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Last Glacial Maximum surface water properties and circulation over Laurentian Fan, western North Atlantic

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ABSTRACT

Millennial scale events marked by the contribution of detrital sand are recorded in North Atlantic sediments during the Last Glacial Maximum (LGM), between Heinrich events (HE) 1 and 2, and left their imprint on Laurentian Fan (LF – 43°N) sediments off eastern Canada. The LF counterpart of the well-known detrital events consist of glacial red-brick sediments resulting from subglacial flows separated by olive-grey sediments appears at ∼21.4–19.9 and ∼19.5–18.65 cal kyr BP. High-resolution analyses of diatom assemblages and lithic grains coupled with planktonic oxygen isotopic records reveal that while the red sediment is almost barren of diatoms, foraminifera and lithics (>150 μm), they are abundant in the olive-grey sediment. Diatom assemblages reveal three phases during these events: (1) initial relatively warm/temperate conditions followed by (2) very cold surface water and drifting ice, and (3) a final phase characterized by relatively warmer waters and the appearance of detrital carbonate. Although these events possibly reflect the variability specific to the slope water region, they are likely the response to Atlantic Meridional Overturning Circulation perturbations and ice-sheet instability. Through a chain of mechanisms, meltwater inputs into the North Atlantic led ultimately to an increased volume of tropical waters and part of the heat stored in the subsurface was flushed by a brief convective episode that was not sustained, accounting for the return of cold conditions after the events. The sequence of mechanisms deduced from the paleo data here and elsewhere is consistent with previous modeling results. These data suggest that the detrital events between Heinrich event 1 and 2 may be synchronous across the North Atlantic, and that the LGM was probably not a time of prolonged steady state in the climate system.

1. Introduction

The Laurentide Ice Sheet (LIS) played an important role in global climate thanks to its large extent. Through melting and ice supply into the Arctic and North Atlantic, the LIS had a direct impact on the Atlantic Meridional Overturning Circulation (AMOC). The LIS margins also affected marine productivity by influencing the sea-ice system, the ocean mixed-layer depth, and light availability. Finally, it was involved in rapid climate fluctuations such as the Dansgaard–Oeschger cycles (Dansgaard et al., 1993) and Heinrich events (HE) (Bond et al., 1992) that took place during the last glacial period. While the first are best documented in the Greenland ice cores, HE are evident in North Atlantic records of Ice Rafted Debris – IRD (Bond et al., 1992; Bond and Lotti, 1995; Broecker et al., 1992; Hemming, 2004). However, drifting icebergs are not restricted to HE: brief high abundance of lithic grains is also found between HE. Three distinct IRD levels between HE1 and HE2 are identified in the high latitudes of the North Atlantic (>40°N), including the Eastern North Atlantic, Denmark Strait, DSDP site 609 (“a”, “b”, “c” in Bond and Lotti, 1995), the Vøring Plateau (Fronval et al., 1995), the Irminger basin (Detrital Events (DE) “a”, “b” and “c” in Elliot et al., 1998), the Labrador Sea (Low Detrital Carbonate – LDC 1, 2 and 3; Andrews, 1998; Andrews et al., 1994; Stoner et al., 1998, 1996), the Orphan basin (Tripsanas and Piper, 2008) and the Porcupine Seabight (North West European 1/“a”, LGM1 and 2/“b” and “c” in Peck et al., 2006). The DE are viewed as evidence for the instability of the ice-sheets surrounding the North Atlantic (Fronval et al., 1995; Peck et al., 2006; Stoner et al., 1998, 1996) and are also regarded as HE1 precursors (Bond et al., 1999). However, it is still unclear why they did not develop into full HE. They mainly distinguish them-

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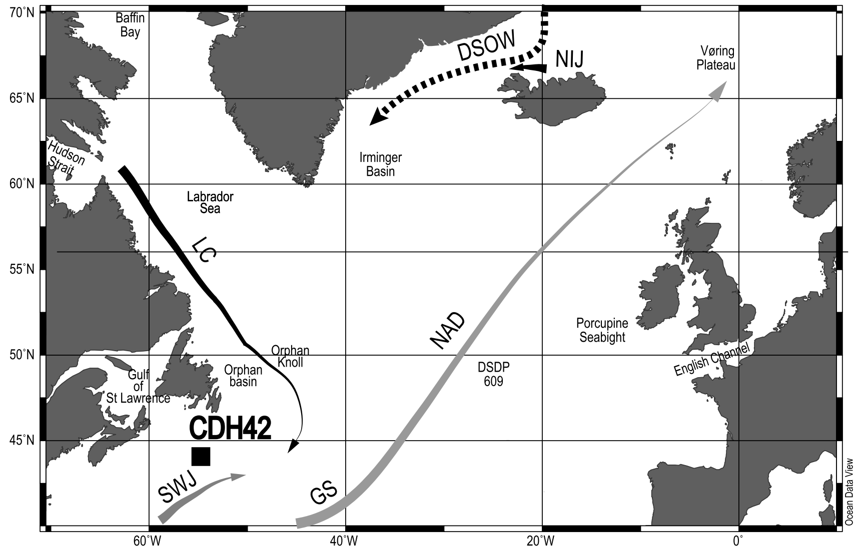

Fig. 1. Location map of sites and oceanographic currents mentioned in this study and core CDH42 location (latitude 43°27.87; longitude 54°45.35). Dashed lines indicate bottom current as the Denmark Strait overflow (DSOW), while black line represent cold currents as the Labrador (LC) and the North Icelandic Jet (NIJ) and grey lines warm and temperate currents as the Slope water Jet (SWJ), the Gulf Stream (GS) and the North Atlantic Drift (NAD).

Fig. 2. Picture of sections 16, 15, 14 and 13 of CDH42. Stars indicate the dated levels. Light grey sediments are interpreted to be Heinrich event 1 (HE1) on the basis of HE1 record in nearby cores (deGelleke et al., 2013; Gil et al., 2015; Leng et al., 2018; Piper and Skene, 1998).

selves from HE by the reduction or even absence of carbonate IRD. Due to their limited sedimentary record, little is known about the corresponding surface hydrography. They are the most referenced DEs of this period, but more DEs that are not necessarily connected to them also occurred. Over LF, these events have been associated with subglacial flows and outbursts flood events (Leng et al., 2018; Tripsanas and Piper, 2008). Here, we present high-resolution records of diatom flora, δ^{18}O on *Neogloboquadrina pachyderma* (s), δ^{13}C on *Uvigerina peregrina* and lithic grains on two coarse grained detrital events (recorded in between subglacial flow deposits) from the Laurentian Fan (LF) to document in detail the associated oceanographic changes and explore their relationship with the North Atlantic detrital events already identified. LF is a key-site in the western North Atlantic since the Laurentian Channel was one of the major outlets for ice and recorded many depositional variations related to LIS fluctuations since the LGM (Piper et al., 2007; Shaw et al., 2006; Skene and Piper, 2003).

2. Material and methods

The long piston core (~28 m) KNR197-10 CDH42 (CDH42) was retrieved from the Laurentian Fan at 3870 m depth (latitude 43°27.87; longitude 54°45.35) on board the RV/Knorr in July 2010 (Fig. 1). Smear slides were examined to determine the microfossil preservation and sampling resolution. Samples were taken between 500 and 914 cm (sections 13 to 16) at 2 to 4 cm spacing, with a higher resolution for the better preserved levels, e.g. olive-grey sediments and thin black mud laminae (Fig. 2). The determination of diatom assemblages was only possible in the two principal intervals of olive-grey sediments (660–685 cm and 820–852 cm). Finally, two older sections of CDH42 were opened (~300 cm in total, sections 11 and 12) to look for more olive-grey sediment intervals, but no equivalent decimeter-scale deposits were detected as deep as 1296 cm.

The age model is based on eight ^{14}C ages on *N. pachyderma* (s) and *G. bulloides* (one sample) obtained from the National Ocean Sciences Accelerator Mass Spectrometer (NOSAMS) facility at Woods Hole Oceanographic Institution (Keigwin and Swift, 2017) plus one new sample from 680 cm (Fig. 2, Table 1). ^{14}C ages were calibrated using the INTCAL13 curve (Reimer et al., 2013), with a standard marine correction of 400 yr (Table 1). No additional local reservoir correction (ΔR) was applied because there is no data for directly determining ΔR for the LGM at our core site. However, if we hypothesize that the conditions would have