Zooming in on the so-called ‘precursor events’ of Heinrich layers

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Abstract. There is still no consensus on the mechanisms that led to the abrupt collapse of the Laurentide ice sheet and the concomitant massive release of icebergs that led to the deposition of thick (Heinrich) layers of ice rafted deposits (IRD) in deep-sea sediments of the North Atlantic. The presence of small IRD peaks occurring ~500-1000 years before the main Heinrich (H) layers with a composition corresponding to NW Atlantic source terranes have led to the suggestion that small European ice sheets may have triggered Heinrich events. The studies that reported these so-called ‘precursor events’ only focused on the IRD peaks surrounding the H layers. These discrete IRD pulses could in fact reflect intensified ice rafting during cool phases of a millennial-scale cycle. Here we propose to study the provenance of IRD between Heinrich layers 2 and 4 in a core from the Atlantic margin off the British Isles. This study should constrain the sequence of events that led to the deposition of Heinrich layers and shed light on the mechanisms responsible for H events.

Introduction

Heinrich layers (H layers) consist of six repeated intervals of massive ice-rafted deposits found in North Atlantic deep-sea sediments. Their sedimentological characteristics imply massive and abrupt release of icebergs into the North Atlantic Ocean. It is well known that the bulk of the ice rafted debris (IRD) forming H layers comes from the Laurentide ice sheet. Provenance studies have attributed the characteristic high content in detrital carbonate of H layers to a calving ice margin that overrode the carbonate-floored Hudson Bay/Strait in NE Canada. Similarly, lead and argon isotopes measured on feldspar and amphibole grains retrieved from H layers have identified the source area of the IRD as being the Churchill province of the Canadian Shield, thereby reinforcing the Laurentide ice sheet origin for H events (*see* review by Hemming, 2004).

While the Laurentide ice sheet (LIS) was unequivocally the main contributor to H layers, the mechanisms that led to the massive discharge of icebergs from the NE margin of the LIS is still a matter of debate. The recognition that H layers are preceded by small IRD peaks with source terranes corresponding to sectors once covered by European ice sheets led to the suggestion that H events may have been caused by events that originated from the northeastern sector of the Atlantic region (Grousset et al., 2000; 2001; Scourse et al., 2000). These so-called “precursor events” imply that the smaller-size ice sheets of the NW Atlantic were quicker to respond to external forcing, and that the release of icebergs and meltwater from these ice sheets may potentially have destabilized the LIS through a series of feedbacks. This hypothesis challenges the favored theory for H events, which is based on glaciological processes intrinsic to the internal dynamics of large ice sheets and that implies an abrupt draw down of the LIS (MacAyeal, 1993).

Several issues are related to the ‘precursors events’. Studies that have identified ‘precursor events’ have done so by looking at the petrographic and isotopic composition of IRD pulses that immediately precede and follow the main carbonate-rich intervals that form H layers. The occurrence of these discrete 'European' IRD peaks may simply reflect an increase in volume of the European ice sheets, and the location of the cores from which they were described. These were found in cores taken from sites located off the coast of Great Britain and mainland Europe (north of Spain/west of France). It is thus reasonable to conceive that when the Icelandic, Fennoscandian and British ice sheets were extensive enough to reach sea level, their marine-based ice margins were likely to periodically release icebergs. These icebergs were also likely to get to these locations prior to the ones coming from the LIS located across the Atlantic Ocean. Furthermore, these precursor IRD intervals could be part of a high-frequency (1-2 kyr) pervasive climatic cycle that punctuates deep-sea sediment records of the last glacial cycle in the North Atlantic (Bond and Lotti, 1995), and thus be present in between H layers. Consequently, these precursors IRD may be in fact a response of the marine ice margin of the NW Atlantic ice sheets to cooling phases (Dansgaard-Oeschger, D-O, cycles).

Nonetheless, the occurrence of H and 'precursor' events demonstrates that ice sheets were fully involved with the ocean and atmosphere during millennial-scale climate oscillations of the last glacial period (*e.g.* Hemming, 2004). The exact relationship (cause/response) of H events to other near-simultaneous climate variability found globally in other climate proxies remains, however, contentious. Investigating the provenance of ambient IRD material throughout sediment sequences of the last glacial cycle may thus elucidate the sequence of events that led to the sudden export of iceberg armadas from the LIS.

Proposed study

In June 2004 the authors participated in a 2-week scientific cruise on board the Marion Dufresne II. One of the main objectives of this cruise was to recover cores with high sedimentation rates in strategic locations that can potentially monitor the influence of NW European ice sheet surges. During this cruise, PI Ian Hall from Cardiff University (Wales, UK) offered us to work on the provenance of IRD from a sediment core in which a wide array of paleoclimate proxies will be produced. The goal of this proposal is thus to obtain funding that will allow us to perform analytical work on targeted sediment intervals, and thereby raise data to prepare a NSF-based proposal.

The core we will study is located in the NE Atlantic margin off the British Isles (Fig. 1) and was the focus of a multiproxy paleoceanographic study for the last deglaciation that also revealed the occurrence of precursor-type events preceding H layers by ~500-1000 years (Knutz et al., 2001). This core provides an outstanding opportunity to address the issues related to the precursor events, and the large-volume sediment core retrieved allows the study of ambient IRD, which are in lesser quantity than H layers.

Our strategy is to look at the provenance of significant IRD layers between H layers 2 and 4. On these samples we plan to obtain information on the source area of IRD, and thus the contributing ice sheets, through a wide range of methods: We will do sedimentological analyses such as lithic grain counts of the coarse fraction (>150) and identification of the main mineral types present in this fraction. We also plan to count the number of planktonic foraminifers as H layers are generally depleted in forams. Based on the results of these counts, we will select 50 samples for Nd isotope measurements, and we will select a subset of 2-3 samples for $^{40}Ar/^{39}Ar$ analysis of individual hornblende grains to better constrain the sources.

Conclusions and Implications

We propose to study the provenance of IRD layers in a core located in the NE Atlantic margin near the British Isles. The location of this core allows the study of the behavior of the Icelandic, Fennoscandian and British ice sheets, and their respective contribution to IRD in this region, especially with respect to timing with Heinrich events. The study of IRD of marine isotope stage 3 may reveal if precursor events were only attributed to pre-Heinrich events or if they were part of millennial-oscillation trend of iceberg export. These results should shed light on the processes that led to Heinrich events. In the Labrador Sea, Heinrich events also seem to be associated with important discharge of meltwater. The close proximity of the NW European ice sheets to site of deep-water formation make them strong candidate for causing climate change. If the precursors IRD peaks were indeed part of a pervasive millennial-scale cycle, and were accompanied by similar meltwater discharges, albeit smaller, the release of meltwater may potentially have disturbed convection, and thus be part of the mechanisms that led to millennial climate variability. Consequently, this study can also bring insights on the mechanisms acting behind millennial-scale oscillations.

Budget

$4000 for 50 Nd analyses at 8 analyses per day and $500/day;
$2000 for 50 Ar analyses at $40/analysis (15-30 grains in 2 to 4 samples, depending on availability);
Total requested: $6000

References

Bond, G.C., Lotti, R., Iceberg discharges into the North Atlantic on millennial time scales during the last deglaciation, Science, 267, 1005-1010.

Grousset, F.E. et al., Were the north Atlantic Heinrich events trigerred by the behavior of European ice sheets?, Geology, 28, 123-126.

Grousset, F.E. et al., 2001, Zooming in on Heinrich layers, Paleoceanography, 16, 240-259.

Hemming, S.R., 2004, Heinrich events: massive late Pleistocene detritus layers of the north Atlantic and their global climate imprint, Review of Geophysics, v. 42, RG1005, doi:10.1029/2003RG000128.

Knutz, P.C. et al., 2001, Multidecadal ocean variability and the NW European ice sheet surges during the last deglaciation, Geochem. Geophys. Geosyst., 3, 1077, doi:10.1029/2002GC000351.

MacAyeal, D.R., 1993, Binge/purge oscilations of the Laurentide Ice Sheet as a cause of North Atlantic Heinrich events: Paleoceanography, 8, 775-784.

Scourse, J.D., Hall, I.R., and 3 others, 2000, The origin of Heinrich layers: evidence from H2 for European precursor events, Earth and Planetary Science Letters, 182, 187-195.

Figure 1: see next page.

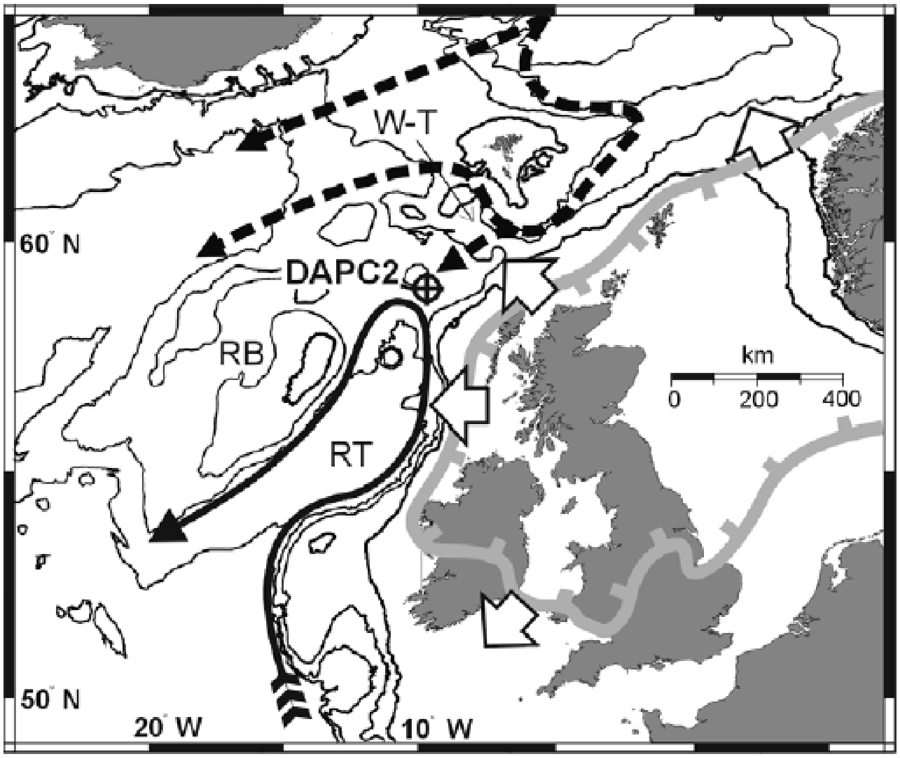

Figure 1: The core (MD04-2828) we will study is located nearby the DAPC2 core shown on this figure (*from* Knutz et al., 2001). Broad white arrows indicate the main glacimarine outlets. Thin-continuous black arrows illustrates a northerly boundary current driven by recirculated North Atlantic Deep Water, which flows along the European continental slope at depths of 2-3 Km. Thick-broken arrows represent Norwegian Sea Overflow Water, which enters the NE Atlantic across the shallow sills between Iceland and Scotland. RB – Rockall Bank; RT – Rockall Trough; W-T – Wywille-Thompson Ridge. Contour lines represent 200 m (thick line), 1000, 2000, and 3000 m (thin lines) water depth.