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Extreme Meltwater events in the Arctic: the marine sedimentary record of Meltwater Pulse 1a

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Abstract

The upper continental slope of the Storfjorden-Kveithola Trough Mouth Fans (NW Barents Sea) contains a several m-thick late Pleistocene sequence of ice meltwater derived deposits (plumites). Radiocarbon ages revealed that deposition occurred during about 130 years at a very high sedimentation rate of 3.4 cm a-1. Palaeomagnetic and rock magnetic analyses confirm the existence of a prominent, short-living sedimentary event. On the acoustic record the plumites appear laterally continuous and were correlated with the sedimentary sequences described west of Svalbard and neighbouring glacial depositional systems representing a major event at regional scale that was appointed to correspond to the deep-sea sedimentary record of the Meltwater Pulse-1a.

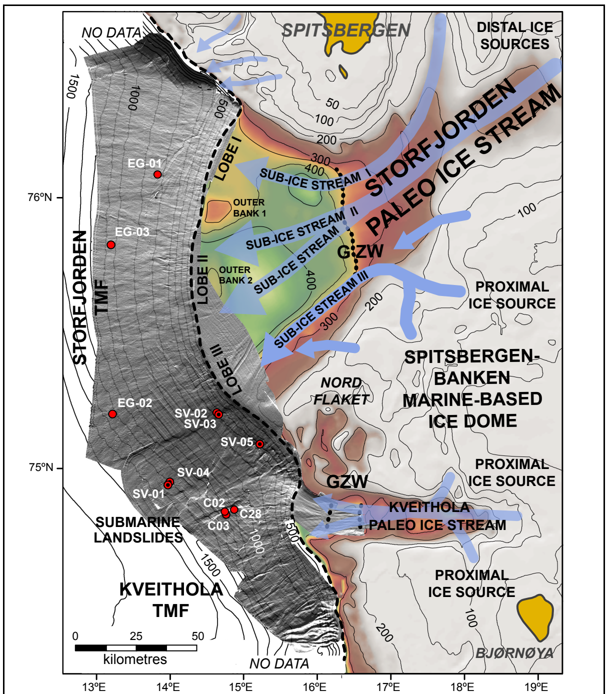

Figure 1: Map of the study area with inferred direction of the main ice streams during LGM. Red dots indicate the location of the studied cores. SV=SVAIS cores; EG= EGLACOM; C=CORIBAR; GZW=Grounding Zone Wedges.

Introduction

A meltwater pulse (MWP) is a short-lived, global acceleration in sea-level rise resulting from intense front- and subglacial meltwater release, surging ice-streams into oceans and iceberg discharge during ice-sheets disintegration. Four main meltwater pulses have been pointed to have occurred during the last deglaciation phase: MWP-19ka, also known as MWP-1a0, about 19 cal ka BP (Clark et al. 2004); MWP-1a, 14.650-14.310 cal a BP (Deschamps et al. 2012); MWP-1b, 11.500-11.000 cal a B.P. (Bard et al. 2010); and MWP-1c at about 8.000 cal a BP (Harris et al. 2008). Of these events, MWP-1a was possibly the most prominent leading to a global sea-level rise of about 20 m in the course of 340 a (Deschamp et al. 2012). Evidences of the existence MWP-1a have been found in many low-latitude areas but straightforward evidence is still lacking in polar areas where the event is thought to have originated. Four ice-sheets are considered as possible candidates responsible for shaping the global sea-level curve: the Laurentide, Fennoscandian, Barents and Antarctic ice-sheets. Scarce and ambiguous evidences of MWP-1a imprints in the polar areas are puzzling and do not help resolve the controversy on its origin. Ten sediment cores collected during the projects SVAIS (2007), EGLACOM (2008), and CORIBAR (2013) on the Storfjorden-Kveithola TMFs (Fig. 1), evidenced the existence of a prominent interlaminated deposit that in the upper slope is over 4.5 m-thick. Sub-bottom profiles indicate that this deposit is continuously distributed over the area reaching thickness of 20 m offshore the Storfjorden lobe III and Kveithola Trough (Fig. 1). The sediments cores were analyses for physical, compositional and palaeomagnetic characteristics. The age model was based on rocks palaeomagnetic parameters and 50 C^{14} radiometric dating.

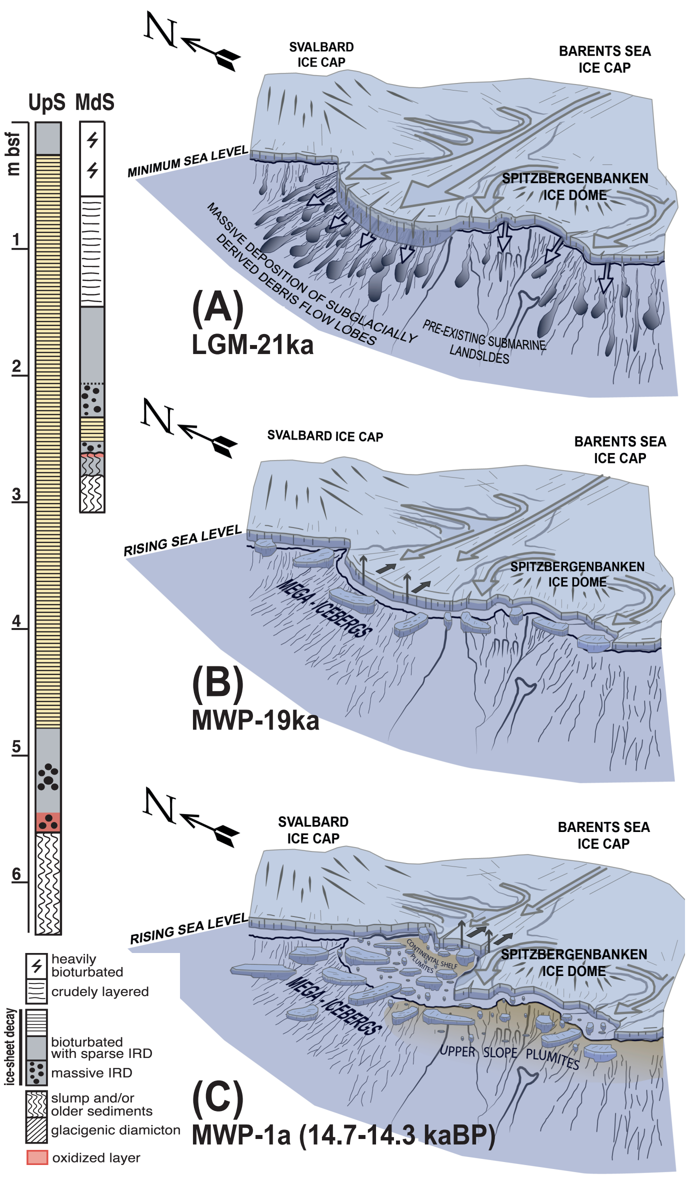

Figure 2: *Schematic representation of the three main ice stream phases during and after LGM: (A) maximum glacial expansion at 21 ka; (B): the inception of ice stream decay during MWP-19ka; (C): the ice stream collapse during/after MWP-1a. A startigraphic scheme of the upper-slope (UpS) and middle-slope (MdS) cores is also reported (modify after Lucchi et al., 2015).*

Results and discussion

The presence of clustered glacigenic debris flows forming Trough Mouth Fans of the North-western Barents Sea continental margin confirms fully glaciated conditions to the shelf breack occurred during the Last Glacial Maximum (LGM, Lucchi et al., 2013, among others). Dating of these deposits indicate full glacial conditions at ca. 21 cal ka BP (Jessen et al. 2010, Fig. 7A). There is a large consensus on considering enhanced summer insulation as the primary mechanism determining the onset of the northern hemisphere deglaciation. Intense ice-melting from the northern hemisphere ice-sheets and mountain glaciers produced a large volume of meltwaters with deposition of a several m-thick laminated sequence on the northern continental margins (Tripsanas and Piper 2008, among others). This event produced a first abrupt global sea level rise (MWP-19ka) with renewal of the Atlantic Meridional Overturning Circulation (He et al. 2013). The oxidized, massive IRD overlying LGM sediments in the studied cores, records the Storfjorden ice-stream response to MWP-19ka responsible for ice sheet instability and breakdown of the outer part of the grounded ice-shelf (Fig. 7B). Oxidized sediments, characterized by low sulphur content, presence of planktonic foraminifera, and marine-derived organic matter indicate deep ocean ventilation with ice-free (or seasonal) surface conditions. These environmental characteristics support the re-establishment of a vigorous thermohaline circulation in the north Atlantic after the LGM. At the same time, the detachment and lift-off of the marine-based grounded ice-streams on the deep Antarctic shelves (South-eastern Weddell Sea, Antarctic Peninsula and Amundsen Sea) in response to sea-level forcing during MWP-19ka, lead to the deposition of a thick laminated sequence underneath the Antarctic ice-shelves (Weber et al., 2014). Antarctic meltwater release was in turn responsible for a further strengthening of the Atlantic Meridional Overturning Circulation accelerating the climate warming of the North Atlantic region (onset of the Bølling-Allerød warm interval, Weaver et al. 2003), promoting a further sea level rise forcing the lift-off of shallower marine grounded ice streams including the Storfjorden and Kveithola ice streams in the northern margins. Ice shelves are more sensitive to warm sub-glacial inflows forcing their rapid melting and retreat (Shepherd et al. 2003), therefore, the re-enhanced warm North Atlantic inflow was responsible for fast decay of the Storfjorden and Kveithola ice-streams with extensive ice melting and retreat to an inner grounding line, contributing significantly to global sea level rise during MWP-1a (Fig. 7C). This phase of the ice sheet decay, was accompanied by intense calving from the retreating ice stream that in the Storfjorden Trough is inferred to have generated the release of multi-keel megabergs responsible for the mega-scours visible on the multibeam record of the Storfjorden outer continental shelf at 390 m water depth below present-day sea level. The melting of the main Storfjorden ice streams (lobes I and II, Fig. 1) occurred with a rapid retreat to the shallower grounding zone wedges located on the middle shelf (thinner plumites offshore lobe I and II). On the contrary, the Kveithola and the south-western Storfjorden ice stream, were probably active longer as they were fed by a closer ice catchment area (Spitsbergenbanken ice cap), producing a larger sequence of plumites on the continental slope facing lobe III and the Kveithola Trough (Fig. 2). Rocks palaeomagnetic parameters of the studied cores confirm the existence of a prominent short-lived event (about 130 years long). Stratigraphic equivalent deposits to the studied plumites have been reported from other areas offshore the West and North Svalbard margin including the Yermak Plateau, and the southern Barents Sea (Lucchi et al., 2015 and references therein), indicating a nearly synchronous regional event responsible for a massive sediment input likely accompanied by a huge flux of fresh meltwater into the northern Atlantic and Arctic Oceans.

Conclusion

The sedimentary record on the upper slope of the Storfjorden-Kveithola TMFs contains a several m-thick sequence of plumites deposited under an extensive meltwater event associated to fast palaeo-ice streams decay. Radiometric dating and rock palaeomagnetic characteristics confirm the existence of a short-lived (ca. 130 years) prominent event. Stratigraphic equivalent deposits have been reported from other areas offshore the West and North Svalbard margin including the Yermak Plateau, and the southern Barents Sea, indicating a nearly synchronous regional event responsible for a massive sediment input likely accompanied by a huge flux of fresh meltwater into the northern Atlantic and Arctic Oceans. According to palaeomagnetic and stratigraphic correlation and radiocarbon ages we assigned this event to the Meltwater Pulse 1a.

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