A Diatom Tale of Heinrich Event 1 in the Western North Atlantic

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Heinrich event 1 (H1) is a climate event resulting from the release into the North Atlantic of a huge volume of sea ice and icebergs from the northern hemisphere ice sheets. Heinrich events are revealed by the presence of lithic grains, known as Ice Rafted Debris (IRD), in numerous sediment cores of the North Atlantic (*Hemming*, 2004). Because the sediments corresponding to this event are largely composed of IRD in the belt of maximum accumulation, it is difficult to get a detailed well-dated description of the event.

However, we present a remarkable high-resolution diatom records from two western North Atlantic sites, the Bermuda Rise and the Laurentian Fan, to assess its impacts on North Atlantic surface circulation and its timing. At these sites, planktonic diatoms (microscopic algae) trace the conditions of surface waters (euphotic zone), in particular surface productivity, salinity and temperature changes. The comparison of diatoms at these two sites separated by 10º in latitude will also help to show the spatial extent of H1 across the northwest Atlantic.

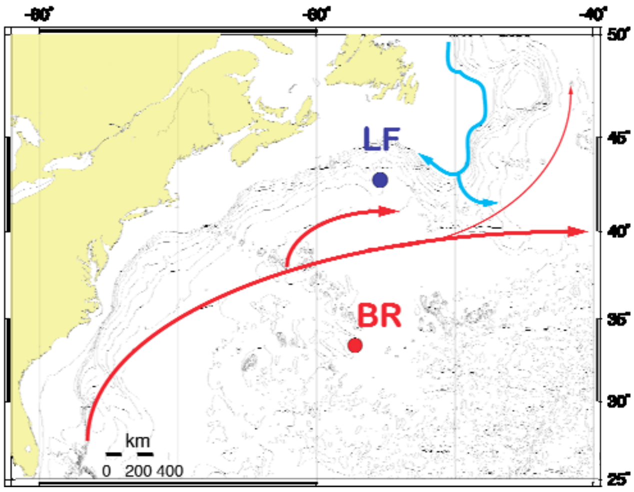

Figure 1. Location map of studied cores: Laurentian Fan (LF) and Bermuda Rise (BR). The red arrows indicate the main pathway of the Gulf Stream and derived currents. The blue arrows represent the Labrador Current.

The correspondences between the records show that the event is composed of three phases: the two first (A and B) correspond to major pulses of Ice Rafted Debris (IRD) and the third phase (C) relates to its immediate aftermath.

Phase A occurred from ~16.5/16.8 to 16.1 ka. It is initiated by the IRD pulse 1 and marked by an abrupt increase in diatom production over the Bermuda Rise. Over the Laurentian Fan, the diatom production also tended to increase. A much more accentuated cooling is indicated over the Laurentian Fan. The notable increase in cold-water diatom species over the Bermuda Rise (from 0.2% to 4.6%) was probably related to the presence of ice, while the enhanced contribution of warm water diatoms likely reflected the increase in the local diatom production expected at this latitude.

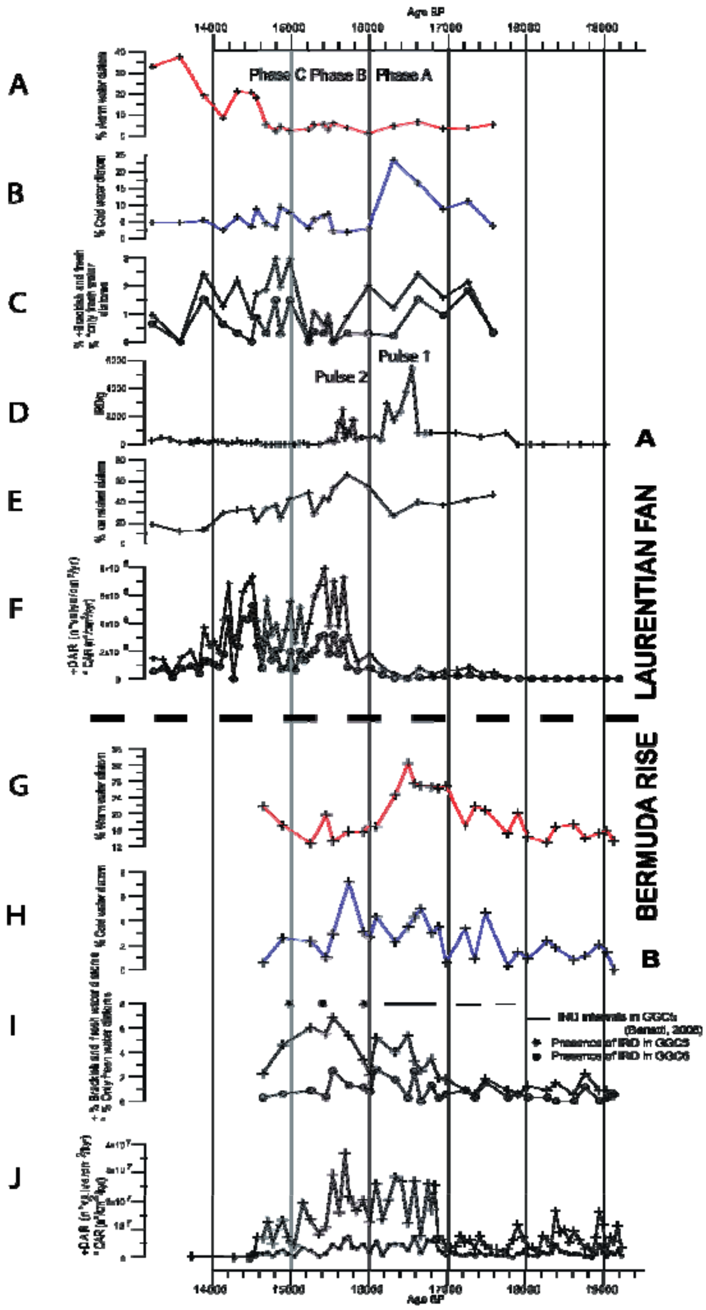

Figure 2. Data from GGC14: A- % Warm water diatom, B- % cold water diatom, C- % Brackish and fresh water diatoms (+) and % Fresh water diatom only (°), D- n° IRD/g, E- % ice related diatoms, F- Diatom Accumulation Rates (+) –DAR (n°valves/cm^2/kyr) and *Chaetoceros* Accumulation Rates (°) –CAR (n°valves/cm^2/kyr). Data from BR: G- % warm water diatom, H- % cold water diatom, I- % of

brackish and fresh water diatoms (+) and % of fresh water diatom only (°) and intervals comprising IRD (*Benetti*, 2006 for GCC5), J- (+) DAR (n° valves/cm^2/kyr) and (°) CAR (n°valves/cm^2/kyr).

The coincidence of the arrival of icebergs (evidenced by the IRD) and the increase in diatom production suggests that icebergs stimulated diatom productivity (*Gil et al.*, 2009). Although there is no modern analog in the North Atlantic to sustain this hypothesis, several examples of primary productivity generated by the presence of icebergs in the Southern Ocean (SO) have been reported (*Schwarz and Schodlok*, 2009; *Smith et al.*, 2007).

Phase B, from ~16.1 to 15.2 ka, corresponds to the maximum in diatom production. The second IRD pulse (pulse 2) was less important than pulse 1 and the presence of IRD in Bermuda Rise sediments is sparse. Over the Laurentian Fan, there were fewer low salinity indicators and a peak in abundance of ice related diatoms, suggesting again the presence of ice over the site. Over the Bermuda Rise, the diatom production was clearly linked to an increase in low salinity water. Brackish and fresh water diatoms grew in situ or were transported by icebergs. Nowadays, such an increase in diatom productivity is generated by cold-core rings and their input in nutrients (*Group*, 1981). The melting of icebergs must have amplified these oceanographic processes.

Finally, phase C took place between 15.2 and 14.6 ka. Over the Bermuda Rise, the decrease in brackish and fresh water diatoms was linked to the progressive disappearance of diatoms in the sediments and to a warming of the surface water starting at 15.2 ka. Such warming may mark the origin of the Bølling warming or just reflect a return to ambient conditions expected for that latitude. Another possibility is that diatom productivity was also amplified by the silica leakage from the Southern Ocean (SO) during deglaciation (*Bradtmiller et al.*, 2007). Silica rich water such as the Antarctic Intermediate Water (AAIW) could have been brought to the euphotic zone through mode-water eddies (*Gil et al.*, 2009). In contrast, the Laurentian Fan site was still under the influence of melt water and the transition to warmer conditions started later at 14.6 ka. As H events are defined by the presence of IRD in the sediment, it is difficult to relate directly this increase to the consequences of H1. The icebergs and/or the sea-ice would have only prevailed at northern latitudes by this time and it would explain why those conditions generating diatom productivity did not affect the Bermuda Rise.

The icebergs and their meltwater likely stimulated an immediate increase in productivity over the Bermuda Rise, while over the Laurentian Fan the increase in diatom abundance was progressive during pulse 1 (major pulse recorded at both sites) but fast during pulse 2. These suggest that to stimulate the productivity, there is a need for a critical amount of icebergs. The simultaneity of the records from either side of the Gulf Stream confirms that H1 is composed of a sequence of events. The phasing is particularly evidenced around 16 ka, between the two IRD pulses, when the low salinity anomaly from the Bermuda Rise is clearly diminished. The disturbances induced by H1 appear to end ~14.6 ka over the Bermuda Rise, while over the Laurentian Fan, the high diatom production persists until 14.1 ka and the salinity anomaly until 13.8 ka.

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Human-Nature Relationship in Mediterranean Streams: Integrating Different Types of Knowledge to Improve Water Management

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Streams are dynamic systems that are influenced by natural and anthropogenic factors. In the Mediterranean region, social and ecological systems co-existing in streams are intrinsically linked as a result of long human occupation. Here, these links vary greatly across small distances due to geomorphology, resulting in great diversity across space, which poses particular challenges for understanding and managing these systems.