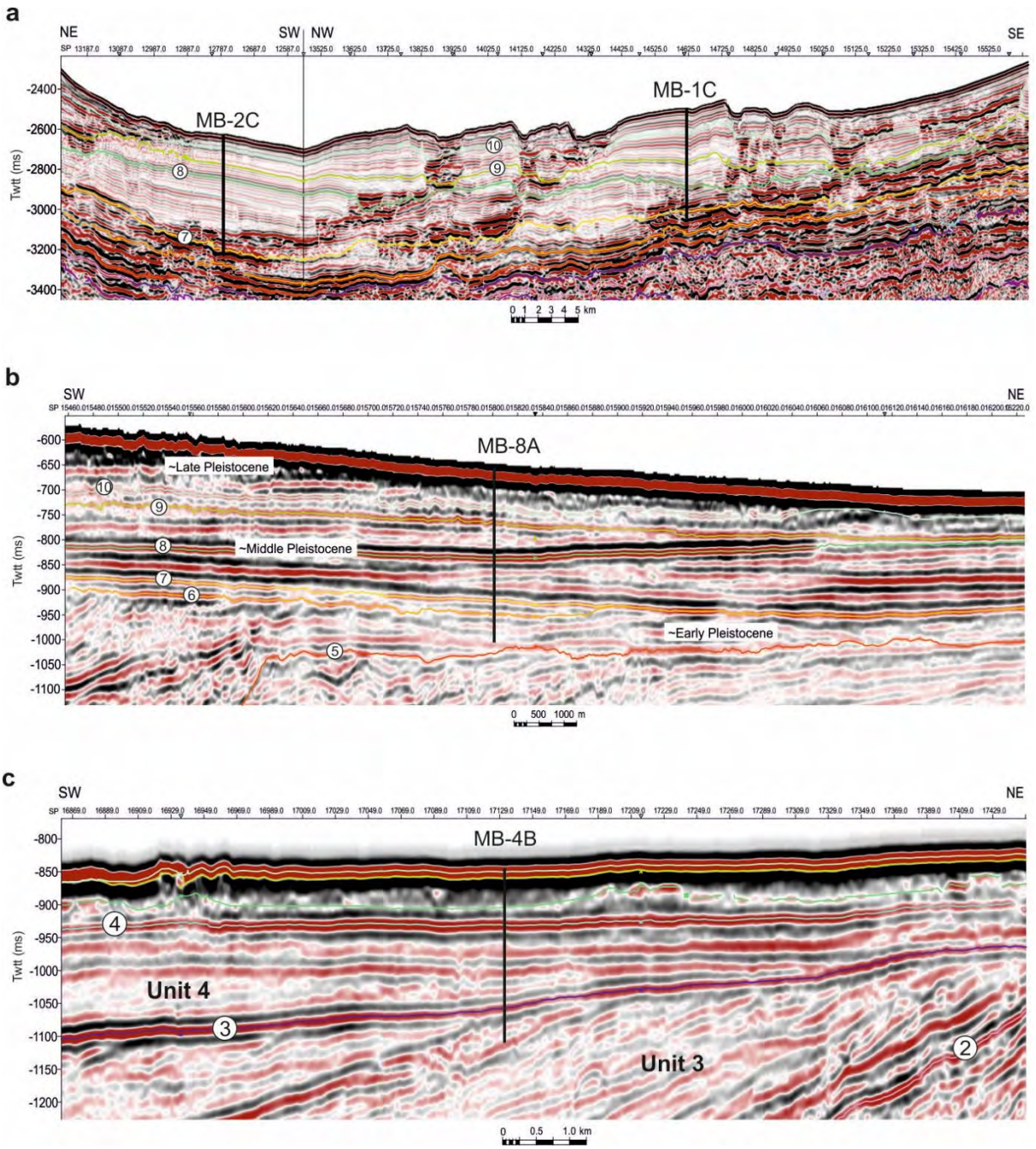


Figure 3. Seismic sections showing examples of drill sites targeting different sections of the Pleistocene prograding wedge (see positions in Fig. 1b). (**a**) Sites MB-1 and MB-2 below the West Greenland continental margin, aimed at recovering a composite high-resolution record from sedimentary drift deposits (units 8-11) of likely Middle-Late Pleistocene age with horizon 7 as depth target. (**b**) Site MB-8 coring through top-set strata of the Melville Bugt trough-mouth fan that represents an intra-trough accumulation zone (units 6-11). The objective is to obtain cores from even, continuous reflections of positive amplitudes that may represent glacial-marine and/or marine interglacial intervals of early-middle Pleistocene age. (**c**) Site MB-4 targets strata that onlaps top of prograding unit 3, interpreted as marine to glacial-marine deposits of early Pleistocene age. Vertical scale in two-way-travel-time (twtt). Shot points shown as horisontal scale. Crossing lines indicated by green triangles. Seismic data courtesy of TGS. See also Site Figures. Seismic data courtesy of TGS.

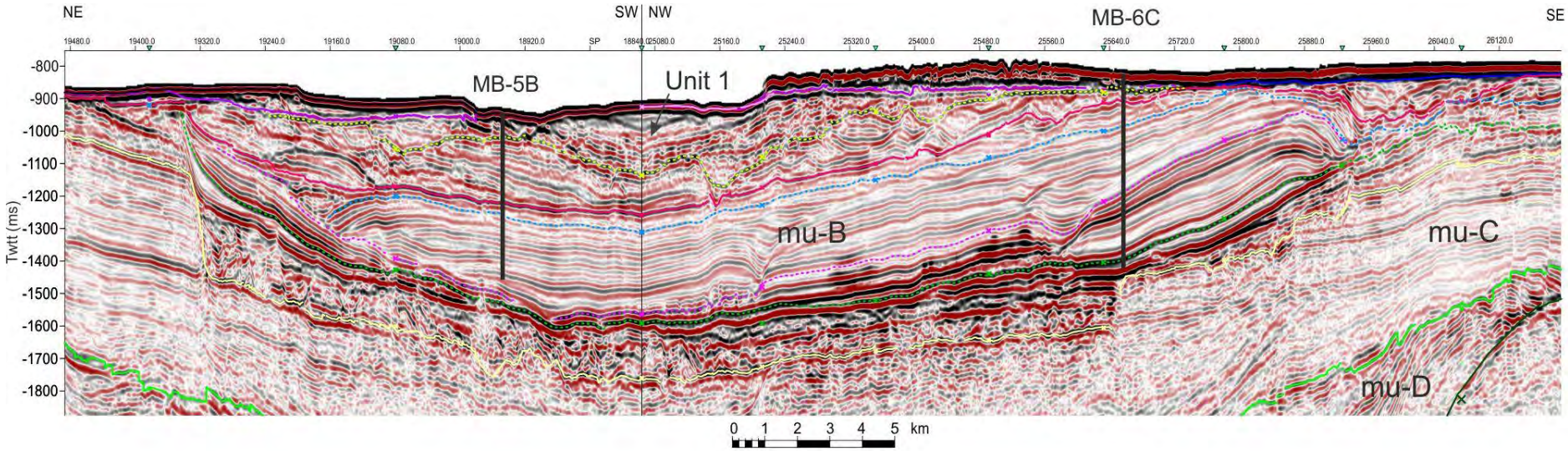


Figure 4. Seismic profile showing the position of MB-5B and MB-6C aimed at recovering a composite sequence of high-accumulation-rate contourite drifts of likely Pliocene age (see position in Fig. 1b). The sites are designated to core through juxta-posed sedimentary bodies of mega-unit B representing focussed sedimentation below a major slide complex excavating the flanks og mega-unit C (probably late Miocene; see also Fig. 2). In addition, MB-5B will core through about 50-80 meters of clinoformal deposits that form the youngest part of the prograding wedge (unit 1). The intention is to capture, at highest possible resolution, the transition from a marine current-controlled environment to glacial-marine conditions on the West Greenland margin. MB-6B targets an expanded and distinctly asymmetric-mounded sedimentary section, which potentially may represent the early Pliocene. Target depth for site MB-6C at 620 mbsf is a strong, inclined (~2.5°) seismic horizon. Internal horizons mapped to guide the site selection at this locality are shown by stippled colouration. Vertical scale in two-way-travel-time (twtt). Shot points shown as horisontal scale. Crossing lines indicated by green triangles. Seismic data courtesy of TGS.

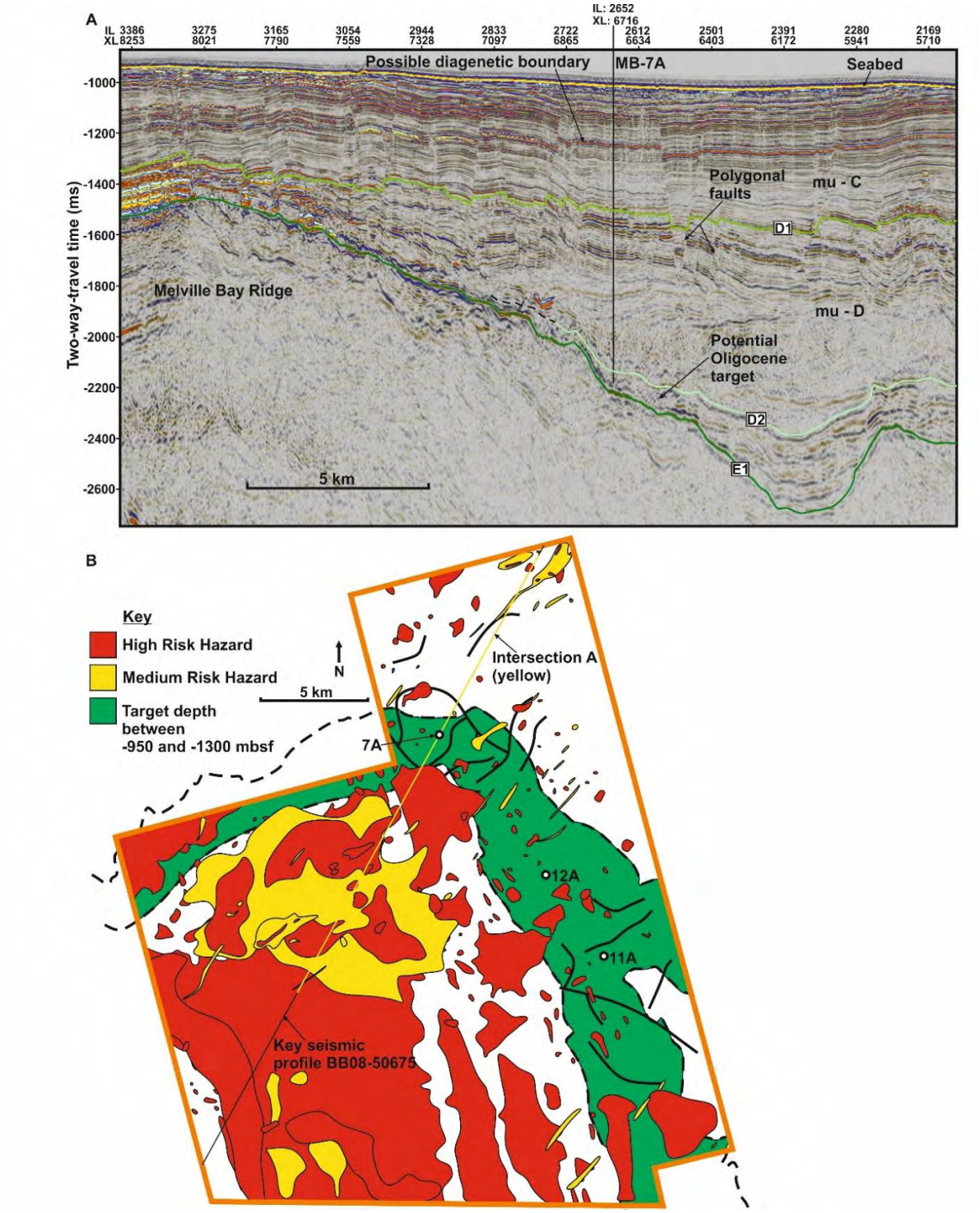


Figure 5. (**a**) Seismic section, extracted from a high-res 3D data cube (Cairn-PITU-2011), displaying site MB-7 (see position in Fig. 1b). The site objective is to recover a relatively continuous early-late Miocene succession (mega-units D and C) with a potential Oligocene depth target over the Melville Bay Ridge (horizon d2; see also Fig. 2). The succession onlaps the ridge structure and is intersected by numerous polygonal faults related to shale compaction-dewatering. A strong continuous reflector seen within mu-C is possibly a diagenetic boundary (silica transformation?). (**b**) The selection of site 7A and alternate sites 11A and 12A are based on a risk assessment study made possible by the 3D seismic data cube volume. The green zone represents an area where the target horizon can be reached at depths of 1200-1300 mbsf and drilling hazards avoided (e.g. deep-seated faults, fluid-flow/gas features, BSR's). Seismic data courtesy of Cairn.

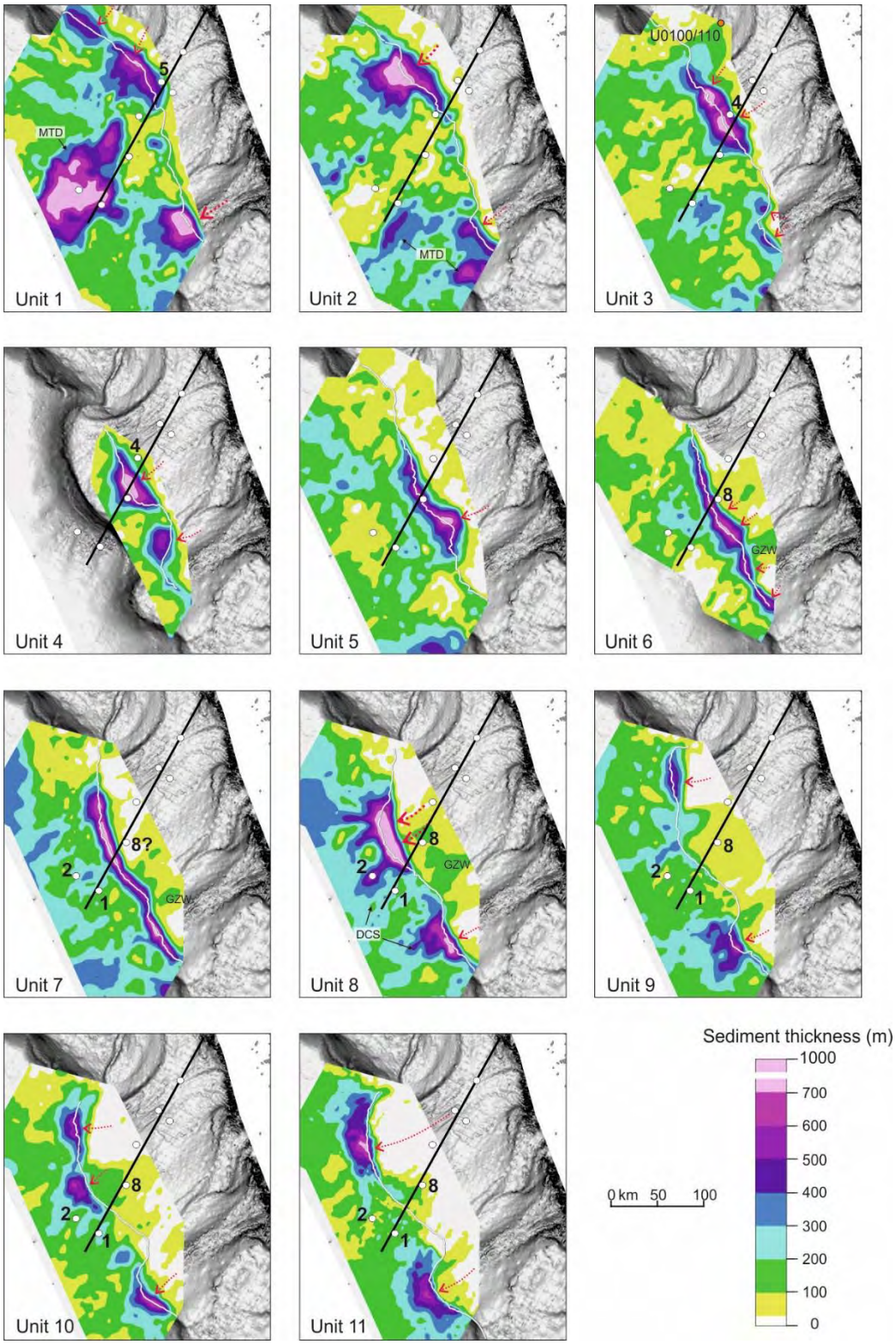


Figure 6. Maps showing thickness distribution for each of the prograding units (Knutz *et al.* In review). Thick white lines demarcate the shelf break position of the top unit horizon. Red arrows show inferred routes of streaming ice. MTD = mass-transport deposits, GZW = grounding zone wedge, DCC = Drift-Channel Complex. Thicknesses < 25 m (white areas) are below the seismic resolution. Key seismic transect and primary site positions (see Fig. 1 and 2) are indicated by black line and white circles. Site numbers are shown where unit penetration is expected.

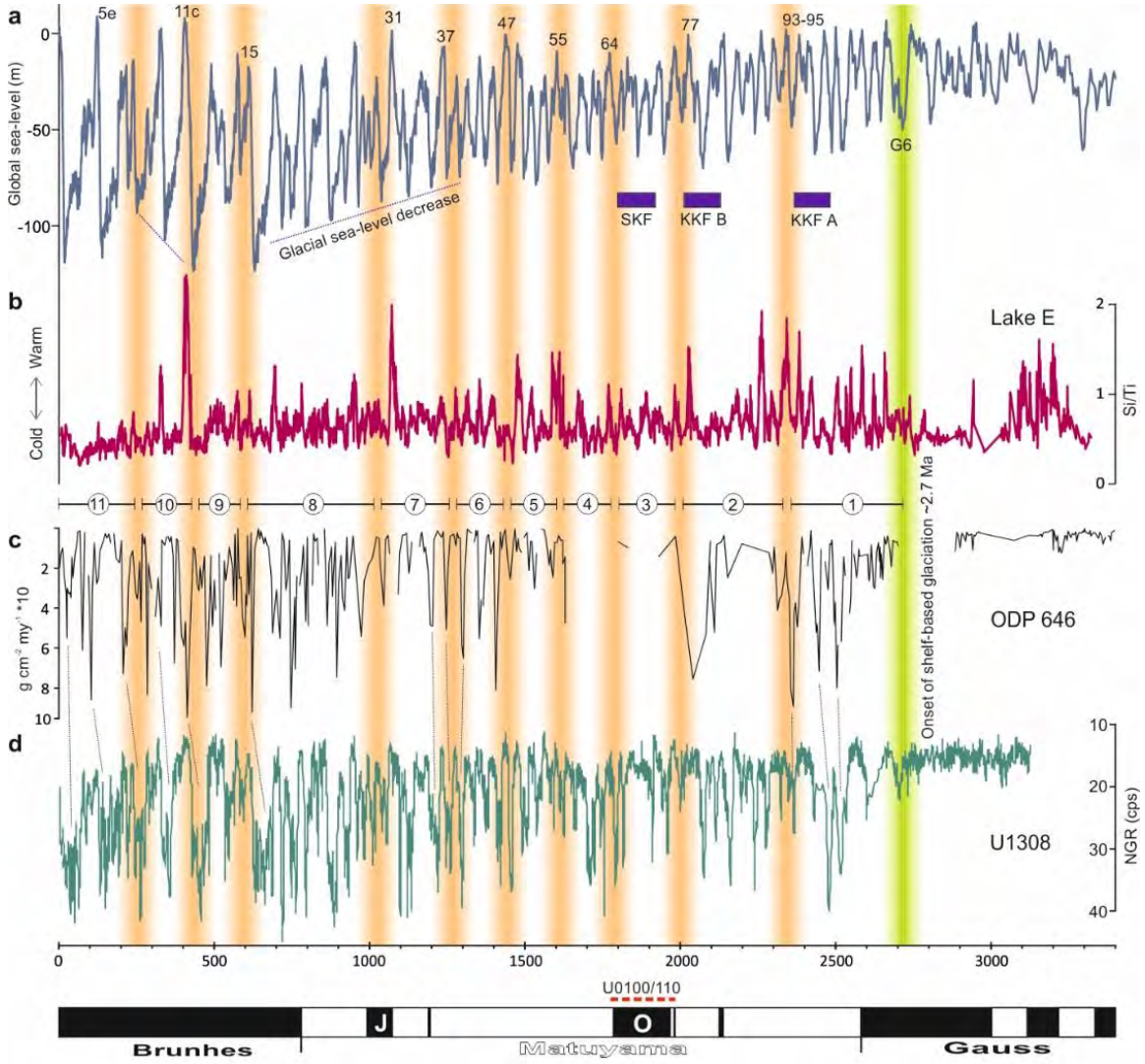
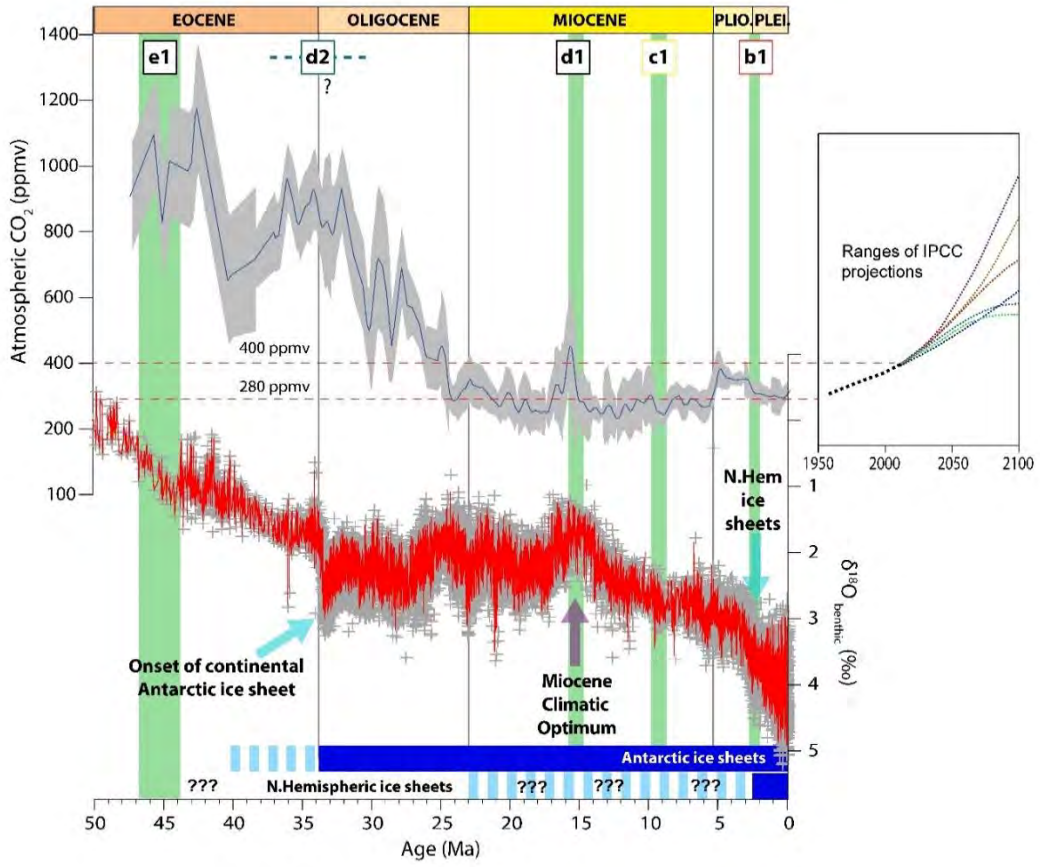


Figure 7. Correlation of prograding units, refered to as glacial advance mega-cycles of the northwest GrIS, with regional and global climate proxies from 3.4 Ma to present (Knutz et al. In review). (**a**) Global sea-level curve (Miller *et al*. 2011) constructed from the LR4 benthic $\delta^{18}O$ stack (Lisiecki & Raymo 2005). (**b**) Si/Ti record from Lake El' Gygytgyn, northeast Russia, with high values indicating warmer Arctic climates (Melles *et al*. 2012). (**c**) Flux (g cm^{-2} my^{-1}) of coarse fraction (>63 um) from ODP 646, eastern Labrador Sea (Wolf & Thiede 1991) with data outliers omitted. (**d**) Natural Gamma-Ray variation from U1308 (Hodell & Channell 2016) reflecting supply of clastic glacigenic material to the central North Atlantic. Age model is based on well biostratigraphy for the pre-glacial and limited paleomagnetic information from unit 3 (Knutz *et al*. In review). The vertical bands reflects uncertainty in the range of several glacial-interglacial cycles. SKF = Store Koldewey Fm (Bennike *et al*. 2010). KKF = Kap København Fm (Funder *et al.* 2001).

a



b

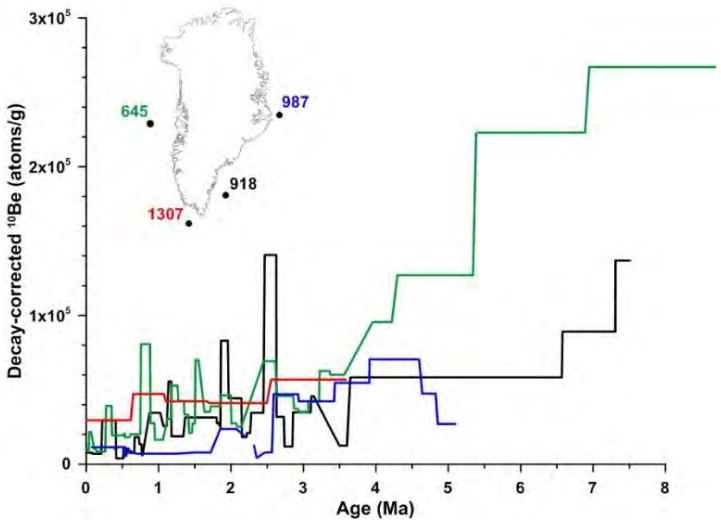


Figure 8. (**a**) Estimated chronology of seismic stratigraphic horizons abounding mega-units of the northwest Greenland margin shown in the context of Cenozoic climate evolution. Atmospheric CO_2 reconstruction (gray area) is based on all available proxy data (Beerling and Royer 2011, Anagnostou *et al*. 2016, Zhang *et al*. 2013). Future CO_2 predictions is from IPCC. Benthic foraminiferal $\delta^{18}O$ after Zachos *et al*. 2008. Figure modified from Śliwińska *et al*. (in preparation).. (**b**) Four marine sediment cores from Greenlandic margins analysed for *in situ* cosmogenic ^{10}Be at the University of Vermont. Core sites shown by number on inset map. Decay corrected concentrations plotted based on published core age models. All cores show overall decrease in ^{10}Be concentration over time likely reflecting progressive glacial erosion of pre-Quaternary regolith.

Parameter	Proxy	Full Ice	Termination	Interglacial	Super-interglacial	Pre-GrIS
		Sites 1, 2, 8, 4, 5	Sites 1, 2, 8, 4, 5	Sites 1, 2, 8, 4, 5	Sites 1, 2, 8, 4, 5	Sites 5, 6, 7
Icesheet configuration indicators						
Iceberg production	*IRD*	+ to ++	++++	0 to +	0	0
Land exposure	*^{10}Be*	0	0	+	++	+++
Ice cover	*$^{10}Be/^{26}Al$*	<7 (burial)	<7 (burial)	7	7	7
Terrigenous flux	*Volumetric sed. rate, sedimentary magnetism, NGR*	+ to ++	+++++	+	+	+ to ++
Terrestrial productivity	*Pollen, leaf waxes, DNA, fossils*	0	+	++	+++	++++
Sediment sourcing	*Elemental, magnetic, mineral, and isotopic provenance*	Glacial flowline, warm – polythermal bed	Glacial flowline, warm bed	Multiple ice-rafted sources, reworked glacial	Fluvial, reworked glacial, more local	Fluvial, basin only
Weathering intensity	*Mineralogy, grain size and texture*	0	0	+	++	++++
Glacial meltwater	*Salinity reconstructions using ~^{18}O and trace elements in foraminifera, palmitic acid ~D*	0 to +	++++	++	0	0 to +
Environmental indicators						
Depositional processes (Shelf environment)	*Lithofacies description*	Tills	Glacial-marine, diamicton	Hemipelagic	Hemipelagic	Hemipelagic, contourite, deltaic
Depositional processes (Basin environment)	*Lithofacies description*	Glacial-marine, plumites/turbidites	Glacial-marine, plumites/turbidites	Hemipelagic, glacial-marine, contourite	Hemipelagic, contourite	Hemipelagic, contourite
Terrestrial climate	*Pollen, brGDGT, leaf wax ~D*	Cold, dry	Transitional	Warm, wet	Warmer, wetter	Warmest, wettest
Ocean water conditions (surface/subsurface)	*Dinoflagellate, diatom and foraminifera; isoGDGTs (e.g. TEX_{86}), shell trace elements*	Cold	Cool, strongly stratified	Warm, highly seasonal	Very warm	Very warm
Sea Ice	*IRD, Dinoflagellates and diatoms; biomarkers (HBIs, e.g. IP_{25})*	+++	++ to +++	+	0-?	0-?

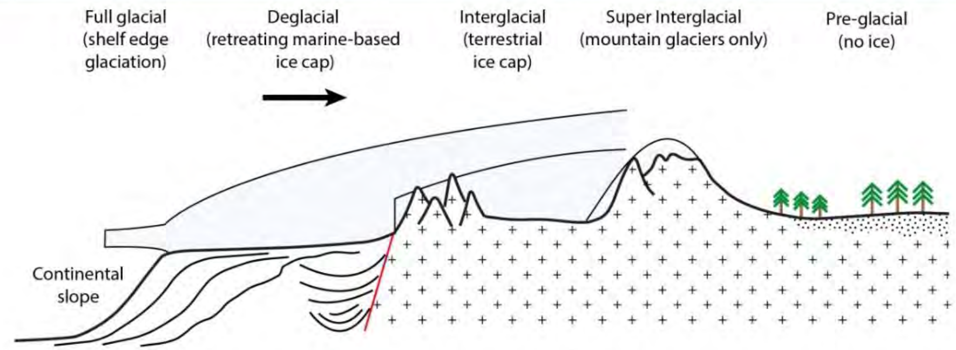


Table 1. Diagnostic template for proxy interpretation. The combination of different proxy results will provide information on glacial response and paleo-environmental settings associated with 5 overall stages of ice sheet configuration. Drill sites linked to each glaciation stage are shown in the second row. Environmental parameters and proxies used to measure those parameters shown in columns to the left. Hypothesized parameter response to each glaciation stage shown in columns to the right. IRD = Ice-Rafted Debris. NGR = Natural Gamma-Ray. BrGDGT = Branched Glycerol Dialkyl Glycerol Tetraethers. IsoGDGTs = Iso-Glycerol Dialkyl Glycerol Tetraethers. HBIs = Highly Branched Isoprenoids.

Methods	Valid time range	Achievable resolution (yr)	Uncertainty (yr)	Requirements/notes
Paleomagnetics				
Polarity reversals	Oligocene to present	10^5	10^3 to 10^4	Stratigraphic continuity
Geomagnetic excursions	Quaternary	10^4 to 10^5	10^3	Stratigraphic continuity, minimal diagenesis
Paleosecular variation	late Pleistocene to present	10^3	10^2 to 10^3	Stratigraphic continuity, minimal diagenesis
Relative paleointensity	late Pliocene to present	10^3 to 10^4	10^3	Good stratigraphic continuity, minimal diagenesis
Biostratigraphy				
Dinoflagellate cysts and acritarchs	Oligocene to present	10^5 to 10^6	10^5	Good preservation
Agglutinated benthic foraminifera	Oligocene to present	10^5 to 10^6		Present in $CaCO_3$-free deposits
Benthic foraminifera	Miocene to present	10^5 to 10^6		$CaCO_3$ preservation best during glacials
Planktic foraminifera	Miocene to present	10^5 to 10^6		$CaCO_3$ preservation best during glacials
Diatoms	Oligocene to present	10^5 to 10^6		Preservation best during terminations (high sedimentation rate)
Radiolaria	Oligocene to present	10^5 to 10^6		Preservation best during terminations (high sedimentation rate)
Calcareous nanofossils	Miocene to present	10^4 to 10^5	10^5	$CaCO_3$ preservation best during glacials
Ecostratigraphy (organic microfossils)	<1 Myr	10^5		
Other methods				
Radiocarbon	<50,000 yr	10^3	10^2 to 10^3	Organic matter or $CaCO_3$ preservation, constrained marine reservoir effect
Foraminifera $\delta^{18}O$ (Benthic & Planktic)		10^3 to 10^4	10^3 to 10^4	$CaCO_3$ preservation, constrained water mass changes
CRN burial dating				Deposited with surface production ratio
Sr isotopes	Oligocene to Miocene	10^6		$CaCO_3$ preservation
Optically stimulated Luminescence	<1 Myr	10^4 to 10^5	10^4 to 10^5	No resetting events
Amino acid racemization	<1 Myr	10^5	10^5	Good amount of forams
U/Th on solitary corals	<300 Kyr			Coral samples
Orbital tuning	Oligocene to present	10^4	10^4	Stratigraphic continuity

Table 2. Template for chronological methods

Proposed site	Lat. Long (dec. degrees)	Seafloor depth (mbss)	Sed. depth (mbsf)	Seismic data; SP/Inline/Xline	Operations description	Transit/port call (days)	Coring/drilling (days)	Logging (days)
					Start of expedition: St. John's, NF, Canada	3		
					Transit to MB-1C	**6.3**		
MB-1C	73.0001	1809	473	BB10-5068125; 13444	Hole A: APC to refusal (~250 mbsf)		1.4	
	-63.0065				Hole B: APC to refusal (~250 mbsf)		1.1	
					Hole C: APC to refusal, XCB to TD		2.4	
					Logging: Triple Combo, FMS sonic, VSI-checkshot			1.3
					Transit to MB-2C	**0.1**		
MB-2C	73.1150	1957	537	BB10-5063125; 12768	Hole B: APC to refusal (~250 mbsf)		1.4	
	-63.7904				Hole A: APC to refusal (~250 mbsf)		1	
					Hole C: APC to refusal, XCB to TD		3	
					Logging: Triple Combo, FMS sonic			0.7
					Transit to MB-8A	**0.2**		
MB-8A	73.4870	497	370	BB10-506875; 15796	Hole A: RCB to TD. Hole B (optional); flush, APC/XCB		2.7	
	-62.2682				Logging: Triple Combo, FMS sonic, VSI-checkshot			1
					Transit to MB-7A	**0.4**		
MB-7A	74.5136	737	1173	PITU-3D; 2658/6728	Hole A: RCB to TD. Drill in casing to 400 mbsf.		8.3	
	-60.6792				Logging: Triple Combo, FMS sonic, VSI-checkshot			2.5
					Transit to MB-6B	**0.1**		
MB-6C	74.1254	609	620	ANU-3D; 19108/17140	Hole A: RCB to TD		3.4	
	-60.9510				Logging: Triple Combo, FMS sonic, VSI-checkshot			1.4
					Transit to MB-5B	**0.1**		
MB-5B	74.2116	704	520	ANU-3D; 17168/18616	Hole A: RCB to TD		3	
	-61.3397				Logging: Triple Combo, FMS sonic			0.6
					Transit to MB-4B	**0.1**		
MB-4B	73.8711	630	340	BB10-506625; 17131	Hole A: RCB to TD. Hole B (optional): flush, APC/XCB		2.4	
	-62.0342				Logging: Triple Combo, FMS sonic			0.6
					Transit to St. John's	**6.5**		
					End of expedition	16.8	30.1	8.1
Transit, drilling and loggin						55.0		
Waiting-on-ice:						1.5		
Total expedition days:						56.5		

Table 3. Site and operational information with estimated time schedule for drilling and transit.

Proposed site	Lat.	Long.	Seafloor depth (mbss)	Horizon target (mbsf)	Sediment depth (mbsf)*	Average Vp	Priority	Objectives
MB-1C	73.0001	-63.0065	1809	455	473	1800	1.1	1 & 5
MB-20A	72.9118	-63.0642	1928	446	464	1800	1.2	1& 5
MB-2C	73.1150	-63.7904	1957	518	537	1800	2.1	1 & 5
MB-22A	73.1388	-63.6402	1850	583	611	1800	2.2	1 & 5
MB-21A	73.6439	-64.8251	1954	722	751	1850	2.3	1 & 5
MB-8A	73.4870	-62.2682	497	345	370	2200	3.1	1 & 5
MB-3B	73.5032	-62.4861	498	360	375	2200	3.2	1 & 5
MB-7A	74.5136	-60.6792	737	1160	1173	2050	4.1	2 & 3
MB-11A	74.4283	-60.4086	747	1150	1170	2050	4.2	2 & 3
MB-12A	74.4597	-60.5049	739	1125	1145	2050	4.3	2 & 3
MB-10A	74.4584	-61.1792	698	1183	1200	2050	4.4	2 & 3
MB-6C	74.1254	-60.9510	609	600	620	1900	5.1	3, 4 & 6
MB-15A	74.1217	-60.9909	605	605	625	1900	5.2	3, 4 & 6
MB-5B	74.2116	-61.3397	704	500	520	1900	6.1	3, 4 & 6
MB-13A	74.2118	-61.3958	707	520	540	1900	6.2	3, 4 & 6
MB-14A	74.2109	-61.2704	663	490	510	1900	6.3	3, 4 & 6
MB-4B	73.8711	-62.0342	630	315	340	2200	7.1	1 & 5
MB-9A	73.9650	-61.4959	580	250	270	2150	7.2	1 & 5
* Including "rat hole" for logging tools								

Table 4. Site information, prioritization and links to objectives. Primary sites marked in green. The anticipated high-recovery sites MB-1 and MB-2 (and associated alternates 20, 21, 22) will be drilled first, followed by site MB-8 on the outer shelf margin. The deepest site 7 (or alternates 10, 11, 12) will be drilled as the fourth priority to allow for an iceberg contingency plan. In case of an iceberg moving into the safety perimeter of MB-7, a free fall funnel will be deployed and JR can proceed drilling at nearby sites MB-5 and MB-6. Drilling at site 7 can then resume once the iceberg risk is over.

IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover a high-resolution paleoceanographic record of a early/middle-late Pleistocene sediment drift system corresponding to the most recent part of the trough-mouth-fan history (scientific objectives 1 and 5). Site MB-1C is targeting expanded intervals of units 9, 10 and 11 and overlaps stratigraphically with the strata drilled at site MB-2C. Site was moved from 1B position to avoid amplitude anomaly at target depth. MB-1C is located 3.9 km from nearest crossing line to provide optimal coverage of units 9, 10 and 11.
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	MB-01C	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 73.0001	Jurisdiction:	Greenland
Longitude:	Deg: -63.0065	Distance to Land: (km)	215
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	1809

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	473	0
Total Sediment Thickness (m)	2500	
Total Penetration (m):	473	

General Lithologies: Clayey-silty mud with dropstones

Coring Plan: (Specify or check)

Hole A: APC to refusal
Hole B: APC to refusal
Hole C: APC to refusal; XCB to TD

APC ☑ XCB ☑ RCB ☐ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 4.9 | Logging: 1.3 | Total On-site: 6.2

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other:

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IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-01C	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: BB10-5068125 Position: 13444 This data is currently confidential (TGS)
2b Deep penetration seismic reflection (crossing)	yes	Line: BB10-10525 Position: 14612 This data is currently confidential (TGS)
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	yes	Parasound profiles
7 Swath bathymetry	yes	Multibeam
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-01C	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple-APC/XCB; logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known
6. What "special" precautions will be taken during drilling?	Standard precuations
7. What abandonment procedures need to be followed?	Standard abandonment procedures
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard); gas-charged sands (unknown but site selected to avoid amplitude anomalies)

Proposal #: 909 - Full 2	Site #: MB-01C	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-01C (primary)

Scientific Objectives: 1 and 5

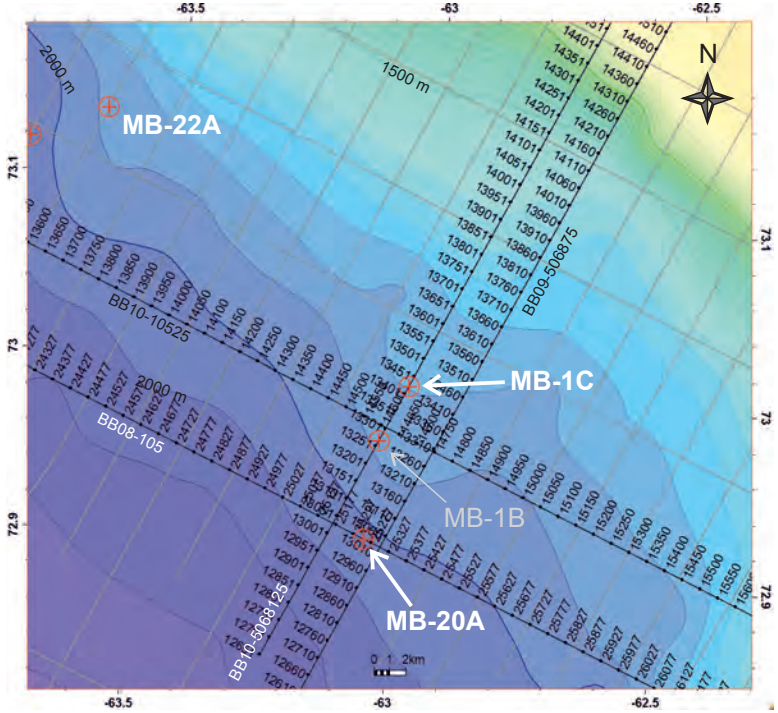
Coordinates: 73.0001/-63.0065
Shot point: 13444 (BB10-5068125)
Penetration: 473 m
Water depth: 1809 m

SSDB locations:
Location map: Map_MB-1C_MB-20A.jpg
Seismic data figure: BB10-5068125.jpg
SEG-Y data: bb10_line-5068125_flt-scl-stk_t101845_crop.sgy
Navigation: bb10-5068125-navigation-utm-lat-lon.txt

Additional information: Multibeam, parasounder profiles, seismic velocity data

Site MB-1C: (A) Bathymetry map of the lower slope below the Melville Bugt Trough-Mouth Fan shown with 100 m depth contours. The crossing seismic lines are shown with shot points. (**B**) Seismic section shown with interpreted horizons. The strata package above horizon 7 (depth target), displaying a wavy, semi-continous reflection character, is interpreted as a contourite drift formed in juxtaposition to a channel system. The strong reflections below horizon 7 are interpreted as channel deposits (e.g. slumps, turbidites, plumites?). MB-1C is expected to recover silty-sandy muds; presumably of Early/Middle - Late Pleistocene age. Site was moved from position 1B position to avoid reflection amplitude at horizon 8. MB-1C is located 3.9 km from nearest crossing line to provide optimal coverage of units 9, 10 and 11 (horizon 8 to seabed).

A



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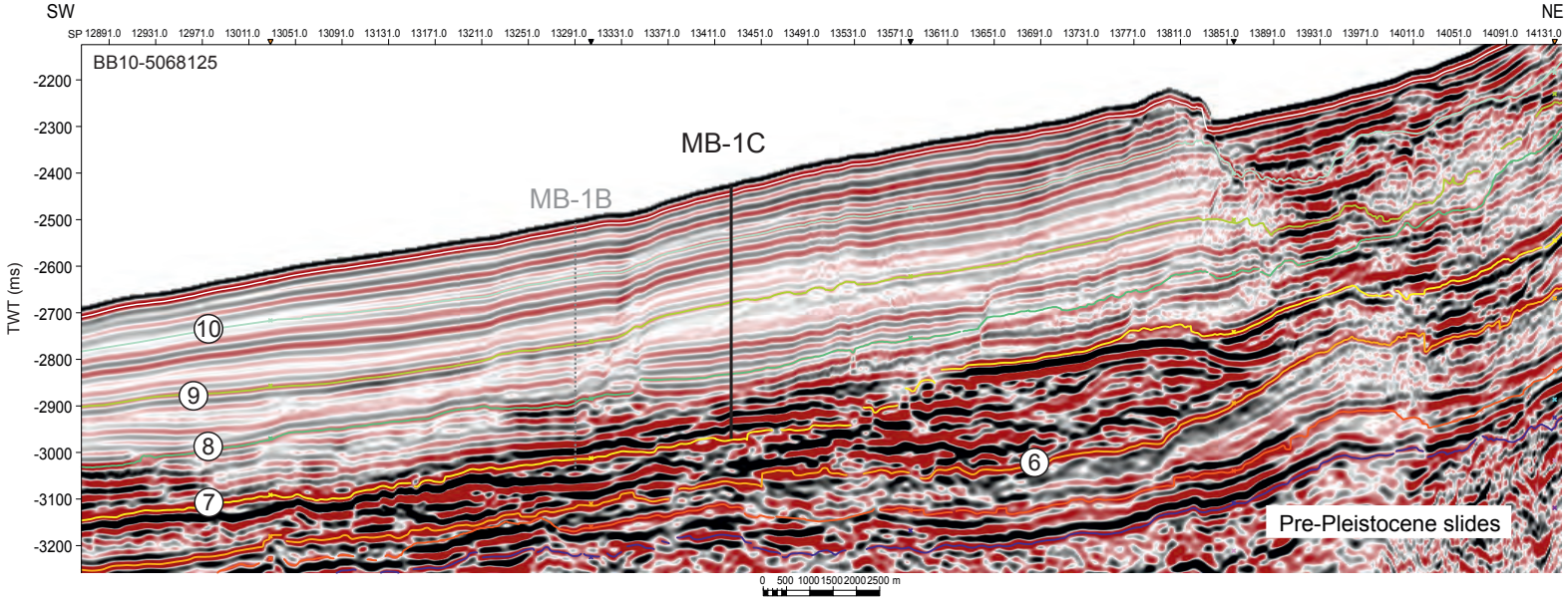

IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover a high-resolution paleoceanographic record of a middle-late Pleistocene sediment drift system corresponding to the most recent part of the trough-mouth-fan history (scientific objectives 1 and 5). Site MB-20A targets expanded intervals of units 9, 10 and 11 and overlaps stratigraphically with the strata drilled at site MB-2C. The site is located ~1.2 km NW of nearest crossing line to avoid strong reflections at target depth (e.g. channel sands).
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	MB-20A	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 72.9118	Jurisdiction:	Greenland
Longitude:	Deg: -63.0642	Distance to Land: (km)	216
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	1928

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	464	0
Total Sediment Thickness (m)	2500	
Total Penetration (m):	464	

General Lithologies: Clayey-silty mud with dropstones

Coring Plan: (Specify or check)

Hole A: APC to refusal
Hole B: APC to refusal
Hole C: APC to refusal; XCB to TD

APC ☑ XCB ☑ RCB ☐ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 4.9 | Logging: 1.3 | Total On-site: 6.2

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other:

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IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-20A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: BB08-105 Position: 25254
2b Deep penetration seismic reflection (crossing)	yes	Line: BB09-506875 Position: 13028 This data is currently confidential (TGS)
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Multibeam
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-20A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple-APC/XCB; logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known
6. What "special" precautions will be taken during drilling?	Standard precautions
7. What abandonment procedures need to be followed?	Standard abandonment procedures
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazardy); gas-charged sands (unknown but site selected to avoid amplitude anomalies)

Proposal #: 909 - Full 2	Site #: MB-20A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-20A (alternate)

Scientific Objectives: 1 and 5

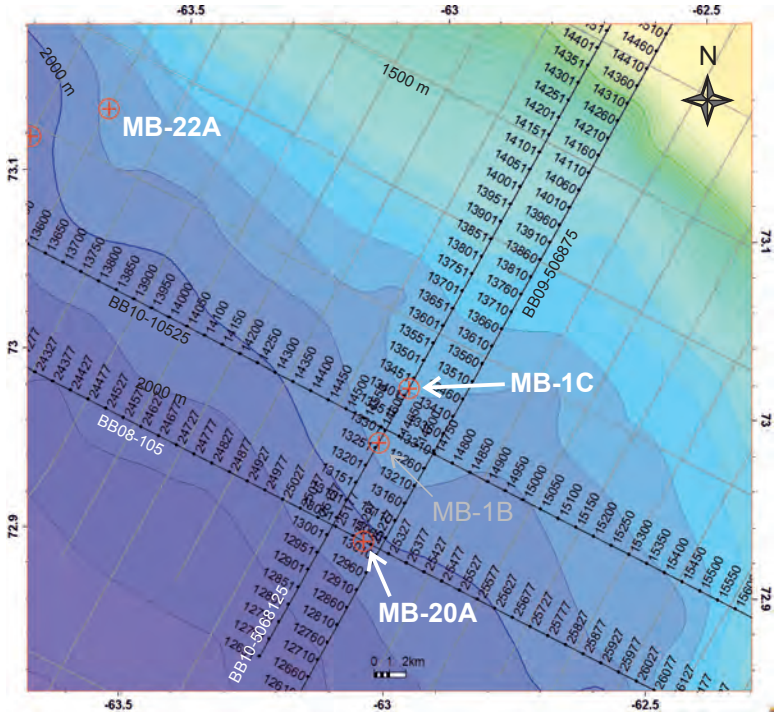
Coordinates: 72.9118/-63.0642
Shot point: 25254 (BB08-105)
Penetration: 464 m
Water depth: 1928 m

SSDB locations:
Location map: Map_MB-1C_MB-20A.jpg
Seismic data figure: BB08-105.jpg
SEG-Y data: BB08-105_crop.sgy
Navigation: bb08-105-navigation-utm-lat-lon.txt

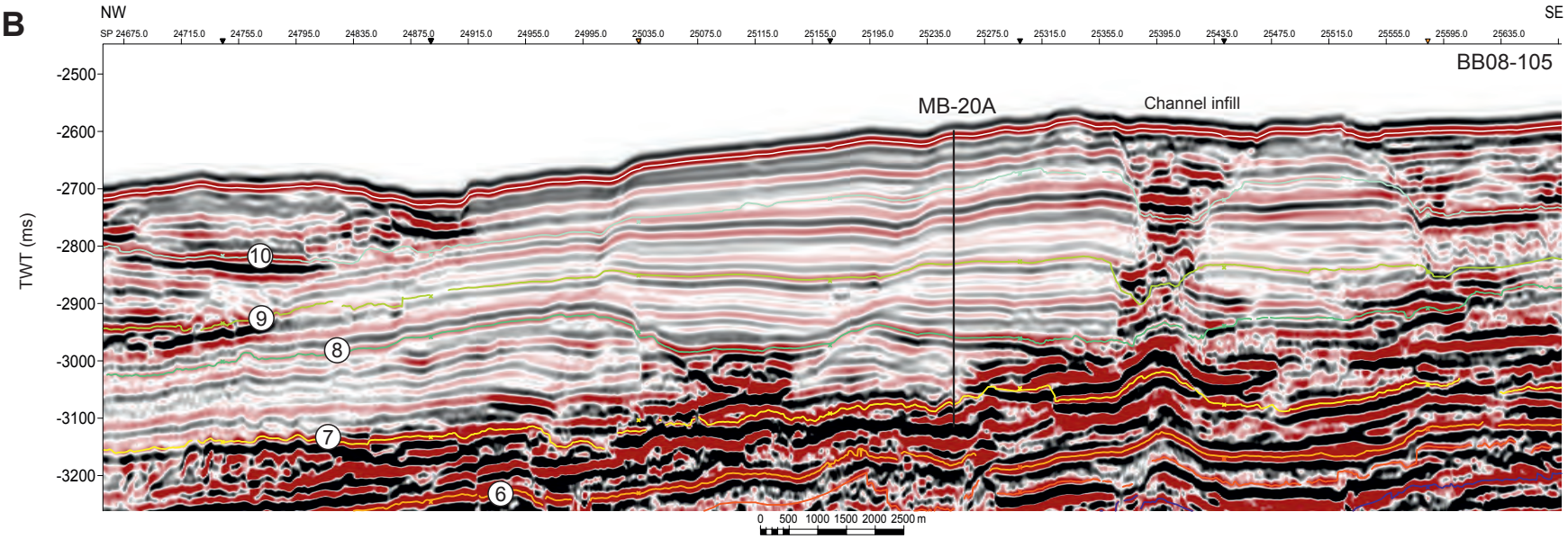
Additional information: Multibeam bathymetry, seismic velocity data

Site MB-20A: (**A**) Bathymetry map of the lower slope below the Melville Bugt Trough-Mouth Fan shown with 100 m depth contours. The crossing seismic lines are shown with shot points. (**B**) Seismic section shown with interpreted horizons. The strata package above horizon 7 (depth target), displaying a wavy, semi-continous reflection character, is interpreted as a contourite drift formed in juxtaposition to a channel system. The strong reflections below horizon 7 are interpreted as channel deposits (e.g. slumps, turbidites, plumites?). MB-20A is expected to recover silty-sandy muds; presumably of Middle - Late Pleistocene age. Site is located ~1.2 km away from crossing line to avoid strong reflections at target depth that might be channel sands.

A



B



IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover a high-resolution paleoceanographic record of a early/middle-late Pleistocene sediment drift system corresponding to the most recent part of the trough-mouth-fan history (scientific objectives 1 and 5). Site MB-2C targets an expanded interval of unit 8 and overlaps stratigraphically with the strata drilled at site MB-1C. The site is located ~1 km off the nearest crossline to obtain optimal stratigraphic coverage of unit 8 (beween horizons 7-8) and avoid amplitude anomaly at the base of this unit.
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	MB-02C	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 73.1150	Jurisdiction:	Greenland
Longitude:	Deg: -63.7904	Distance to Land: (km)	260
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	1957

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Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	537	0
Total Sediment Thickness (m)	2500	
Total Penetration (m):	537	

General Lithologies: Clayey-silty mud with dropstones

Coring Plan: (Specify or check)

Hole A: APC to refusal (~250 mbsf)
Hole B: APC to refusal (~250 mbsf)
Hole A: APC to refusal (~250 mbsf), XCB to TD

APC ☑ XCB ☑ RCB ☐ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☐			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 5.4 | Logging: 0.7 | Total On-site: 6.1

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other:

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IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-02C	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: BB10-5063125 Position: 12768 This data is currently confidential (TGS)
2b Deep penetration seismic reflection (crossing)	yes	Line: BB09-1055 Position: 13471 This data is currently confidential (TGS)
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	yes	Parasound profiles
7 Swath bathymetry	yes	Multibeam
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-02C	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple-APC/XCB; logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known
6. What "special" precautions will be taken during drilling?	Standard precautions
7. What abandonment procedures need to be followed?	Standard abandonment procedures
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard); gas-charged sands (unknown but site selected to avoid amplitude anomalies)

Proposal #: 909 - Full 2	Site #: MB-02C	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909 Site MB-02C (primary)

Scientific Objectives: 1 and 5

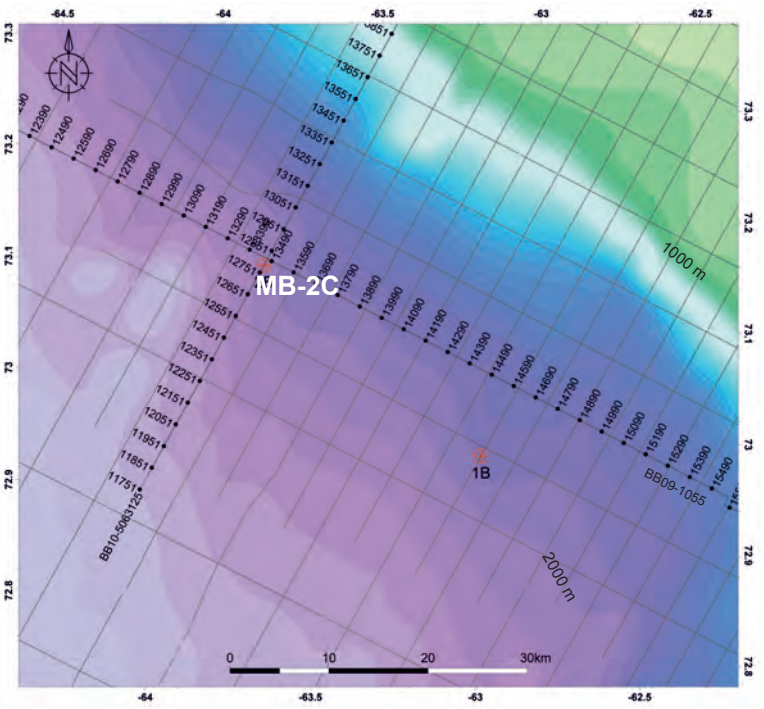
Coordinates: 73.1150; -63.7904
Shot point: 12768 (BB10-5063125)
Penetration: 537 m
Water depth: 1957 m

SSDB locations:
Location map: Map_MB-1B_MB-2B.jpg
Seismic data figure: BB10-5063125.jpg
SEG-Y data: bb10_line-5063125_flt-scl-stk_t101845_crop.sgy
Navigation: bb10-5063125-navigation-utm-lat-lon.txt

Additional information: Multibeam, parasounder profiles, seismic velocity data,

Site MB-2C: (A) Bathymetry map of the lower slope below the Melville Bugt Trough-Mouth Fan shown with 50 m depth contours. The crossing seismic lines are shown with shot points. **(B)** Seismic section shown with interpreted horizons. The strata package above target horizon 7, displaying a continous reflection character, is interpreted as a contourite drift abounding a channel system. MB-2C is expected to recover silty-sandy muds; presumably of Early/Middle - Late Pleistocene age. The site is located 1 km off the nearest crossline to obtain optimal stratigraphic coverage of unit 8 (beween horizons 7-8) and avoid amplitude anomaly at the base of this unit.

A



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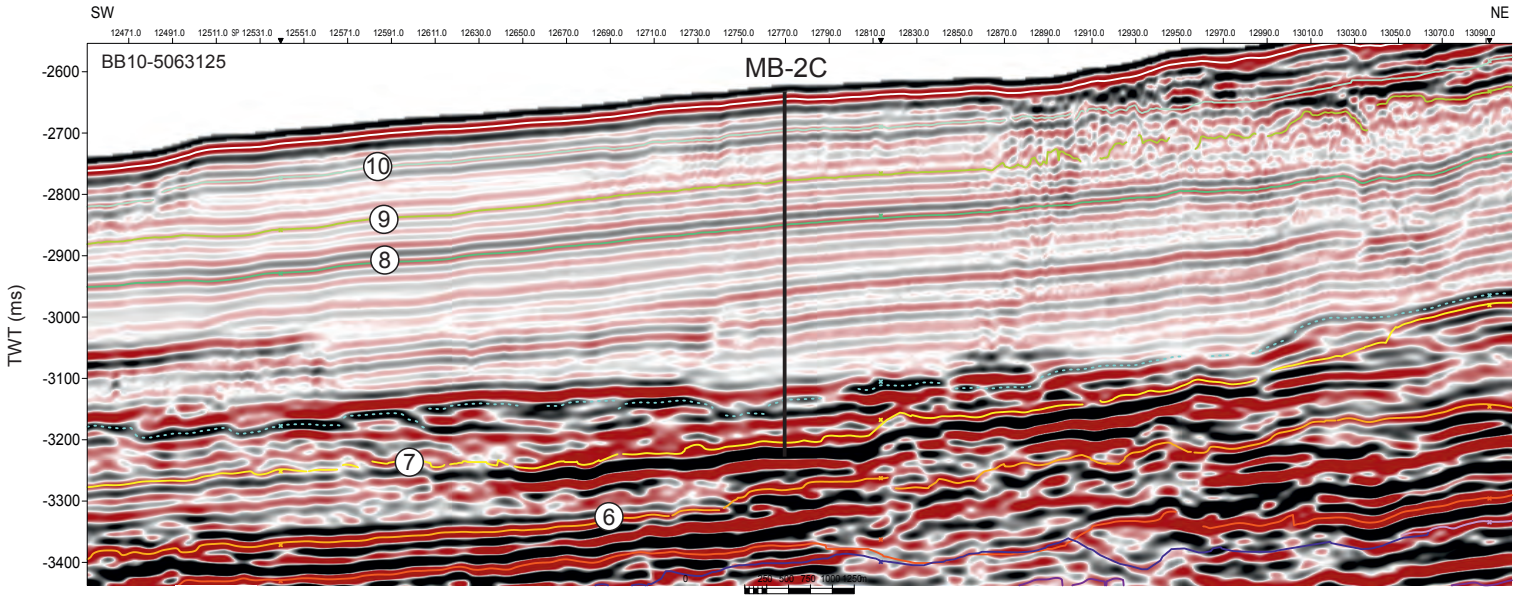


IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover a high-resolution paleoceanographic record of a early/middle-late Pleistocene sediment drift system corresponding to the most recent part of the trough-mouth-fan history (scientific objectives 1 and 5). Site MB-22A targets an expanded interval of unit 8 and overlaps stratigraphically with the strata drilled at site MB-1C.The site is located ~1 km off the nearest crossline to obtain optimal stratigraphic coverage of unit 8 (beween horizons 7-8) and avoid drilling into strong reflections (e.g. channel sands).
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	MB-22A	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 73.1388	Jurisdiction:	Greenland
Longitude:	Deg: -63.6402	Distance to Land: (km)	220
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	1850

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	611	0
Total Sediment Thickness (m)	2500	
Total Penetration (m):	611	

General Lithologies: Clayey-silty mud with dropstones

Coring Plan: (Specify or check)

Hole A: APC to refusal (~250 mbsf)
Hole B: APC to refusal (~250 mbsf)
Hole A: APC to refusal (~250 mbsf), XCB to TD

APC ☑ XCB ☑ RCB ☐ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☐			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 5.7 | Logging: 0.7 | Total On-site: 6.4

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other:

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-22A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: BB09-506375 Position: 12939 This data is currently confidential
2b Deep penetration seismic reflection (crossing)	yes	Line: BB09-1055 Position: 13610 This data is currently confidential
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Multibeam
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-22A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple-APC/XCB; logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	Not known
6. What "special" precautions will be taken during drilling?	Standard precautions
7. What abandonment procedures need to be followed?	Standard abandonment procedures
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard); gas-charged sands (unknown but site selected to avoid amplitude anomalies)

Proposal #: 909 - Full 2	Site #: MB-22A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-22A (alternate)

Scientific Objectives: 1 and 5

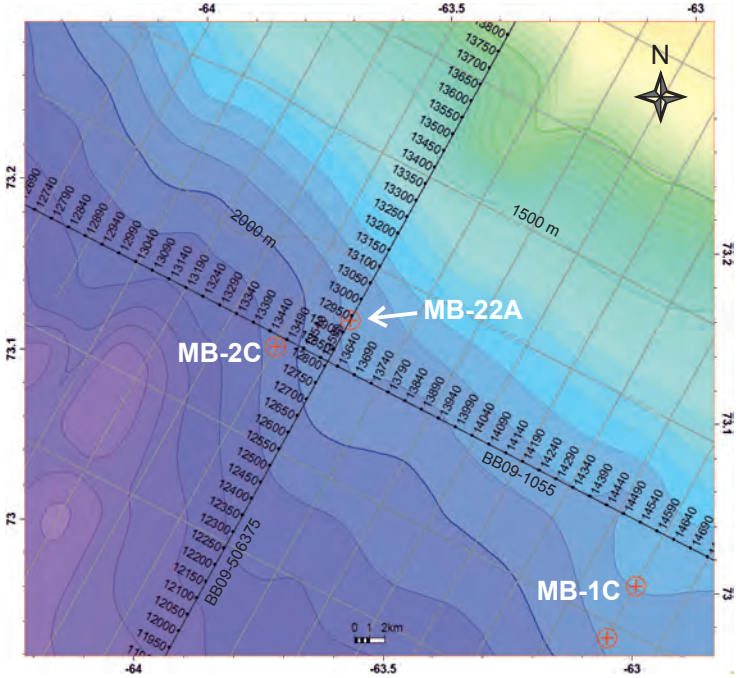
Coordinates: 73.1388/-63.6402
Shot point: 12939 (BB09-506375)
Penetration: 611 m
Water depth: 1850 m

SSDB locations:
Location map: Map_MB-2B_MB-22A.jpg
Seismic data figure: BB09-506375.jpg
SEG-Y data: BB09-506375_crop.sgy
Navigation: bb09-506375-navigation-utm-lat-lon.txt

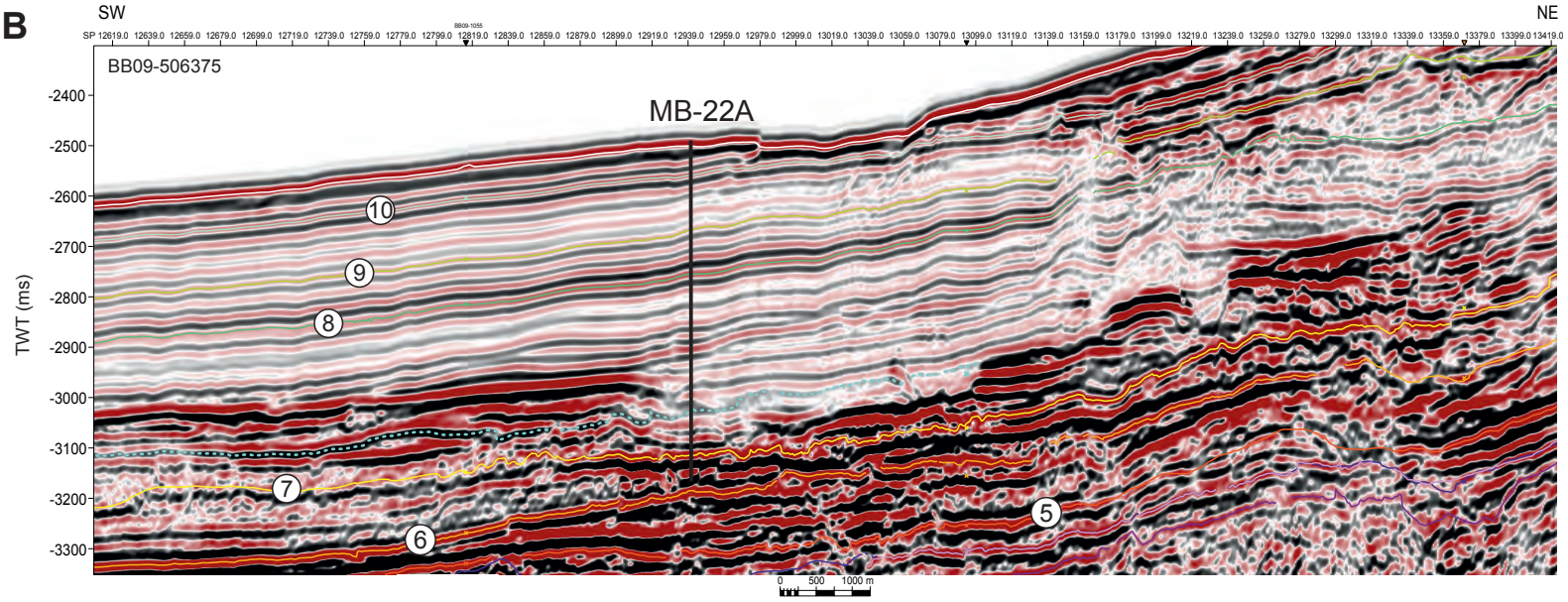
Additional information: Multibeam bathymetry, seismic velocity data

Site MB-22A: (A) Bathymetry map of the lower slope below the Melville Bugt Trough-Mouth Fan shown with 50 m depth contours. Crossing seismic lines are shown with shot points. **(B)** Seismic section shown with interpreted horizons. The strata package above target horizon 7, displaying a semi-continous reflection character, is interpreted as a contourite drift abounding a channel system. MB-22A is expected to recover silty-sandy muds; presumably of Early/Middle - Late Pleistocene age. Early depositional stage of unit 8 is marked by punctuated line.The site is placed between two crosslines to optimize stratigraphic coverage of unit 8 (beween horizons 7-8) and avoid drilling onto strong reflectures (e.g. channel sands).

A



B



IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover a high-resolution paleoceanographic record of a early/middle-late Pleistocene sediment drift system corresponding to the most recent part of the trough-mouth-fan history (scientific objectives 1 and 5). Site MB-2C targets an expanded interval of unit 8 and overlaps stratigraphically with the strata drilled at site MB-1C. Moreover, the site has potential for recovering stratified sediments of units 5-7. The site is located 3.8 km off nearest crossing line to optimize stratigraphic coverage and avoid intervals of slope re-deposition (e.g slumps). Requires drilling through ~150 m of younger fan/slope sediments.
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	MB-21A	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 73.6439	Jurisdiction:	Greenland
Longitude:	Deg: -64.8251	Distance to Land: (km)	223
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	1954

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	751	0
Total Sediment Thickness (m)	2500	
Total Penetration (m):	751	

General Lithologies: Clayey-silty mud with dropstones; thin mass-transport deposits/turbidites

Coring Plan: (Specify or check)

Hole A: APC to refusal (~250 mbsf)
Hole B: APC to refusal (~250 mbsf), XCB to TD; possibly flush through upper 150 m.

APC ☑ XCB ☑ RCB ☐ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☐			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 5.8 | Logging: 0.7 | Total On-site: 6.5

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other:

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IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-21A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: BB08-107 Position: 17032
2b Deep penetration seismic reflection (crossing)	yes	Line: BB07-208 Position: 23529
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	no	Multibeam
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-21A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Triple-APC/XCB; logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known
6. What "special" precautions will be taken during drilling?	Standard precautions
7. What abandonment procedures need to be followed?	Standard abandonment procedures
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard); gas-charged sands (unknown but site selected to avoid amplitude anomalies)

Proposal #: 909 - Full 2	Site #: MB-21A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

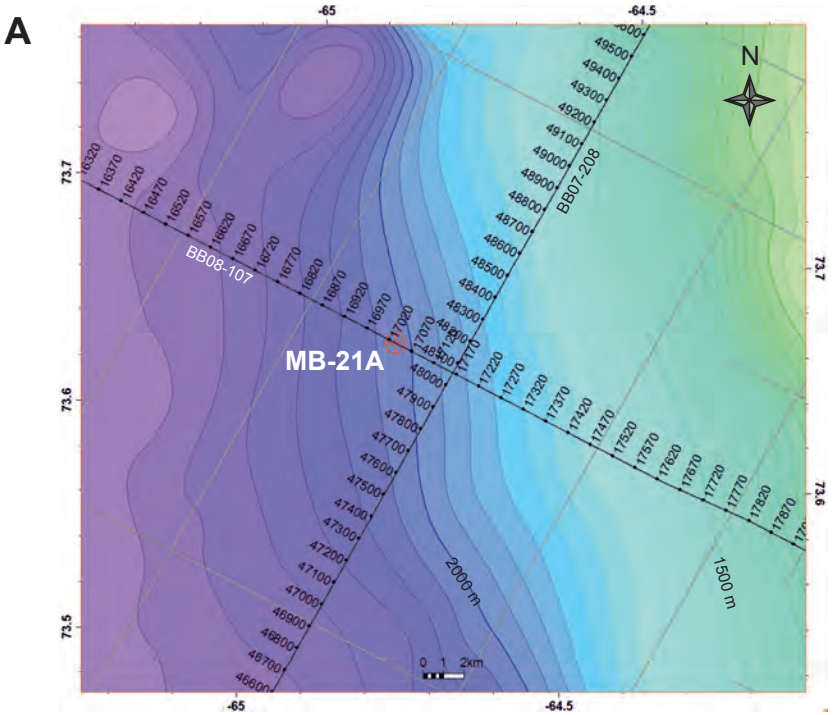
Proposal 909-Full-2 Site MB-21A (alternate)

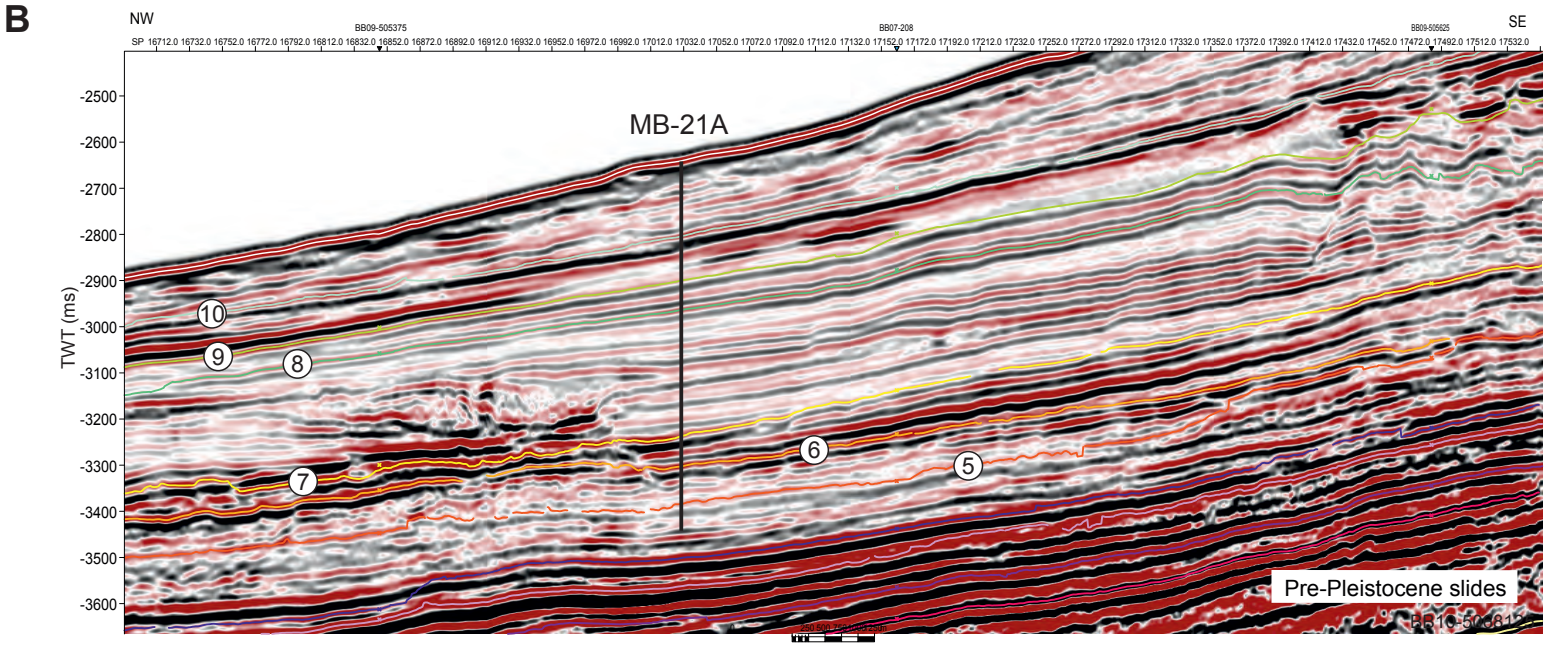
Scientific Objectives: 1 and 5

Coordinates: 73.6439; -64.8251
Shot point: 17032 (BB08-107)
Penetration: 751 m
Water depth: 1954 m

SSDB locations:
Location map: Map_MB-21A.jpg
Seismic data figure: BB08-107.jpg
SEG-Y data: BB08-107_crop.sgy
Navigation: bb08-107-navigation-utm-lat-lon.txt

Additional information: Seismic velocity data





Site MB-21A: (A) Bathymetry map of the upper slope below the Melville Bugt Trough-Mouth Fan shown with 50 m depth contours. The crossing seismic lines are shown with shot points. **(B)** Seismic section shown with interpreted horizons. Strata package above target horizon display a semi-continous reflection character with wavy-forms, interpreted as a slope contourite drift. MB-21A is expected to recover silty-sandy muds of likely Early - Late Pleistocene age. The site is located 3.8 km off nearest crossing line to optimize stratigraphic coverage of unit 8 and, recover relatively undisturbed strata between horizon 7 and 5 (depth target) and avoid intervals of slope (re)deposition (e.g slumps).

IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover deglacial and interglacial intervals of potentially early-middle Pleistocene age within top-set strata of the trough-mouth fan. High priority for scientific objectives 1 and 5. Site MB-8A penetrates a package of flat-lying, semi-continuous reflections that onlap glacial unconformities of units 6, 7, 8 and 9 (target depth is a positive reflection above horizon 6). The site is ~1 km offset from the nearest crossline to optimize recovery of the identified onlapping reflections.
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	MB-08A	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 73.4870	Jurisdiction:	Greenland
Longitude:	Deg: -62.2682	Distance to Land: (km)	197
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	497

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	370	0
Total Sediment Thickness (m)	4000	
Total Penetration (m):	370	

General Lithologies: Diamicton, mud with dropstones, sandy-silty mud

Coring Plan: (Specify or check)

Hole A: RBC to TD.
Hole B (optionally): If marine deposits are poorly recovered flush to relevant depth and resume by APC/XCB until refusion.

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 2.7 | Logging: 1 | Total On-site: 3.7

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☑	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: Compact gravel-rich seabed may be expected

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-08A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: BB10-5068125 Position: 15796 This data is currently confidential
2b Deep penetration seismic reflection (crossing)	yes	Line: BB09-10725 Position: 21378 This data is currently confidential
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Industry data
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling		
14a Water current data		
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-08A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	RCB coring; possibly APC/XCP, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known
6. What "special" precautions will be taken during drilling?	Standard precautions
7. What abandonment procedures need to be followed?	Fill hole with mud/heavy mud
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability); boulders in the shallow sediments (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard)

Proposal #: 909 - Full 2	Site #: MB-08A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-08A (Primary)

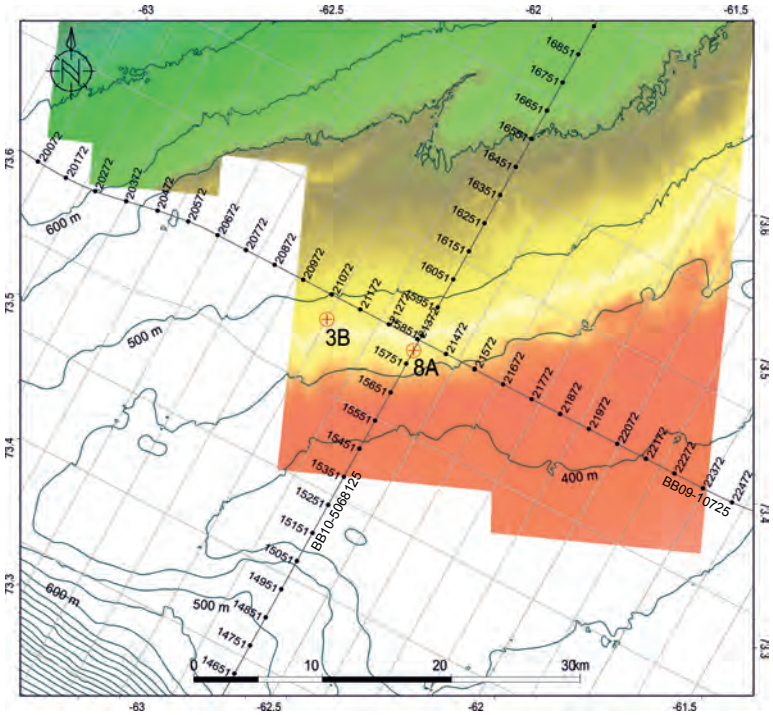
Scientific Objectives: 1 and 5

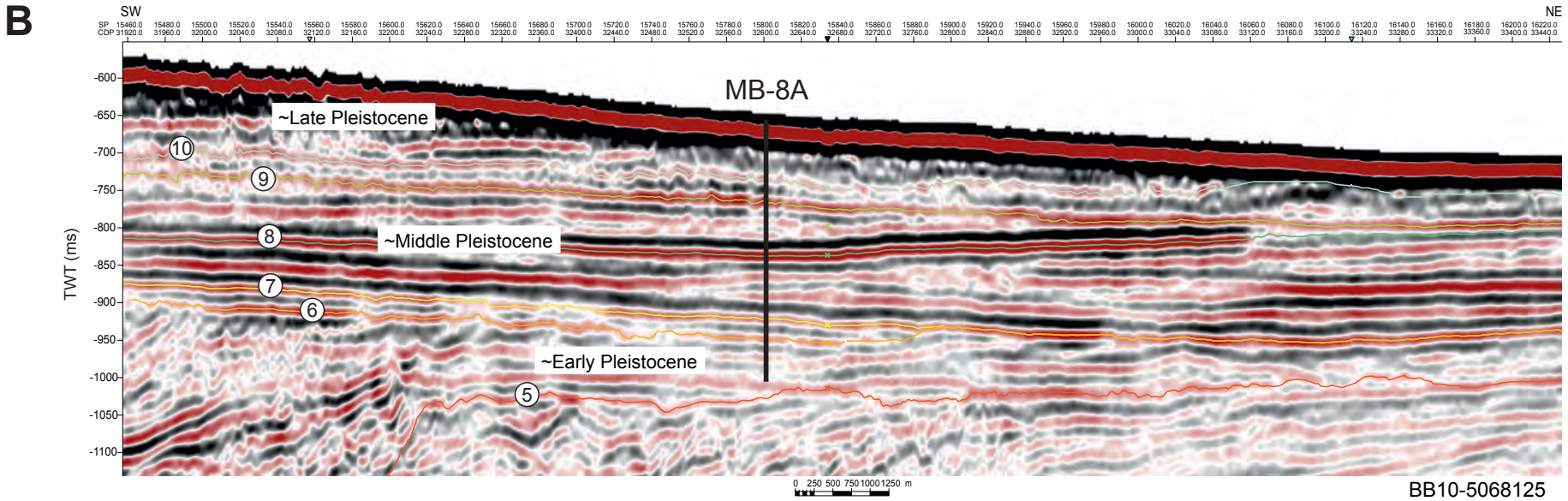
Coordinates:73.4870 ; -62.2682
Shot point: 15796 (BB10-5068125)
Penetration: 370 m
Water depth: 497 m

SSDB locations:
Location map: Map_MB-3B_MB-8A.jpg
Seismic data figure: BB10-5068125.jpg
SEG-Y data: bb10_line-5068125_flt-scl-stk_t101845_crop.sgy

Additional information: Multibeam, seismic velocity data

Site MB-8A: (A) Bathymetry map of the outer shelf margin of the Melville Bugt Trough-Mouth Fan shown with 50 m depth contours. The seismic lines crossing site MB-8A are shown with shot points. (**B**) Seismic section shown with interpreted horizons. Site MB-8A will recover the stratified section above seismic horizon 5. The expected lithologies are proximal glacigenic deposits, e.g. tills, interlayered with muddy marine/glacial-marine strata, probably of Early - Middle Pleistocene age. The site is placed ~1 km off the nearest crossline to optimize penetration of flatlying, onlapping reflections.





IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover deglacial and interglacial intervals of potentially early-middle Pleistocene age within top-set strata of the trough-mouth fan. High priority for scientific objectives 1 and 5. Site MB-3B penetrates a package of flat-lying, semi-continuous reflections that onlap glacial unconformities of units 6, 7, 8 and 9 (TD = top unit 6). The site is placed ~2.7 km off the nearest crossline to optimize recovery of onlapping reflections.
List Previous Drilling in Area	

Section B: General Site Information

Site Name:	MB-03B	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 73.5032	Jurisdiction:	Greenland
Longitude:	Deg: -62.4861	Distance to Land: (km)	190
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	498

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	375	0
Total Sediment Thickness (m)	4000	
Total Penetration (m):	375	

General Lithologies: Diamicton, mud with dropstones, sandy-silty mud

Coring Plan: (Specify or check)

Hole A: RBC to TD.
Hole B (optionally): If marine deposits are poorly recovered flush to relevant depth and resume by APC/XCB until refusion.

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 2.7 | Logging: 1 | Total On-site: 3.7

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☑	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: Compact gravel-rich seabed may be expected

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-03B	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: BB10-5066875 Position: 15463 This data is currently confidential
2b Deep penetration seismic reflection (crossing)	no	Line: BB09-10725 Position: 21096 This data is currently confidential
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	yes	Single Parasound profile
7 Swath bathymetry	yes	Industry data
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-03B	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	RCB coring; possibly APC/XCP, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	Not known
6. What "special" precautions will be taken during drilling?	Standard precautions
7. What abandonment procedures need to be followed?	Fill hole with mud/heavy mud
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability); boulders in the shallow sediments (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard)

Proposal #: 909 - Full 2	Site #: MB-03B	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-03B (alternate)

Scientific Objectives: 1 and 5

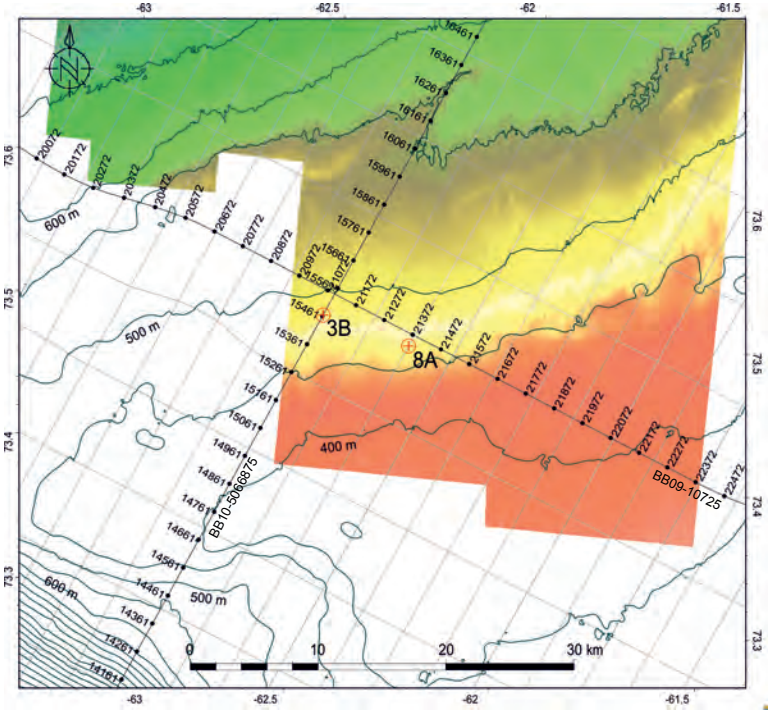
Coordinates: 73.5032; -62.4861
Shot point: 15463 (BB10-5066875)
Penetration: 375 m
Water depth: 498 m

SSDB locations:
Location map: Map_MB-3B_MB-8A.jpg
Seismic data figure: BB10-5066875.jpg
SEG-Y data: bb10_line-5066875_flt-scl-stk_t101845_crop.sgy

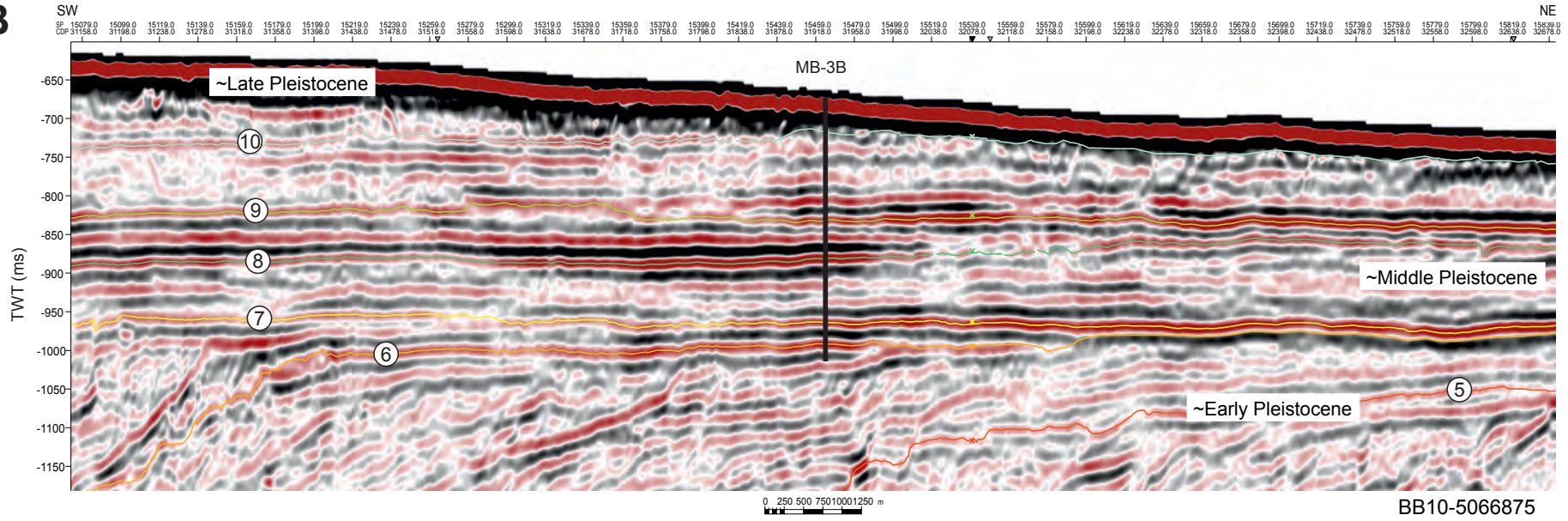
Additional information: Multibeam, seismic velocity data

Site MB-3B: (A) Bathymetry map of the outer shelf margin of the Melville Bugt Trough-Mouth Fan shown with 50 m depth contours. The seismic lines crossing site MB-3B are shown with shot points. (**B**) Seismic section shown with interpreted horizons. Site MB-3B will recover the stratified section above seismic 6 (depth target). The expected lithologies are proximal glacigenic deposits, e.g. tills, interlayered with muddy marine/glacial-marine strata, probably of Early - Middle Pleistocene age. The site is placed ~2.7 km off the nearest crossline to optimize penetration of flatlying, onlapping reflections.

A



B



IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover deglacial and interglacial intervals of potentially early Pleistocene age within top-set strata of the trough-mouth fan (scientific objectives 1 and 5). MB-4B penetrates a package of flat-lying, semi-continuous reflections that onlap a major glacial unconformity (horizon 3). Depth target is a positive-phase horizon within an upper slope front segment of unit 3. MB-4B is offset ~2.5 km from nearest crossline to achieve optimal stratigraphic overage of units 3-4. The site is a primary location due to well-defined onlapping reflections reachable within ~300 mbsf.
List Previous Drilling in Area	Exp. 344S; sites U0100 and U0110 (distance 101 km toward N)

Section B: General Site Information

Site Name:	MB-04B	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#		Jurisdiction:	Greenland
Latitude:	Deg: 73.8711	Distance to Land: (km)	150
Longitude:	Deg: -62.0342		
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	630

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	340	0
Total Sediment Thickness (m)	5500	
Total Penetration (m):	340	

General Lithologies: Diamicton, mud with dropstones, sandy-silty mud

Coring Plan: (Specify or check)

Hole A: RBC to TD.
Hole B (optionally): If marine deposits are poorly recovered flush to relevant depth and resume by APC/XCB until refusion.

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☐			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 2.4 | Logging: 0.6 | Total On-site: 3

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☑	Complicated Seabed Condition	☑	Hydrothermal Activity	☐	July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents)

Other: Compact gravel-rich seabed may be expected

Proposal #: 909 - Full 2	Site #: MB-04B	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: BB10-506625 Position: 17131 This data is currently confidential
2b Deep penetration seismic reflection (crossing)	yes	Line: BB08-108 Position: 24810
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Industry data
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-04B	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	RCB coring; possibly APC/XCP, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known
6. What "special" precautions will be taken during drilling?	Standard precautions
7. What abandonment procedures need to be followed?	Fill hole with mud/heavy mud
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability); boulders in the shallow sediments(low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard)

Proposal #: 909 - Full 2	Site #: MB-04B	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-04B (primary)

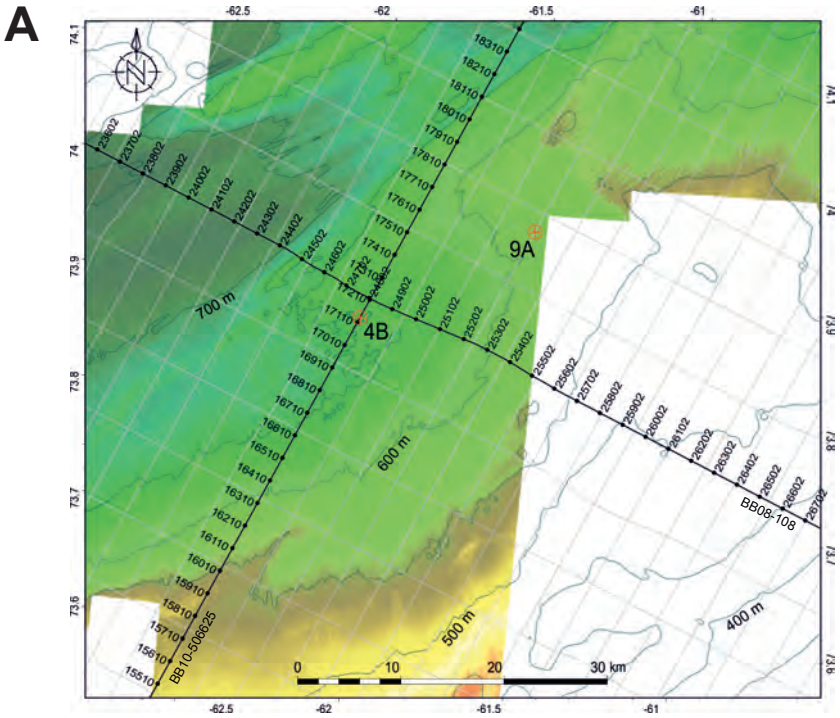
Scientific Objectives: 1 and 5

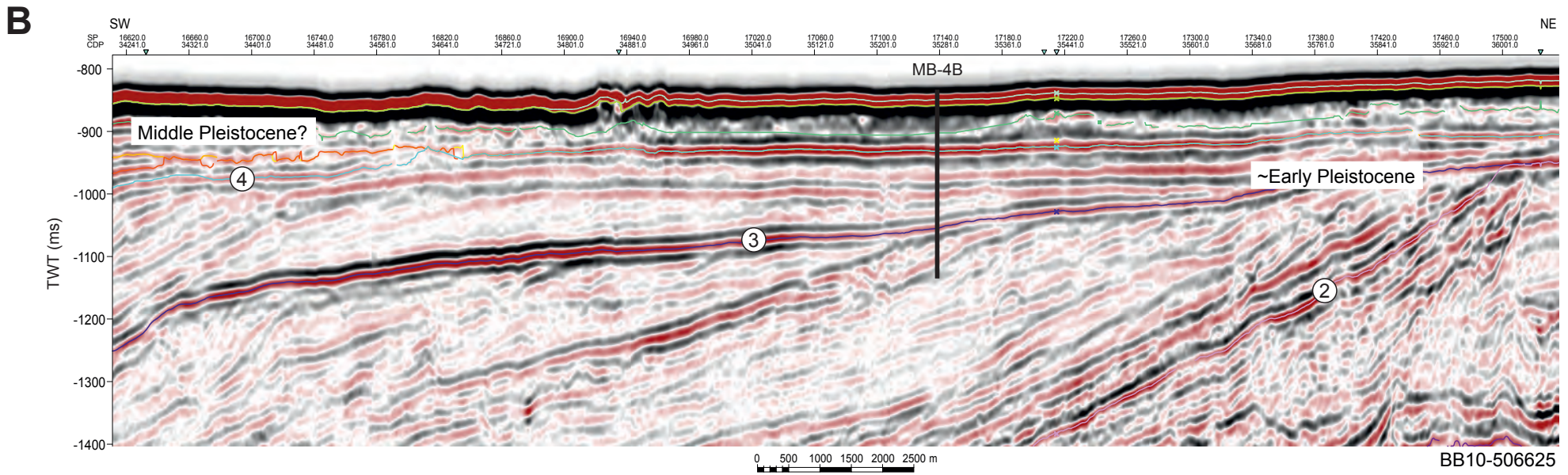
Coordinates:73.8711; -62.0342
Shot point: 17131 (BB10-506625)
Penetration: 340 m
Water depth: 630 m

SSDB locations:
Location map: Map_MB-4B_MB-5B_MB-6B_MB-9A.jpg
Seismic data figure: BB10-506625.jpg
SEG-Y data: bb10_line-506625_flt-scl-stk_t101845_crop.sgy

Additional information: 3D seismic data, multibeam, seismic velocity data,

Site MB-4B: (A) Multibeam bathymetry map of the middle shelf region south of the Melville Bugt trough shown with 50 m depth contours. Seismic crossing lines are displayed with shot points.(**B**) Key seismic section with interpreted horizons and ages. MB-4B captures the pinch-out of seismic unit 4 that onlaps onto horizon 3. Depth target is a positive-phase horizon within slope front segment of unit 3. The site is expected to recover proximal glacigenic deposits, e.g. tills, interlayered with muddy marine/glacial-marine strata, probably of Early Pleistocene age. MB-4B is offset 2.5 km from nearest crossline to achieve optimal stratigraphic coverage of units 3-4.





IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover deglacial and interglacial intervals of potentially early Pleistocene age within top-set strata of the trough-mouth fan (scientific objectives 1 and 5). The site targets strata that onlap horizon 1 (top of oldest prograding unit). Site MB-09A is alternate to MB-4B due to reduced imaging quality of reflection onlaps and stratigraphic coverage. The site is located ~1 km offset from nearest crossing line to achieve optimal penetration of onlapping deposits.
List Previous Drilling in Area	Exp. 344S; sites U0100 and U0110 (distance 95 km toward N)

Section B: General Site Information

Site Name:	MB-09A	Area or Location:	Melville Bay, NE Greenland
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 73.9650	Jurisdiction:	Greenland
Longitude:	Deg: -61.4959	Distance to Land: (km)	133
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	580

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	270	0
Total Sediment Thickness (m)	5500	
Total Penetration (m):	270	

General Lithologies: Diamicton, mud with dropstones, sandy-silty mud

Coring Plan: (Specify or check)

Hole B (optionally): If marine deposits are poorly recovered flush to relevant depth and resume by APC/XCB until refusion

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☐			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 2.2 | Logging: 0.6 | Total On-site: 2.8

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☑	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: Compact gravel-rich seabed may be expected

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-09A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: BB10-5068125 Position: 18138 This data is currently confidential
2b Deep penetration seismic reflection (crossing)	no	Line: BB09-10825 Position: 24705 This data is currently confidential
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Industry data
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-09A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	RCB coring; possibly APC/XCP, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known
6. What "special" precautions will be taken during drilling?	Standard precautions
7. What abandonment procedures need to be followed?	Fill hole with mud/heavy mud
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability); boulders in the shallow sediments(low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard)

Proposal #: 909 - Full 2	Site #: MB-09A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-09A (alternate)

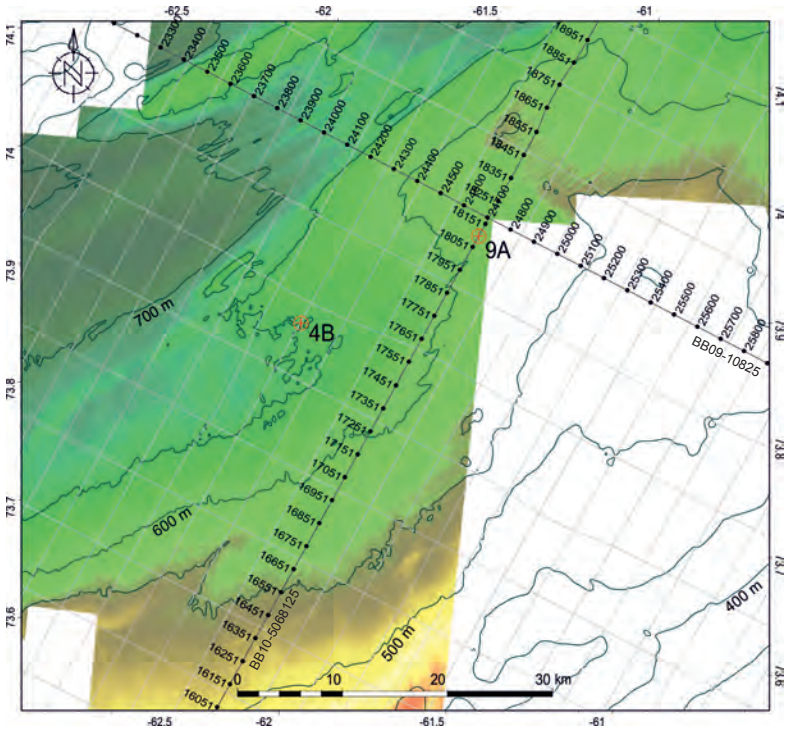
Scientific Objectives: 1 and 5

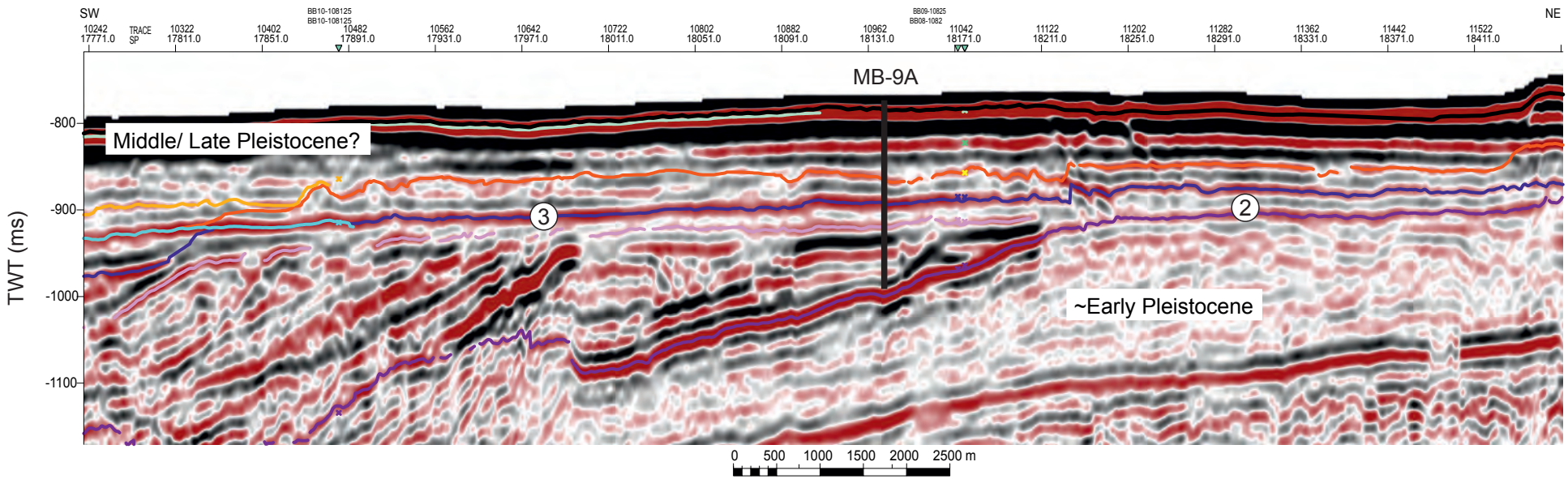
Coordinates: 73.9650; -61.4959
Shot point: 18138 (BB10-5068125)
Penetration: 270 m
Water depth: 580 m

SSDB locations:
Location map: Map_MB-4B_MB-5B_MB-6B_MB-9A.jpg
Seismic data figure: Not uploaded
SEG-Y data: bb10_line-5068125_flt-scl-stk_t101845_crop.sgy

Additional information: Multibeam, seismic velocity data

Site MB-9A: (A) Multibeam bathymetry map of the middle shelf region south of the Melville Bugt trough shown with 50 m depth contours. Seismic crossing lines are displayed with shot points. (**B**) Key seismic section with interpreted horizons and ages. MB-9A captures the pinch-out of seismic unit 3 that onlaps onto horizon 2 (depth taget). The site is expected to recover proximal glacigenic deposits, e.g. tills, interlayered with muddy marine/glacial-marine strata, probably of Early Pleistocene age.





IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	(1) Capture a thin wedge of progradational deposits that may correspond to the earliest shelf-based glaciations in NW Greenland; (2) Recover Neogene contourite drift sediments of likely Pliocene age that can elucidate paleoceanographic conditions prior to the major basinward expansion of the Greenland Ice Sheet (scientific objectives 3, 4 and 6). MB-5B targets the stratigraphically younger interval of the drift deposit that overlaps with the section drilled at site MB-6C. The site is located within the ANU-3D cube. Selected as primary site due to most optimal recovery of the youngest sediments.
List Previous Drilling in Area	Exp. 344S; sites U0100 and U0110 (distance 72 km toward NNW)

Section B: General Site Information

Site Name:	MB-05B	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 74.2116	Jurisdiction:	Greenland
Longitude:	Deg: -61.3397	Distance to Land: (km)	120
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	704

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	520	0
Total Sediment Thickness (m)	4000	
Total Penetration (m):	520	

General Lithologies: Silty to sandy mudstone; gravel-rich sands and muds (upper 50 m).

Coring Plan: (Specify or check): Single hole RCB to TD

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☐			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 3 | Logging: 0.6 | Total On-site: 3.6

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☑	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: Compact gravel-rich seabed may be expected

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-05B	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: BB10-5066875 Position: 18932 This data is currently confidential
2b Deep penetration seismic reflection (crossing)	no	Line: BB10-108625 Position: 25070 This data is currently confidential
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Industry data
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-05B	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single hole RCB, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known. Sites 5B, 6C, 13A, 14A and 15A have been identified based on Shells ANU-3D cube. No major anomalies were observed and minor anomalies were avoided.
6. What "special" precautions will be taken during drilling?	Closely monitoring of headspace gas using the protocol developed during the Exp. 344S that drilled into Cretaceous sediments north of the proposed sites.
7. What abandonment procedures need to be followed?	Fill hole with heavy mud
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability), boulders, gas sands (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard). Gas-charged sands (unknown but obvious seismic amplitude anomalies are avoided).

Proposal #: 909 - Full 2	Site #: MB-05B	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-5B (primary)

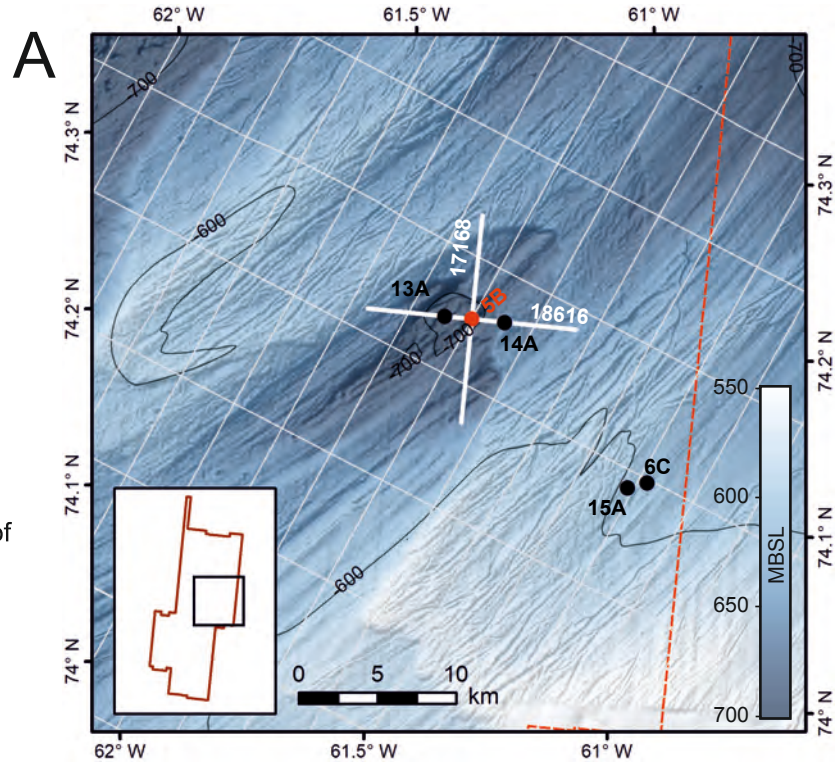
Scientific Objectives: 3, 4 and 6

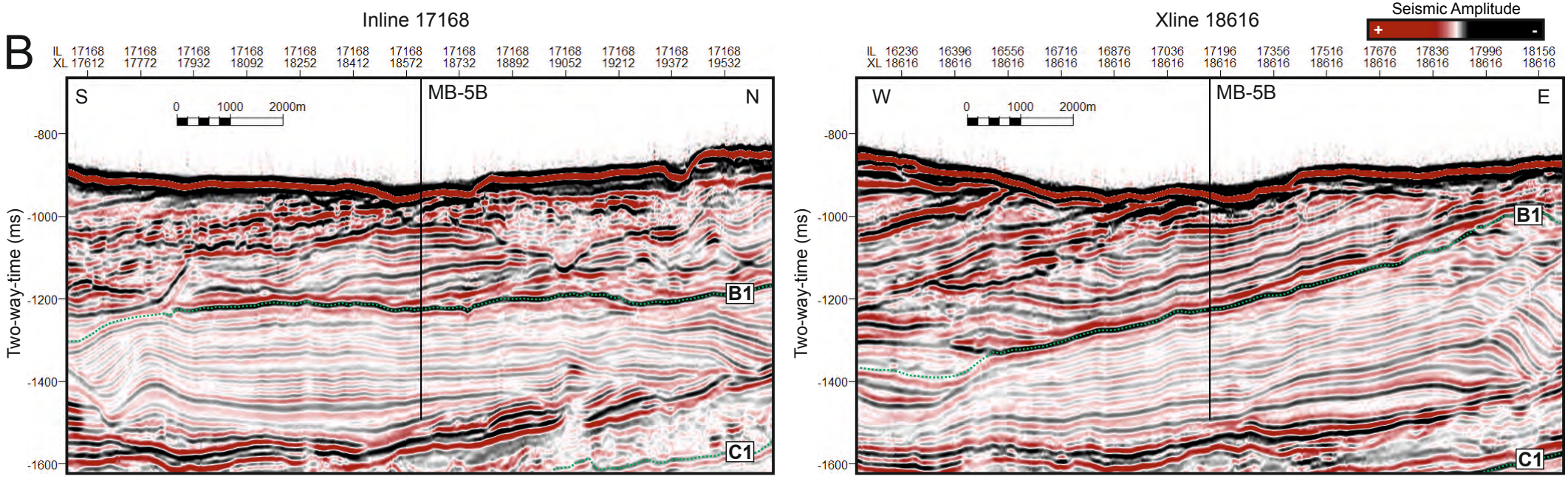
Coordinates: 74.21160000; -61.33970000
Inline-Xline Number: 17168, 18616
Penetration: 520 m
Water Depth: 704 m

SSDB locations:
Location map: Map_MB-5B.jpg
Seismic data figure: Site-5B_ANU-3D_IL-17168.jpg, Site-5B_ANU-3D_XL-18616.jpg
SEG-Y data: Site-5B_ANU-3D_IL-17168.segy, Site-5B_ANU-3D_XL-18616.segy
Navigation: Site-5B_ANU-3D_IL-17168_nav.txt, Site-5B_ANU-3D_XL-18616_nav.txt

Additional information: seismic velocities, horizon grids

Site MB-5B: Drill site aimed at recovering a composite sequence of high-accumulation-rate contourite drifts of mega-unit B (likely Pliocene age) and the earliest glacial clinoforms of mega-unit A (late Pliocene and Early Pleistocene). (**A**) Shaded relief bathymetry map of the middle shelf region within the Melville Bugt Trough, shown with 100 m contours. Seismic crossing lines displayed in panel (B) are shown in the thick white. Thin white lines show the 2D seismic grid. Inset shows the areal coverage of 3D seismic data used to help refine target location. Black circles shows the proposed alternate drill site location and the red circle shows the drill site location for MB-5B. (**B**) Key Inline and Xline seismic sections from the 3D seismic cube (zero-phase). Mega-unit boundaries are shown.





IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	(1) Capture a thin wedge of progradational deposits that may correspond to the earliest shelf-based glaciations in NW Greenland; (2) Recover Neogene contourite drift sediments of likely Pliocene age that can elucidate paleoceanographic conditions prior to the major basinward expansion of the Greenland Ice Sheet (scientific objectives 3, 4 and 6). Site MB-13A (alternate for 5B) targets the stratigraphically younger interval of the drift deposit that overlaps with the section drilled at site MB-6C. The site is located within the ANU-3D cube.
List Previous Drilling in Area	Exp. 344S; sites U0100 and U0110 (distance 70 km toward NNW)

Section B: General Site Information

Site Name:	MB-13A	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 74.2118	Jurisdiction:	Greenland
Longitude:	Deg: -61.3958	Distance to Land: (km)	121
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	707

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	540	0
Total Sediment Thickness (m)	4000	
Total Penetration (m):	540	

General Lithologies: Silty to sandy mudstone; gravel-rich sands and muds (upper 50 m).

Coring Plan: (Specify or check): Single hole RCB to TD

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☐			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 3 | Logging: 0.6 | Total On-site: 3.6

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☑	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: Compact gravel-rich seabed may be expected

Proposal #: 909 - Full 2	Site #: MB-13A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)		
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)	yes	Line: Site-13A_ANU-3D_IL-16896.segy Position: 16896
2b Deep penetration seismic reflection (crossing)	yes	Line: Site-13A_ANU-3D_XL-18616.segy Position: 18616
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		
7 Swath bathymetry		
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation	yes	
17 Other		

Proposal #: 909 - Full 2	Site #: MB-13A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single hole RCB, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known. Sites 5B, 6C, 13A, 14A and 15A have been identified based on Shells ANU-3D cube. No major anomalies were observed and minor anomalies were avoided.
6. What "special" precautions will be taken during drilling?	Closely monitoring of headspace gas using the protocol developed during the Exp. 344S that drilled into Cretaceous sediments north of the proposed sites.
7. What abandonment procedures need to be followed?	Fill hole with heavy mud
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability), boulders, gas sands (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard). Gas-charged sands (unknown but obvious seismic amplitude anomalies are avoided).

Proposal #: 909 - Full 2	Site #: MB-13A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-13A (alternate)

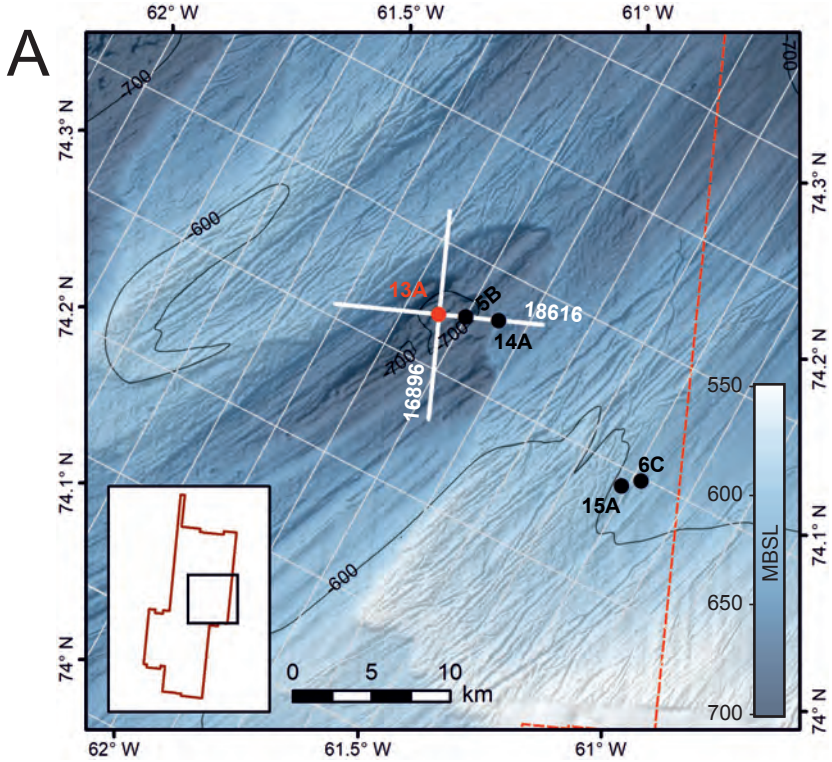
Scientific Objectives: 3, 4 and 6

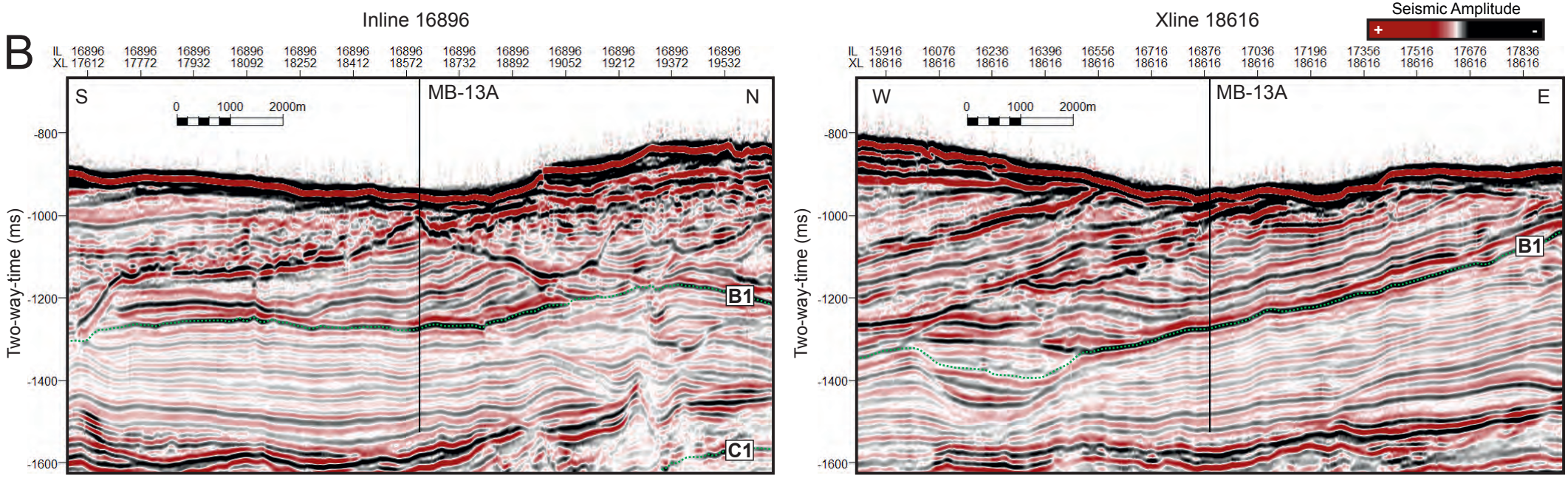
Coordinates: 74.21184154; -61.39578223
Inline-Xline Number: 16896, 18616
Penetration: 540 m
Water Depth: 707 m

SSDB locations:
Location map: Map_MB-13A.jpg
Seismic data figure: Site-13A_ANU-3D_IL-16896.jpg, Site-13A_ANU-3D_XL-18616.jpg
SEG-Y data: Site-13A_ANU-3D_IL-16896.segy, Site-13A_ANU-3D_XL-18616.segy
Navigation: Site-13A_ANU-3D_IL-16896_nav.txt, Site-13A_ANU-3D_XL-18616_nav.txt

Additional information: seismic velocities, horizon grids

Site MB-13A: Drill site aimed at recovering a composite sequence of high-accumulation-rate contourite drifts of mega-unit B (likely Pliocene age) and the earliest glacial clinoforms of mega-unit A (late Pliocene and Early Pleistocene). (**A**) Shaded relief bathymetry map of the middle shelf region within the Melville Bugt Trough, shown with 100 m contours. Seismic crossing lines displayed in panel (B) are shown in the thick white. Thin white lines show the 2D seismic grid. Inset shows the areal coverage of 3D seismic data used to help refine target location. Black circles shows the proposed alternate drill site location and the red circle shows the drill site location for MB-13A. (**B**) Key Inline and Xline seismic sections from the 3D seismic cube (zero-phase). Mega-unit boundaries are shown.





IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	(1) Capture a thin wedge of progradational deposits that may correspond to the earliest shelf-based glaciations in NW Greenland; (2) Recover Neogene contourite drift sediments of likely Pliocene age that can elucidate paleoceanographic conditions prior to the major basinward expansion of the Greenland Ice Sheet (scientific objectives 3, 4 and 6). Site MB-14A (alternate for 5B) targets the stratigraphically younger interval of the drift deposit that overlaps with the section drilled at site MB-6C. The site is located within the ANU-3D cube.
List Previous Drilling in Area	Exp. 344S; sites U0100 and U0110 (distance 72 km toward NNW)

Section B: General Site Information

Site Name:	MB-14A	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 74.2109	Jurisdiction:	Greenland
Longitude:	Deg: -61.2704	Distance to Land: (km)	117
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	663

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	510	0
Total Sediment Thickness (m)	4000	
Total Penetration (m):	510	

General Lithologies: Silty to sandy mudstone; gravel-rich sands and muds (upper 50 m).

Coring Plan: (Specify or check)

Single hole RCB to TD.

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☐			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 3 | Logging: 0.6 | Total On-site: 3.6

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☑	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: Compact gravel-rich seabed may be expected

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-14A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)		
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)	yes	Line: Site-14A_ANU-3D_IL-17504.segy Position: 17504
2b Deep penetration seismic reflection (crossing)	yes	Line: Site-14A_ANU-3D_XL-18616.segy Position: 18616
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		
7 Swath bathymetry		
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation	yes	
17 Other		

Proposal #: 909 - Full 2	Site #: MB-14A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single hole RCB, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known. Sites 5B, 6C, 13A, 14A and 15A have been identified based on Shells ANU-3D cube. No major anomalies were observed and minor anomalies were avoided.
6. What "special" precautions will be taken during drilling?	Closely monitoring of headspace gas using the protocol developed during the Exp. 344S that drilled into Cretaceous sediments north of the proposed sites.
7. What abandonment procedures need to be followed?	Fill hole with heavy mud
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability), boulders, gas sands (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard). Gas-charged sands (unknown but obvious seismic amplitude anomalies are avoided).

Proposal #: 909 - Full 2	Site #: MB-14A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-14A (alternate)

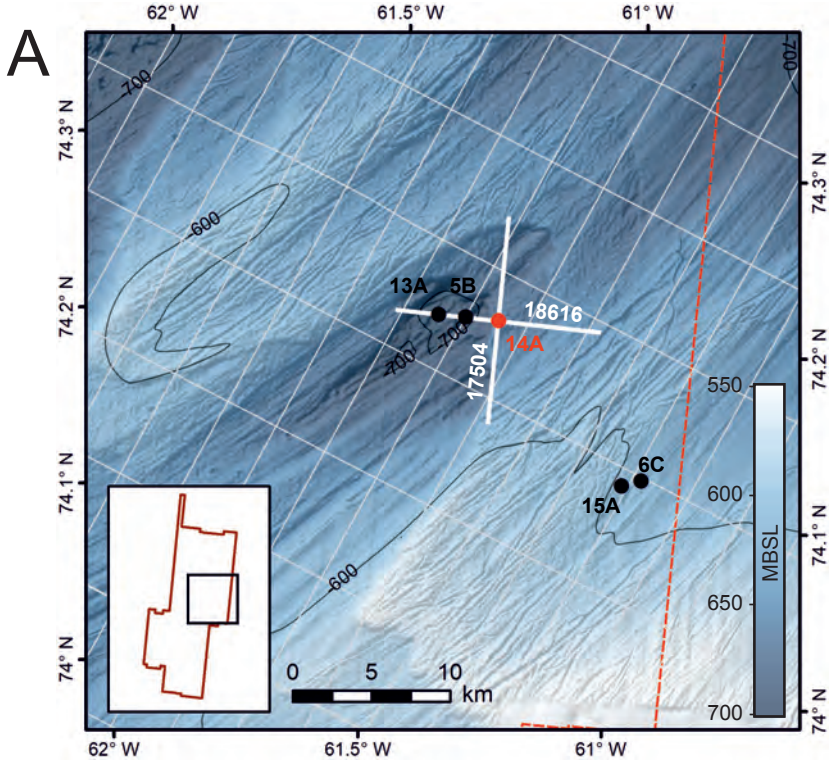
Scientific Objectives: 3, 4 and 6

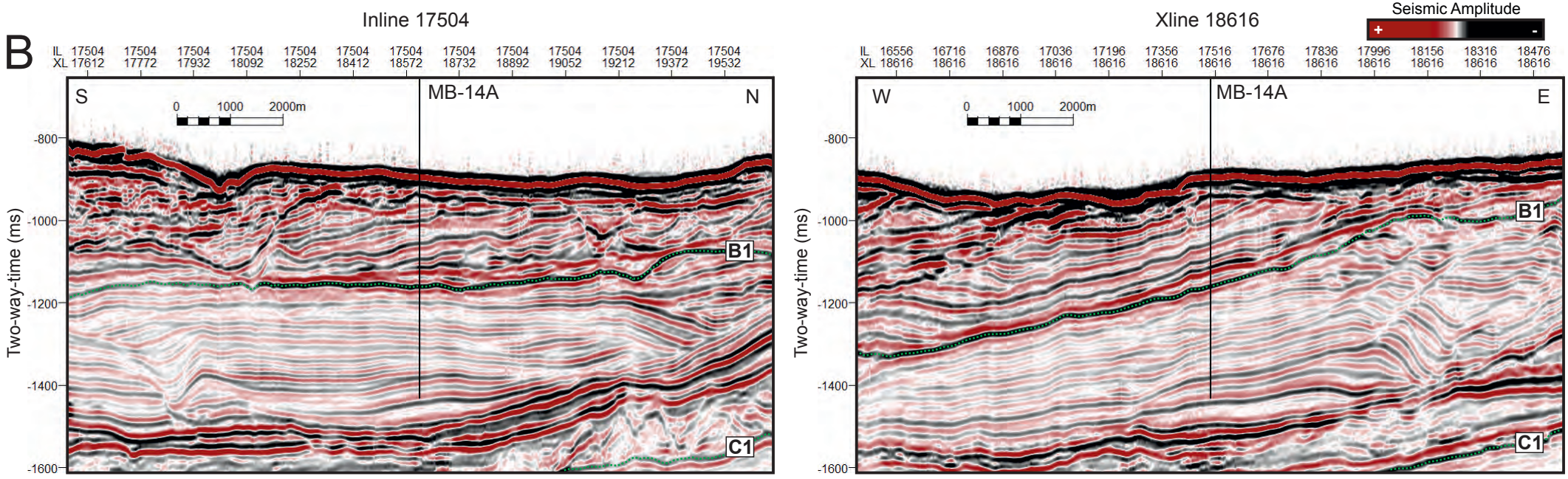
Coordinates: 74.21088557; -61.27037114
Inline-Xline Number: 17504, 18616
Penetration: 510 m
Water Depth: 663 m

SSDB locations:
Location map: Map_MB-14A.jpg
Seismic data figure: Site-14A_ANU-3D_IL-17504.jpg, Site-14A_ANU-3D_XL-18616.jpg
SEG-Y data: Site-14A_ANU-3D_IL-17504.segy, Site-14A_ANU-3D_XL-18616.segy
Navigation: Site-14A_ANU-3D_IL-17504_nav.txt, Site-14A_ANU-3D_XL-18616_nav.txt

Additional information: seismic velocities, horizon grids

Site MB-14A: Drill site aimed at recovering a composite sequence of high-accumulation-rate contourite drifts of mega-unit B (likely Pliocene age) and the earliest glacial clinoforms of mega-unit A (late Pliocene and Early Pleistocene). (**A**) Shaded relief bathymetry map of the middle shelf region within the Melville Bugt Trough, shown with 100 m contours. Seismic crossing lines displayed in panel (B) are shown in the thick white. Thin white lines show the 2D seismic grid. Inset shows the areal coverage of 3D seismic data used to help refine target location. Black circles shows the proposed alternate drill site location and the red circle shows the drill site location for MB-14A. (**B**) Key Inline and Xline seismic sections from the 3D seismic cube (zero-phase). Mega-unit boundaries are shown.





IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover Neogene contourite drift sediments of likely Pliocene age that can elucidate paleoceanographic conditions prior to the major basinward expansion of the Greenland Ice Sheet (scientific objectives 3, 4 and 6). Site MB-6C overlaps stratigraphically with the lowermost section drilled at site MB-5B (and alternates 13A and 14A). The main target is an expanded section of the drift deposit that may contain a high-resolution early Pliocene record. TD is placed 30 ms below a prominent reflection draping over a slide scar. MB-6C is located within the ANU-3D cube.
List Previous Drilling in Area	Exp. 344S; sites U0100 and U0110 (distance 85 km toward NNW)

Section B: General Site Information

Site Name:	MB-06C	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 74.1254	Jurisdiction:	Greenland
Longitude:	Deg: -60.9510	Distance to Land: (km)	115
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	609

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	620	0
Total Sediment Thickness (m)	3000	
Total Penetration (m):	620	

General Lithologies: Silty to sandy mudstone

Coring Plan: (Specify or check)

Single hole RCB to TD

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 3.4 | Logging: 1.4 | Total On-site: 4.8

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☑	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: Compact gravel-rich seabed may be expected

Proposal #: 909 - Full 2	Site #: MB-06C	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: Site-6C_ANU-3D_XL-17140.segy Position: 17140 This is data extracted from Shell-ANU-3D seismic volume
2b Deep penetration seismic reflection (crossing)	yes	Line: Site-6C_ANU-3D_IL-19108.segy Position: 19108 This is data extracted from Shell-ANU-3D seismic volume
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Industry data
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	Navigation file extracted from SEGY
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-06C	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single hole RCB, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	No
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known. Sites 5B, 6C, 13A, 14A and 15A have been identified based on Shells ANU-3D cube. No major anomalies were observed and minor anomalies were avoided.
6. What "special" precautions will be taken during drilling?	Closely monitoring of headspace gas using the protocol developed during the Exp. 344S that drilled into Cretaceous sediments north of the proposed sites.
7. What abandonment procedures need to be followed?	Fill hole with heavy mud
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability), boulders, gas sands (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard). Gas-charged sands (unknown but obvious seismic amplitude anomalies are avoided).

Proposal #: 909 - Full 2	Site #: MB-06C	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-6C (primary)

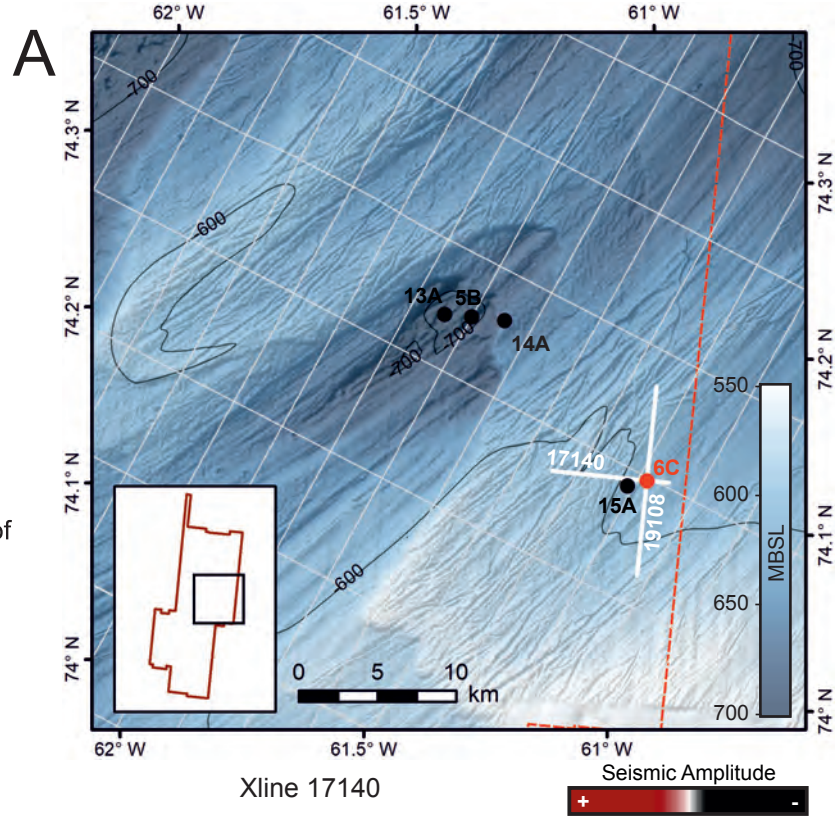
Scientific Objectives: 3, 4 and 6

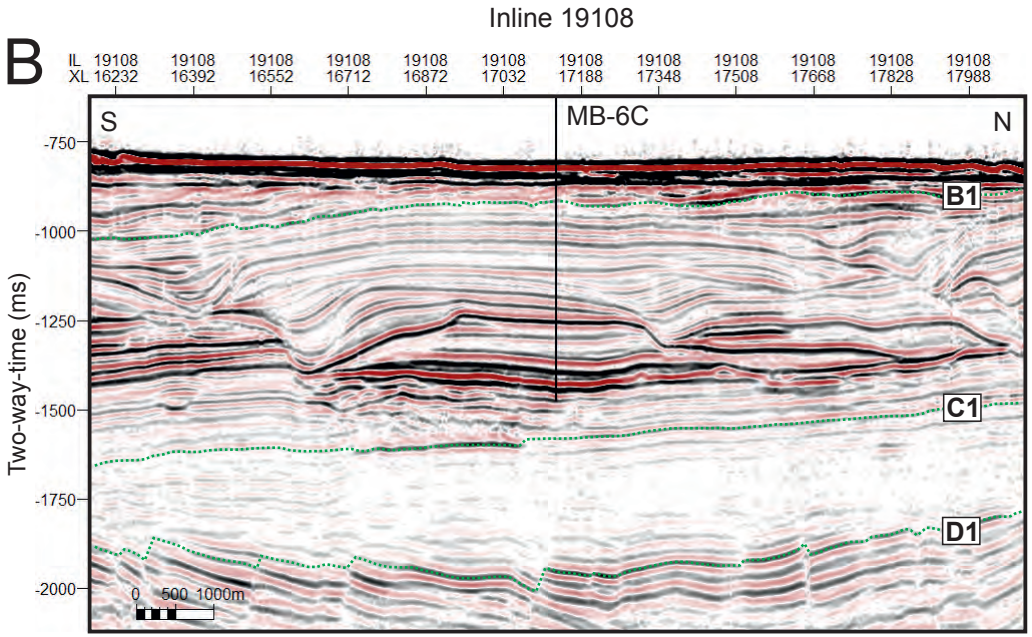
Coordinates: 74.12540379; -60.95100154
Inline-Xline Number: 19108, 17140
Penetration: 620 m
Water Depth: 609 m

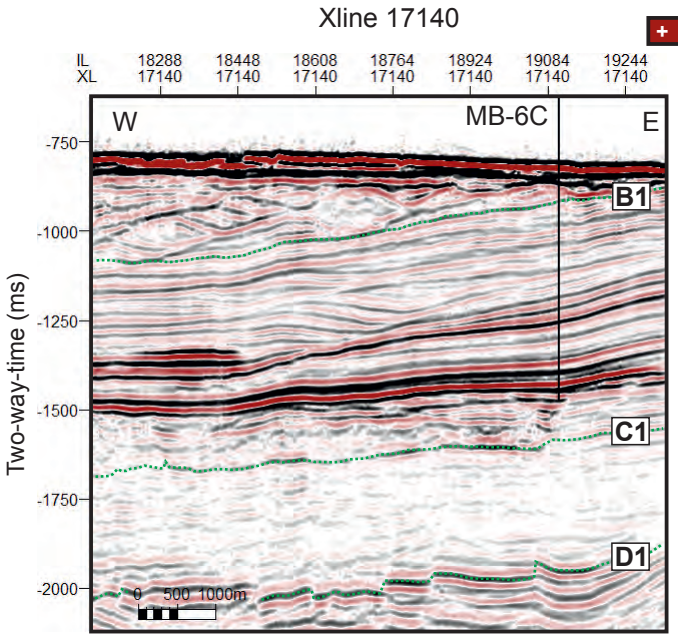
SSDB locations:
Location map: Map_MB-6C.jpg
Seismic data figure: Site-6C_ANU-3D_IL-19108.jpg, Site-6C_ANU-3D_XL-17140.jpg
SEG-Y data: Site-6C_ANU-3D_IL-19108.segy, Site-6C_ANU-3D_XL-17140.segy
Navigation: Site-6C_ANU-3D_IL-19108_nav.txt, Site-6C_ANU-3D_XL-17140_nav.txt

Additional information: seismic velocities, horizon grids, multibeam data

Site MB-6C: Drill site aimed at recovering a composite sequence of high-accumulation-rate contourite drifts of mega-unit B (likely Pliocene age) and the earliest glacial clinoforms of mega-unit A (late Pliocene and Early Pleistocene). (**A**) Shaded relief bathymetry map of the middle shelf region within the Melville Bugt Trough, shown with 100 m contours. Seismic crossing lines displayed in panel (B) are shown in the thick white. Thin white lines show the 2D seismic grid. Inset shows the areal coverage of 3D seismic data used to help refine target location. Black circles shows the proposed alternate drill site location and the red circle shows the drill site location for MB-6C. (**B**) Key Inline and Xline seismic sections from the 3D seismic cube (zero-phase). Mega-unit boundaries are shown.







IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover Neogene contourite drift sediments of likely Pliocene age that can elucidate paleoceanographic conditions prior to the major basinward expansion of the Greenland Ice Sheet (scientific objectives 3, 4 and 6). Site MB-15A overlaps stratigraphically with the lowermost section drilled at site MB-5B (and alternates 13A and 14A). The main target is an expanded section of the drift deposit that may contain a high-resolution early Pliocene record. TD is placed 30 ms below a prominent reflection draping over a slide scar. High priority for scientific objectives 3, 4 and 6. MB-15A is located within the ANU-3D cube.
List Previous Drilling in Area	Exp. 344S; sites U0100 and U0110 (distance 85 km toward NNW)

Section B: General Site Information

Site Name:	MB-15A	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 74.1217	Jurisdiction:	Greenland
Longitude:	Deg: -60.9909	Distance to Land: (km)	111
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	605

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	625	0
Total Sediment Thickness (m)	3000	
Total Penetration (m):	625	

General Lithologies: Silty to sandy mudstone

Coring Plan: (Specify or check)

Single hole RCB to TD

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 3.4 | Logging: 1.4 | Total On-site: 4.8

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☑	Hydrothermal Activity	☐	Preferred weather window
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents)

Other: Compact gravel-rich seabed may be expected

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-15A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)		
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)	yes	Line: Site-15A_ANU-3D_IL-18916.segy Position: 18916
2b Deep penetration seismic reflection (crossing)	yes	Line: Site-15A_ANU-3D_XL-17068.segy Position: 17068
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		
7 Swath bathymetry		
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation	yes	
17 Other		

Proposal #: 909 - Full 2	Site #: MB-15A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single hole RCB, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	None that we are aware of
5. Are there reasons to expect hydrocarbon accumulations at this site?	None known. Sites 5B, 6C, 13A, 14A and 15A have been identified based on Shells ANU-3D cube. No major anomalies were observed and minor anomalies were avoided.
6. What "special" precautions will be taken during drilling?	Closely monitoring of headspace gas using the protocol developed during the Exp. 344S that drilled into Cretaceous sediments north of the proposed sites.
7. What abandonment procedures need to be followed?	Fill hole with heavy mud
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability), boulders, gas sands (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard). Gas-charged sands (unknown but obvious seismic amplitude anomalies are avoided).

Proposal #: 909 - Full 2	Site #: MB-15A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-15A (alternate)

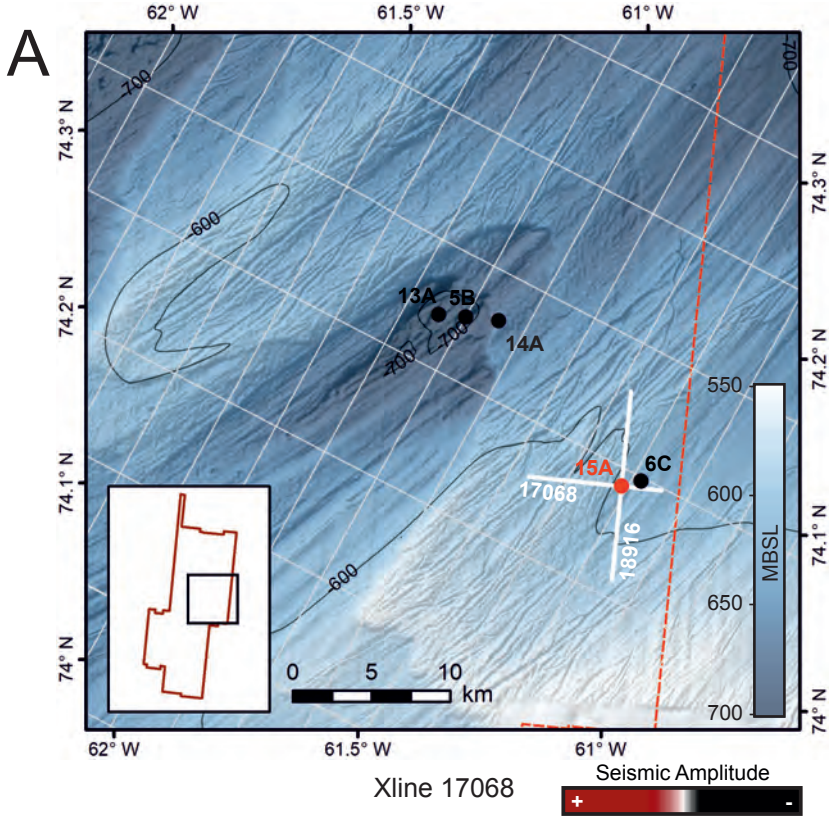
Scientific Objectives: 3, 4 and 6

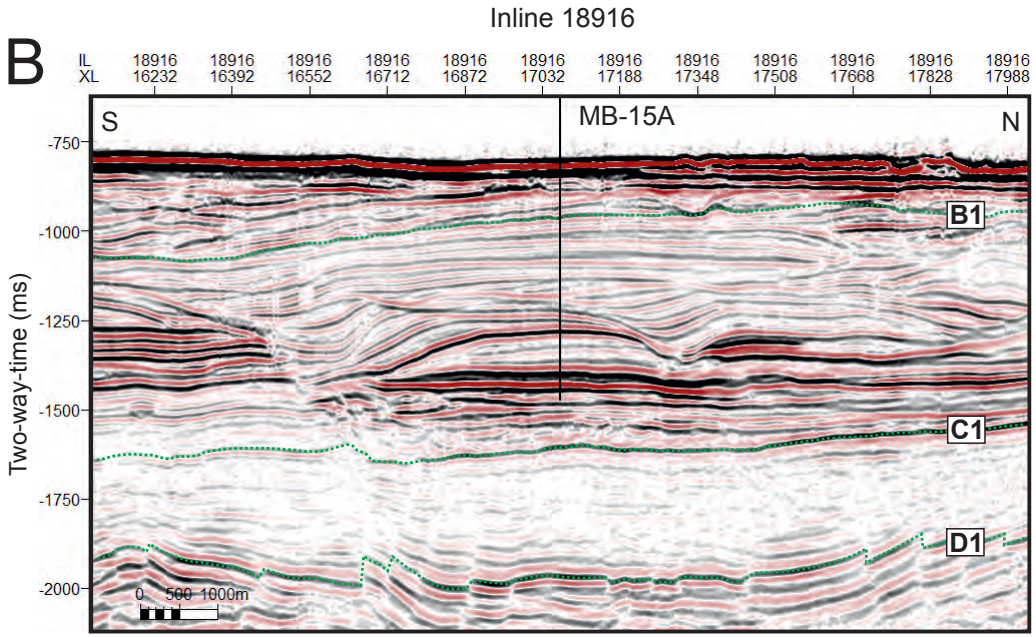
Coordinates: 74.12174136; -60.99091559
Inline-Xline Number: 18916, 17068
Penetration: 625 m
Water Depth: 605 m

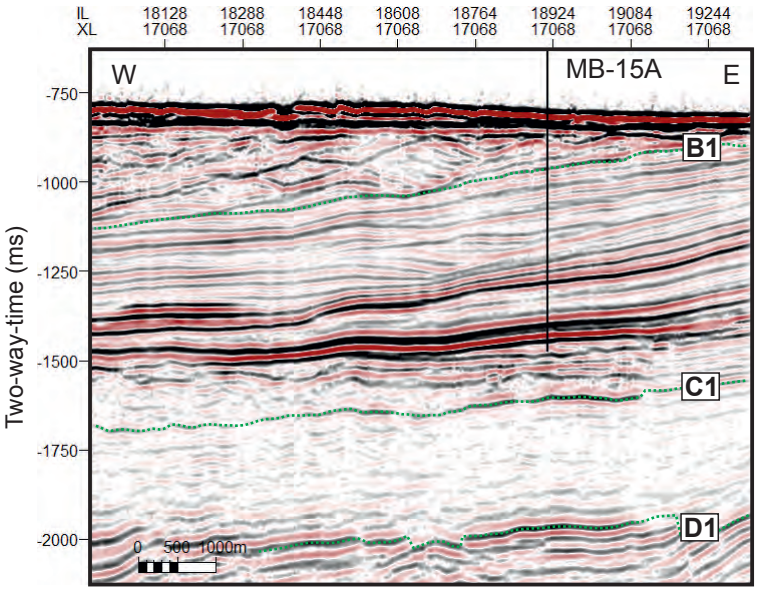
SSDB locations:
Location map: Map_MB-15A.jpg
Seismic data figure: Site-15A_ANU-3D_IL-18916.jpg, Site-15A_ANU-3D_XL-17068.jpg
SEG-Y data: Site-15A_ANU-3D_IL-18916.segy, Site-15A_ANU-3D_XL-17068.segy
Navigation: Site-15A_ANU-3D_IL-18916_nav.txt, Site-15A_ANU-3D_XL-17068_nav.txt

Additional information: seismic velocities, horizon grids, multibeam data

Site MB-15A: Drill site aimed at recovering a composite sequence of high-accumulation-rate contourite drifts of mega-unit B (likely Pliocene age) and the earliest glacial clinoforms of mega-unit A (late Pliocene and Early Pleistocene). (**A**) Shaded relief bathymetry map of the middle shelf region within the Melville Bugt Trough, shown with 100 m contours. Seismic crossing lines displayed in panel (B) are shown in the thick white. Thin white lines show the 2D seismic grid. Inset shows the areal coverage of 3D seismic data used to help refine target location. Black circles shows the proposed alternate drill site location and the red circle shows the drill site location for MB-15A. (**B**) Key Inline and Xline seismic sections from the 3D seismic cube (zero-phase). Mega-unit boundaries are shown.







IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover an upper Miocene interval and continue coring through the Middle Miocene horizon (d1) with TD at horizon d2 of possible Oligocene age. The scope is to elucidate past ocean and terrestrial climates in NE Baffin Bay/Greenland and the onset of ephemeral glaciation in NW Greenland (scientific objectives 2 and 3). Located within PITU-3D high-res cube. Site 7A is selected as the primary site on the basis of a better stratigraphic coverage in the topmost section.
List Previous Drilling in Area	Exp. 344S; sites U0100 and U0110 (distance 62 km toward NW)

Section B: General Site Information

Site Name:	MB-07A	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 74.5136	Jurisdiction:	Greenland
Longitude:	Deg: -60.6792	Distance to Land: (km)	100
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	737

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1173	0
Total Sediment Thickness (m)	6000	
Total Penetration (m):	1173	

General Lithologies: Sandy to silty mudstone, claystone, silliceous ooze

Coring Plan: (Specify or check)

Hole A: RCB coring to TD; casing to 400 mbsf.

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 8.3 | Logging: 2.5 | Total On-site: 10.8

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☑	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: Site 7A and alternates 11A and 12 A are identified using a high-res 3D cube ensuring distance from fluid-related anomalies or deep seated faults

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-07A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)		
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)	yes	Line: Site-7A_PITU-3D_IL-2658.segy Position: 2658 Data extracted from high-res 3D cube
2b Deep penetration seismic reflection (crossing)	yes	Line: Site-7A_PITU-3D_XL-6728.segy Position: 6728 Data extracted from high-res 3D cube
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Industry data
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-07A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single hole RCB, casing, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	BSR's identified in the PITU-3D seismic cube within strata over the Melville Bay Ridge may represent gas hydrates. Sites 7A, 11A and 12 A are located >2.5 km away from the gas hydrate risk zone.
5. Are there reasons to expect hydrocarbon accumulations at this site?	The Melville Bay Ridge hosts a likely gas accumulation seen as bright soft reflections and push-down reflections along its crest in the PITU-3D area. Areas containing bright reflections have been avoided in site selection and the chance of encountering shallow gas or hydrates is considered low.
6. What "special" precautions will be taken during drilling?	Closely monitoring of headspace gas using the protocol developed during the Exp. 344S that drilled into Cretaceous sediments north of the proposed sites.
7. What abandonment procedures need to be followed?	Displacement of hole with heavy mud.
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard). Shallow gas (seismic anomalies in 3D cube avoided, so low probability).

Proposal #: 909 - Full 2	Site #: MB-07A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-7A (primary)

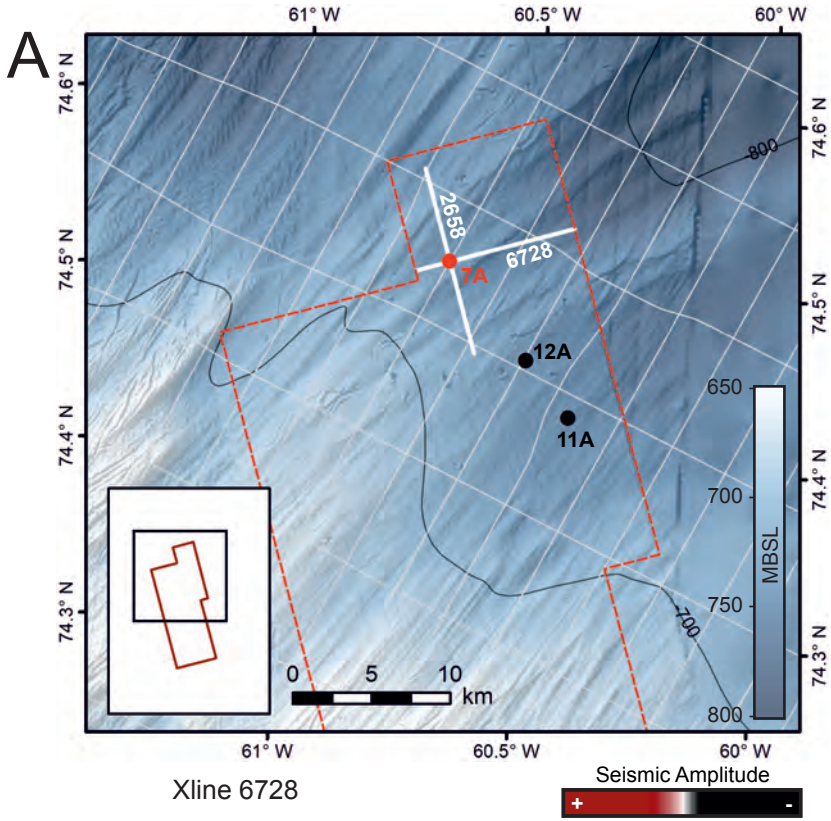
Scientific Objectives: 2 and 3

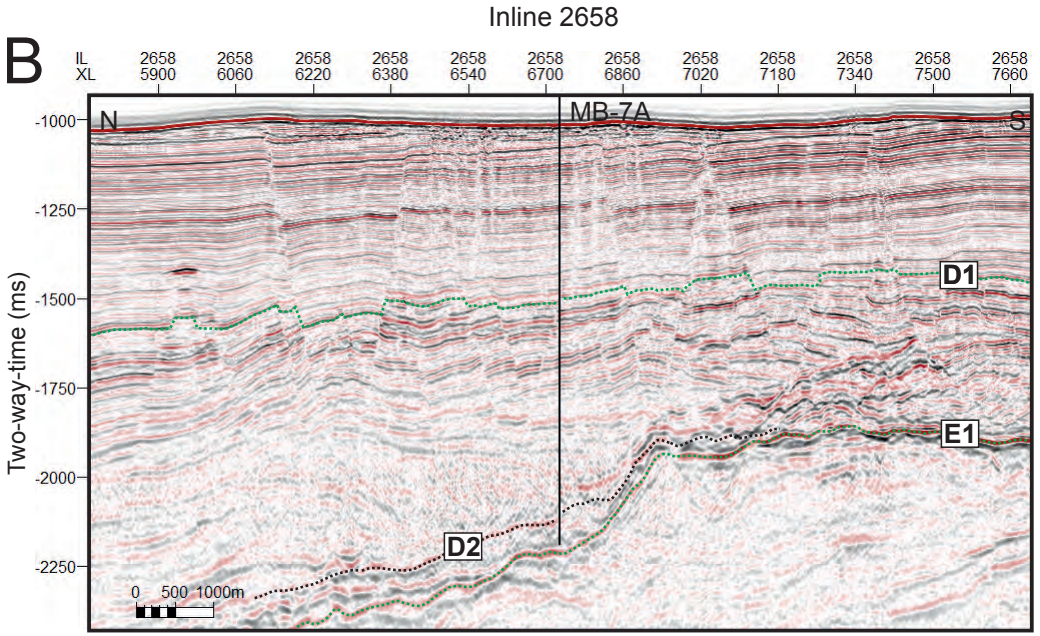
Coordinates: 74.51360000; -60.67920000
Inline-Xline Number: 2658, 6728
Penetration: 1173 m
Water Depth: 737 m

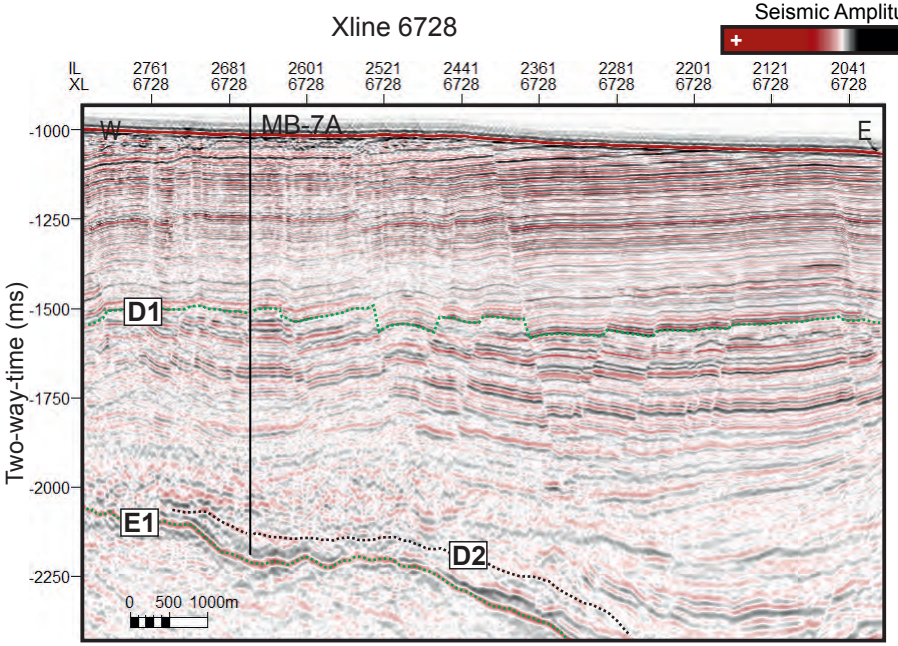
SSDB locations:
Location map: Map_MB-7A.jpg
Seismic data figure: Site-7A_PITU-3D_IL-2658.jpg, Site-7A_PITU-3D_XL-6728.jpg
SEG-Y data: Site-7A_PITU-3D_IL-2658.segy, Site-7A_PITU-3D_XL-6728.segy
Navigation: Site-7A_PITU-3D_IL-2658_nav.txt, Site-7A_PITU-3D_XL-6728_nav.txt
Velocity data:

Additional information: seismic velocities, horizon grids, multibeam data

Site MB-7A: Drill site aimed at recovering Oligocene and Miocene successions that are expected to be fine-grained hemipelagic sediments of mega-units C and D. (**A**) Shaded relief bathymetry map of the middle shelf region within the Melville Bugt Trough, shown with 100 m contours. Seismic crossing lines displayed in panel (B) are shown in the thick white. Thin white lines show the 2D seismic grid. Inset shows the areal coverage of 3D seismic data used to help refine target location. Black circles shows the proposed alternate drill site location and the red circle shows the drill site location for MB-7A. (**B**) Key Inline and Xline seismic sections from the 3D seismic cube (zero-phase). Mega-unit boundaries are shown.







IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover an upper Miocene interval and continue coring through the Middle Miocene horizon (d1) with TD at horizon d2 of possible Oligocene age. The scope is to elucidate past ocean and terrestrial climates in NE Baffin Bay/Greenland and the onset of ephemeral glaciation in NW Greenland (scientific objectives 2 and 3). Located within PITU-3D high-res cube.
List Previous Drilling in Area	Exp. 344S; sites U0100 and U0110 (distance 74 km toward NW)

Section B: General Site Information

Site Name:	MB-11A	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 74.4283	Jurisdiction:	Greenland
Longitude:	Deg: -60.4086	Distance to Land: (km)	89
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	747

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1170	0
Total Sediment Thickness (m)	6000	
Total Penetration (m):	1170	

General Lithologies: Sandy to silty mudstone, claystone, silliceous ooze

Coring Plan: (Specify or check): Single hole RCB to TD; casing to 400 m

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 8.3 | Logging: 2.5 | Total On-site: 10.8

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☑	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: Site 7A and alternates 11A and 12 A are identified using a high-res 3D cube ensuring distance from fluid-related anomalies or deep seated faults

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-11A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: Site-11A_PITU-3D_IL-2280.segy Position: 2280
2b Deep penetration seismic reflection (crossing)	yes	Line: Site-11A_PITU-3D_XL-8578.segy Position: 8578
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		
7 Swath bathymetry		
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation	yes	
17 Other		

Proposal #: 909 - Full 2	Site #: MB-11A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single hole RCB, casing, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	BSR's identified in the PITU-3D seismic cube within strata over the Melville Bay Ridge may represent gas hydrates. Sites 7A, 11A and 12 A are located >2.5 km away from the gas hydrate risk zone.
5. Are there reasons to expect hydrocarbon accumulations at this site?	The Melville Bay Ridge hosts a likely gas accumulation seen as bright soft reflections and push-down reflections along its crest in the PITU-3D area. Areas containing bright reflections have been avoided in site selection and the chance of encountering shallow gas or hydrates is considered low.
6. What "special" precautions will be taken during drilling?	Closely monitoring of headspace gas using the protocol developed during the Exp. 344S that drilled into Cretaceous sediments north of the proposed sites.
7. What abandonment procedures need to be followed?	Displacement of hole with heavy mud.
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard). Shallow gas (seismic anomalies in 3D cube avoided, so low probability).

Proposal #: 909 - Full 2	Site #: MB-11A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-11A (alternate)

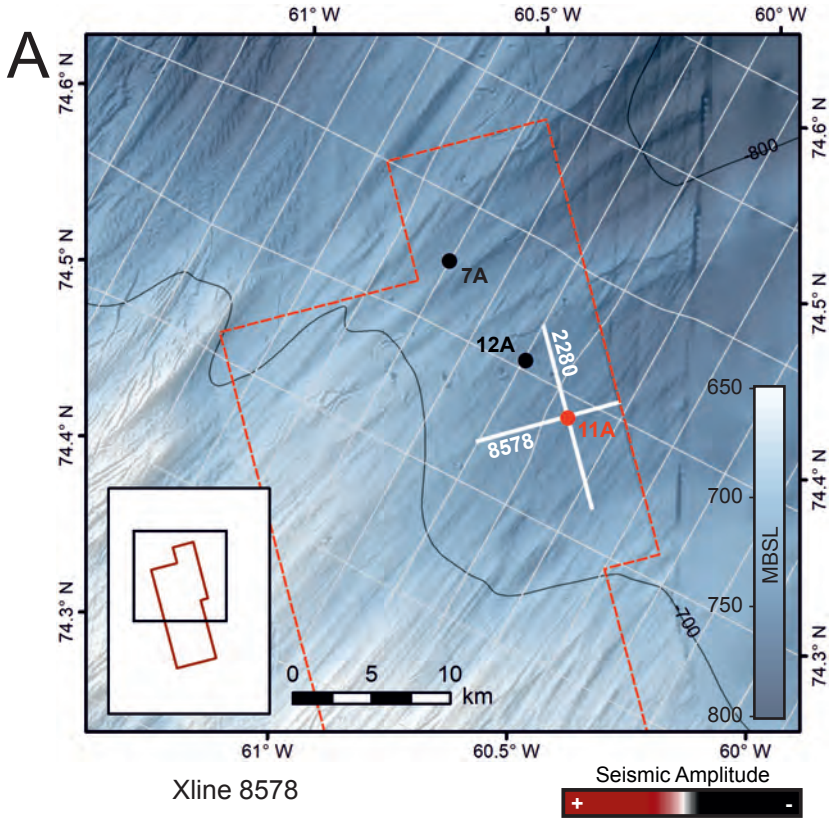
Scientific Objectives: 2 and 3

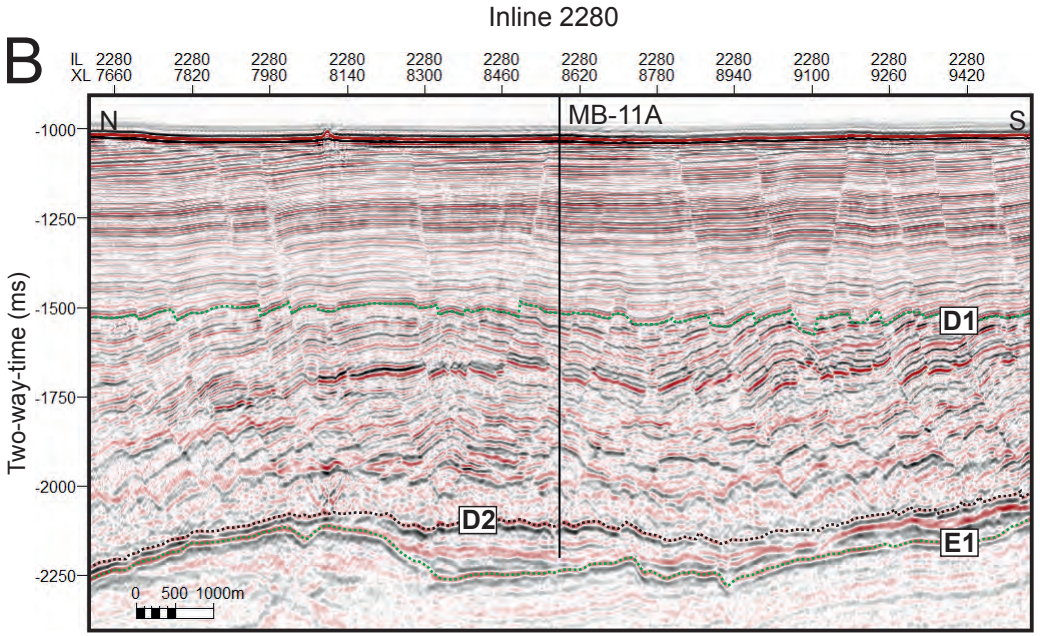
Coordinates: 74.42826067; -60.40858689
Inline-Xline Number: 2280, 8578
Penetration: 1170 m
Water Depth: 747 m

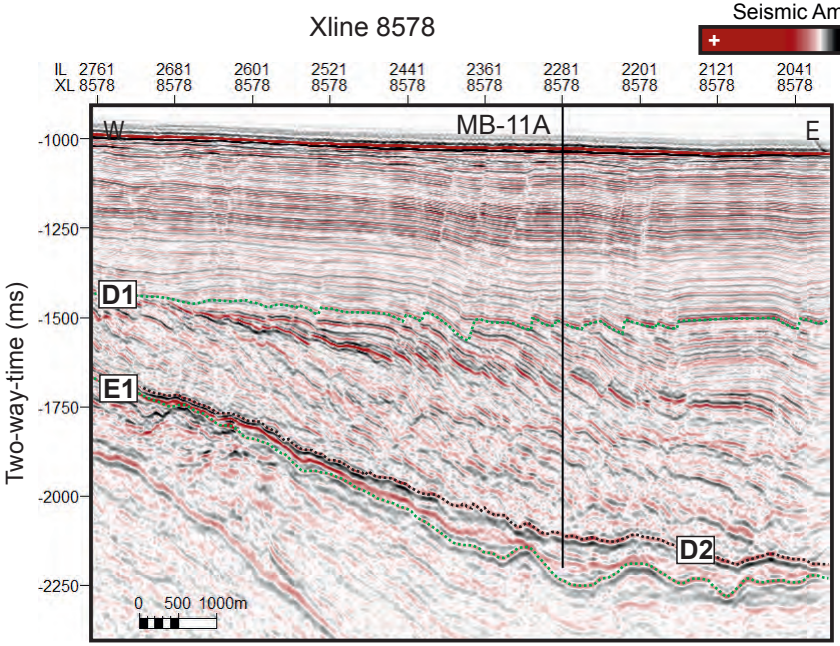
SSDB locations:
Location map: Map_MB-11A.jpg
Seismic data figure: Site-11A_PITU-3D_IL-2280.jpg, Site-11A_PITU-3D_XL-8578.jpg
SEG-Y data: Site-11A_PITU-3D_IL-2280.segy, Site-11A_PITU-3D_XL-8578.segy
Navigation: Site-11A_PITU-3D_IL-2280_nav.txt, Site-11A_PITU-3D_XL-8578_nav.txt
Velocity data:

Additional information: seismic velocities, horizon grids, multibeam data

Site MB-11A: Drill site aimed at recovering Oligocene and Miocene successions that are expected to be fine-grained hemipelagic sediments of mega-units C and D. (**A**) Shaded relief bathymetry map of the middle shelf region within the Melville Bugt Trough, shown with 100 m contours. Seismic crossing lines displayed in panel (B) are shown in the thick white. Thin white lines show the 2D seismic grid. Inset shows the areal coverage of 3D seismic data used to help refine target location. Black circles shows the proposed alternate drill site location and the red circle shows the drill site location for MB-11A. (**B**) Key Inline and Xline seismic sections from the 3D seismic cube (zero-phase). Mega-unit boundaries are shown.







IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover an upper Miocene interval and continue coring through the Middle Miocene horizon (d1) with TD at horizon d2 of possible Oligocene age. The scope is to elucidate past ocean and terrestrial climates in NE Baffin Bay/Greenland and the onset of ephemeral glaciation in NW Greenland (scientific objectives 2 and 3). Alternate site for 7A. Located within PITU-3D high-res cube.
List Previous Drilling in Area	Exp. 344S; sites U0100 and U0110 (distance 70 km toward NW)

Section B: General Site Information

Site Name:	MB-12A	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 74.4597	Jurisdiction:	Greenland
Longitude:	Deg: -60.5049	Distance to Land: (km)	95
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	739

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1145	0
Total Sediment Thickness (m)	6000	
Total Penetration (m):	1145	

General Lithologies: Sandy to silty mudstone, claystone, silliceous ooze

Coring Plan: (Specify or check): Single hole RCB; casing to 400 m

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 8.1 | Logging: 2.4 | Total On-site: 10.5

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☑	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: Site 7A and alternates 11A and 12 A are identified using a high-res 3D cube ensuring distance from fluid-related anomalies or deep seated faults

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-12A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)		
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)	yes	Line: Site-12A_PITU-3D_IL-2413.segy Position: 2413 SEGY files extracted from 3D seismic volume
2b Deep penetration seismic reflection (crossing)	yes	Line: Site-12A_PITU-3D_XL-7902.segy Position: 7902 SEGY files extracted from 3D seismic volume
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)		
5b Refraction (bottom)		
6 3.5 kHz		
7 Swath bathymetry		
8a Side looking sonar (surface)		
8b Side looking sonar (bottom)		
9 Photography or video		
10 Heat Flow		
11a Magnetics		
11b Gravity		
12 Sediment cores		
13 Rock sampling		
14a Water current data		
14b Ice Conditions		
15 OBS microseismicity		
16 Navigation	yes	
17 Other		

Proposal #: 909 - Full 2	Site #: MB-12A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single hole RCB, casing, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None that we are aware of
4. Indications of gas hydrates at this location	BSR's identified in the PITU-3D seismic cube within strata over the Melville Bay Ridge may represent gas hydrates. Sites 7A, 11A and 12 A are located >2.5 km away from the gas hydrate risk zone.
5. Are there reasons to expect hydrocarbon accumulations at this site?	The Melville Bay Ridge hosts a likely gas accumulation seen as bright soft reflections and push-down reflections along its crest in the PITU-3D area. Areas containing bright reflections have been avoided in site selection and the chance of encountering shallow gas or hydrates is considered low.
6. What "special" precautions will be taken during drilling?	Closely monitoring of headspace gas using the protocol developed during the Exp. 344S that drilled into Cretaceous sediments north of the proposed sites.
7. What abandonment procedures need to be followed?	Displacement of hole with heavy mud.
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard). Shallow gas (seismic anomalies in 3D cube avoided, so low probability).

Proposal #: 909 - Full 2	Site #: MB-12A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-12A (alternate)

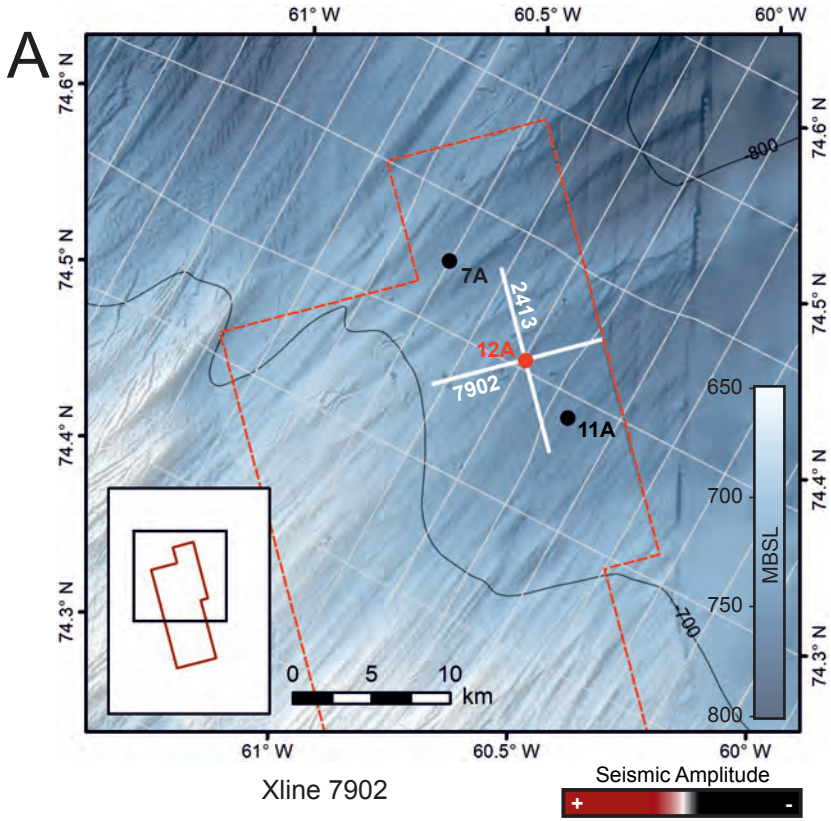
Scientific Objectives: 2 and 3

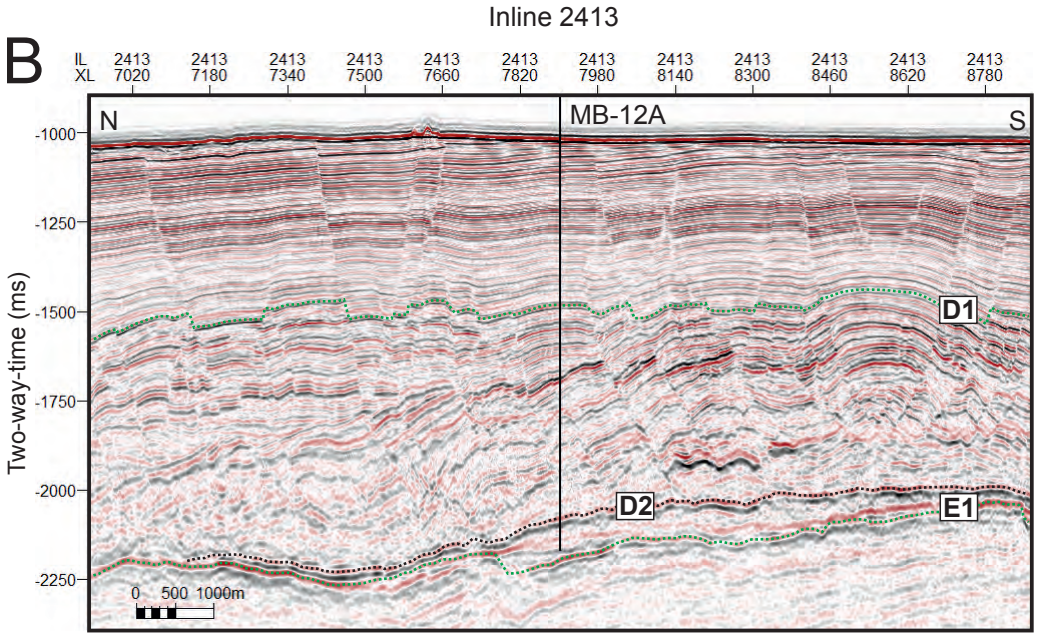
Coordinates: 74.45966394; -60.50491767
Inline-Xline Number: 2413, 7902
Penetration: 1145 m
Water Depth: 739 m

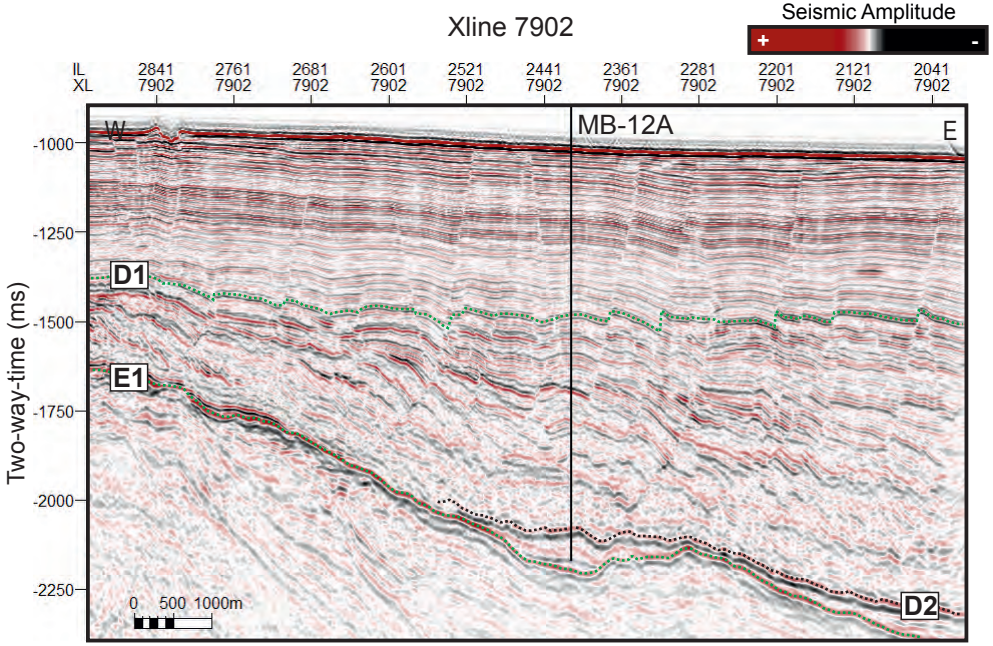
SSDB locations:
Location map: Map_MB-12A.jpg
Seismic data figure: Site-12A_PITU-3D_IL-2413.jpg, Site-12A_PITU-3D_XL-7902.jpg
SEG-Y data: Site-12A_PITU-3D_IL-2413.segy, Site-12A_PITU-3D_XL-7902.segy
Navigation: Site-12A_PITU-3D_IL-2413_nav.txt, Site-12A_PITU-3D_XL-7902_nav.txt
Velocity data:

Additional information: seismic velocities, horizon grids, multibeam data

Site MB-12A: Drill site aimed at recovering Oligocene and Miocene successions that are expected to be fine-grained hemipelagic sediments of mega-units C and D. (**A**) Shaded relief bathymetry map of the middle shelf region within the Melville Bugt Trough, shown with 100 m contours. Seismic crossing lines displayed in panel (B) are shown in the thick white. Thin white lines show the 2D seismic grid. Inset shows the areal coverage of 3D seismic data used to help refine target location. Black circles shows the proposed alternate drill site location and the red circle shows the drill site location for MB-12A. (**B**) Key Inline and Xline seismic sections from the 3D seismic cube (zero-phase). Mega-unit boundaries are shown.







IODP Site Forms

Form 1 – General Site Information

909 - Full 2

Section A: Proposal Information

Proposal Title	Cenozoic evolution of the northern Greenland Ice Sheet exposed by transect drilling in northeast Baffin Bay (CENICE)
Date Form Submitted	2018-10-08 15:03:57
Site-Specific Objectives with Priority (Must include general objectives in proposal)	Recover an upper Miocene interval and continue coring through the Middle Miocene horizon (d1) with TD at horizon d2 of possible Oligocene age. The scope is to elucidate past ocean and terrestrial climates in NE Baffin Bay/Greenland and the onset of ephemeral glaciation in NW Greenland (scientific objectives 2 and 3). MB-10A is located on the edge of the PITU-3D seismic data. Alternate position to site MB-07A.
List Previous Drilling in Area	Exp. 344S; sites U0100 and U0110 (distance 53 km toward NW)

Section B: General Site Information

Site Name:	MB-10A	Area or Location:	Melville Bay, NE Baffin Bay
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 74.4584	Jurisdiction:	Greenland
Longitude:	Deg: -61.1792	Distance to Land: (km)	120
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	698

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1206	0
Total Sediment Thickness (m)	6000	
Total Penetration (m):	1206	

General Lithologies: Sandy to silty mudstone, claystone, silliceous ooze

Coring Plan: (Specify or check): Single RCB coring; casing to 400 m

APC ☐ XCB ☐ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☐	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☑			

Other Measurements:

Estimated Days: Drilling/Coring: 8.5 | Logging: 2.6 | Total On-site: 11.1

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☑	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Preferred weather window: July-September
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☑	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☑	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: Site 10A is located within the PITU-3D area but just outside the high-res cube - hence lower priority than sites 7, 11 and 12.

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 909 - Full 2	Site #: MB-10A	Date Form Submitted: 2018-10-08 15:03:57

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: BB10-5065625 Position: 19946 This data is currently confidential
2b Deep penetration seismic reflection (crossing)	yes	Line: BB10-109125 Position: 25337 This data is currently confidential
3 Seismic Velocity	yes	
4 Seismic Grid	yes	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Industry data
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	
17 Other	no	

Proposal #: 909 - Full 2	Site #: MB-10A	Date Form Submitted: 2018-10-08 15:03:57

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Single hole RCB, casing, logging
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	None based on ODP Exp. 645 results (SE Baffin Bay). EXP 344S encountered methane gas at sites U0110/100 drilling into Cretaceous sediments on the apex of the Melville Bay Ridge (~50 km NW of the 909 transect).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	None
4. Indications of gas hydrates at this location	BSR's identified in the PITU-3D seismic cube within strata over the Melville Bay Ridge may represent gas hydrates. Site 10A is located >1 km away from the gas hydrate risk zone.
5. Are there reasons to expect hydrocarbon accumulations at this site?	The Melville Bay Ridge hosts a likely gas accumulation seen as bright soft reflections and push-down reflections along its crest in the PITU-3D area. Areas containing bright reflections have been avoided in site selection and the chance of encountering shallow gas or hydrates is considered low.
6. What "special" precautions will be taken during drilling?	Closely monitoring of headspace gas using the protocol developed during the Exp. 344S that drilled into Cretaceous sediments north of the proposed sites.
7. What abandonment procedures need to be followed?	Displacement of hole with heavy mud.
8. Natural or manmade hazards which may affect ship's operations	Drifting icebergs (low probability)
9. Summary: What do you consider the major risks in drilling at this site?	Icebergs (known hazard). Shallow gas (seismic anomalies in 3D cube avoided, so low probability).

Proposal #: 909 - Full 2	Site #: MB-10A	Date Form Submitted: 2018-10-08 15:03:57

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
N/A							

Site Figure

Proposal 909-Full-2 Site MB-10A (alternate)

Scientific Objectives: 2 and 3

Coordinates: 74.4584; -61.1792
Shot point: 19946 (BB10-5065625)
Penetration: 1200 m
Water depth: 685 m

SSDB locations:
Location map: Location map not uploaded
Seismic data figure: BB10-5065625.jpg
SEG-Y data: bb10_line-5065625_flt-scl-stk_t101845.sgy

Additional information: 3D seismic data, multibeam, seismic velocity data,

Site MB-10A: (A) Multibeam bathymetry map of the middle shelf region, situated within the Melville Bugt trough, shown with 50 m depth contours. Seismic crossing lines are displayed with shot points. 3D data cube outlined in orange. (**B**) Key seismic section with interpreted horizons and assumed ages. MB-10A penetrates the Late Miocene and Early Miocene successions separated by horizon d1. TD is horizon d2 of possible Oligocene age. The site is expected to recover mainly fine-grained hemipelagic sediments, possible with smectite and intervals rich in opal CT.