GC12A CC: 524 C Monday 1030h

Impact of Ice Surges and Major Drainage Events on Thermohaline Circulation and Climate: Geologic Records and Numerical Simulations II *(joint with OS, C)*

Presiding: **D C Barber,** Bryn Mawr College**; A de Vernal,** Universit du Qubec Montral

GC12A-01 1030h

Meltwater discharge and the triggering of Younger Dryas : new data on the chronology of Champlain Sea transgression in the St-Lawrence River Valley

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Accurate chronology of ice retreat is crucial to understand the Ocean-Atmosphere couple at the end of the Pleistocene. The St-Lawrence River Valley is key in this regard, and two sedimentary sequences from Mount Saint-Hilaire, in the middle of the valley, contain a record that sheds new lignt on ice retreat and the penecontemporaneous proglacial marine invasion. Basal AMS-dates on terrestrial plant macrofossils coupled with an extrapolation from the pollen content of underlying postglacial lake sediments at Hemlock Carr (243 m), show that local ice retreat occurred around 11 350 14C yr BP. Cross-dating of such macrofossils (10 510 $\pm$ 60 14C yr BP) with shells from marine sediments (12 200 14C yr BP) catched in the neighbouring Lake Hertel's basin (169 m) show a ca. 1700 14C years difference mainly ascribed to the effect of old, glacially-derived carbon in the upper shallow waters of the Champlain Sea. The pollen-based chronological extrapolation at Lake Hertel indicates that the marine invasion occurred around 11 100 $\pm$ 100 14C yr BP. This result supports the chronology based on deep-water invertebrate marine fauna (Rodrigues, 1988). The 14C assessment of the New-England varve chronology (Ridge et al. , 1999) is thus confirmed. Deglaciation of the entire Saint-Lawrence River Valley took place within 1000 14C years. The chronology of ice retreat in southern Québec is shortened and made younger. This prompts major revision of all the associated paleohydrological events. Routing of the glacial meltwaters to the North Atlantic was impossible before 11 100 14C yr BP. The abrupt transition from Glacial Lake Candona (ca. 220 m) to the proglacial phase of the Champlain Sea (ca. 190 m) at 11 100 14C yr BP implies an input of glacial meltwater to the ocean estimated at 1500 km3. This may well have affected the thermohaline circulation in the North Atlantic and triggered the Younger Dryas oscillation.

GC12A-02 1045h INVITED

Freshwater Ocean Forcing Scenarios for the Megaflood From Glacial Lake Agassiz

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The presumed trigger for the 8.2 cal kyr BP cold event was the outburst flood that drained glacial Lake Agassiz northward to Hudson Bay and ultimately to the Labrador Sea. The released flood volume was $\sim$ 151, 000 km^3, roughly 12 times that of Lake Superior, the largest contemporary freshwater body. The most plausible flood release mechanism was subglacial drainage beneath the disintegrating Laurentide Ice Sheet. Physical modelling of this megaflood, constrained by studies of modern analogues, suggests that the peak flood discharge was in the range 5–10 Sv and the flood duration was 0.5–1.0 years. To examine the ocean response to outburst floods from Lake Agassiz it is necessary to define plausible forcing scenarios. Based on geological constraints, current understanding of contemporary outburst floods and paleohydraulic modelling, we propose three plausible scenarios for freshwater forcing: (i) a single flood following which river discharge is diverted northward from the St. Lawrence system to Hudson Bay; (ii) a two-step drawdown of the lake surface first from 230 m asl to 127 m asl and subsequently from 127 m asl to sea level. This would yield a two-pulse flood with continuous outflow to Hudson Bay; (iii) a two-pulse flood where the initial flood drained the lake to sea level and the ice dam reformed, allowing a partial refilling and a subsequent smaller flood. These scenarios provide guidelines for numerical experiments using a global ocean circulation model. Results of the computer experiments indicate that the outbursts from glacial Lake Agassiz could definitely cause a substantial change of thermohaline circulation (THC) in the Atlantic Ocean. The experiments also target the key questions of how fast THC recovered and how sensitive is THC to the routing, intensity, duration and single- or double-pulse character of the flood

GC12A-03 1105h

Multiproxy Evidence of Late Glacial Laurentide Ice Sheet Meltwater Re-routing From the Gulf of St. Lawrence to Hudson Strait

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The IMAGES cores MD99-2220 (48°38.32'N/68°37.93'W, 320 m) and MD99-2221 (48°10.60'N/69°30.35'W, 212 m) collected in the lower St. Lawrence Estuary provide a unique record for the reconstruction of large scale (sub-continental) hydrological changes and oceanographic variations because of its location, at the mouth of the St. Lawrence River watershed. An absolute calendar chronology spanning the last $\sim$9400 years was established based on calibrated AMS-^{14}C dates on mollusc shells and constraints from rock-magnetic and paleomagnetic secular variation data. By $\sim$8.5 ka cal BP ($\sim$7.7 ^{14}C kyr BP), a major change of the sedimentation rates was recorded, from $>$ 33 m/ka to $\sim$1.5 m/ka, as a consequence of the re-routing of meltwater-freshwater outflow, from the St. Lawrence River pathway to the Hudson Bay and Strait, after the collapse of the residual Hudson Bay ice dome. Reconstruction of sea-surface conditions based on dinocyst transfer functions in core MD99-2220 permitted a few paleoclimatic conclusions on a regional scale. The $\sim$8.5 ka cal BP transition was followed by a drastic decrease of sea-ice cover, together with increased salinity and winter sea-surface temperatures. Maximum February temperatures (well above the freezing point) and salinity ($\sim$34) in surface waters characterized the 8.3-7.5 ka cal BP interval. Additional information are provided by data from the IMAGES core MD95-2033 (44°39.87'N/55°37.21'W, 1412 m) collected on the Laurentian Fan off Cabot Strait, near the outlet of the Laurentian Trough into the North Atlantic. A few AMS-^{14}C measurements in planktonic foraminifers and the oxygen isotope stratigraphy permitted the establishment of a chronostratigraphy, which also indicate a major change in sedimentation rate during the early Holocene, from a late glacial rate of $\sim$120 cm/ka to a postglacial rate of $\sim$40 cm/ka. Sm-Nd isotopic analyses in sediment provide important information about the source of sediment supplies, thus about freshwater-meltwater routes. In core MD95-2033, LGM sediment depicts the most radiogenic signatures (ϵNd = -10 to -11) and the main change is recorded after $\sim$8.5 ka cal BP ($\sim$7.7 ^{14}C kyr BP). The sediment spanning the deglaciation until about 8.5 ka cal BP yielded ϵNd values between -12 and -13, whereas the overlying postglacial sediment yielded values ranging from -15 to -20. The change in ϵNd values after ca. 8.5 ka cal BP and the decrease in sediment accumulation rates together indicate reduction in meltwater flux and sedimentary supplies from the Paleozoic-dominated southeastern sector of the Laurentide ice sheet margin through the Gulf of St. Lawrence. The re-routing of meltwaters, from the Gulf of St. Lawrence to the Hudson Strait, resulted in a relative increase of low ϵNd sediments from Precambrian shield rocks carried by the Labrador Current to the slope site.

GC12A-04 1120h

Inter-basin Sea Surface Salinity Contrasts and the Fate of Ocean Thermohaline Circulation: Application to 8.2 ka Outburst Floods from Glacial Lake Agassiz

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For decades, substantial modeling effort has been directed to understanding freshwater impacts on the thermohaline ocean circulation (THC) in order to decipher the glacial cycles of the Pleistocene. Longer-term glacial-interglacial oscillations are paced by variations in Earth's orbital parameters, but shorter-term fluctuations of climate, especially in the North Atlantic region, are clearly driven by internal climate dynamics on millennial and longer time scales. Interactions between ocean and cryosphere are the main candidates for controlling such climate changes. However, the geologic record indicates that the transitions between cold and warm climates within the millennial-scale fluctuations were very fast, lasting for only decades or shorter. The THC is, perhaps, the only viable candidate for such short and abrupt changes. Our recent numerical experiments revealed that sea surface salinity contrasts between the North Atlantic and North Pacific are the most critical for the THC functioning. These contrasts depend on many factors, including the synergy between water vapor disparity between the two oceans and freshwater removal from the catchment area in the mid-latitudinal North Atlantic. However, many believe that this synergy may have been disrupted by fast cryosphere-ocean interactions causing substantial changes in the THC operation. There are several examples of such events since the Last Glacial Maximum. One involved huge outburst floods from glacial lakes that formed along the southern margin of the Laurentide Ice Sheet. The largest of these lakes was glacial Lake Agassiz, which drained into Hudson Bay around 8.45 calendar kyr ago (nominally 8.2 kyr BP). The estimates of freshwater discharged into the northern North Atlantic suggest that these amounts of freshwater could be sufficient for large-scale disturbance of THC. We present our most recent computer simulations of the role of sea surface salinity contrasts between the Atlantic and Pacific Oceans. These results include the scenarios of the Lake Agassiz outburst floods at 8.2 ka that caused sudden disruptions of THC and Atlantic-Pacific salinity balance. The THC response in some of the scenarios demonstrates that THC indeed could be influenced quite strongly. However, this response varies substantially in different scenarios showing its dependence on the intensity, duration, and routes of ice surges.

URL: http://www.essc.psu.edu/~dseidov/

GC12A-05 1135h

Is there a Marine Biotic Imprint of Periodic Climate Oscillations During the Holocene? The Message of Calcareous Phytoplankton

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Rapidly deposited sediments and strong environmental gradients make the oceanic realms in the vicinities of Iceland and Norway, very sensitive areas to Holocene hydrological and climate changes. Of additional interest is that recent anomalies in oceanic circulation may manifest themselves by an advection of Arctic waters and drifting ice along eastern Greenland and western Iceland, through the Denmark strait, to as far south as the latitude of Britain. This specific pathway for hydrographic anomalies is thought to characterize both present (Great Salinity Anomaly of the last 1960's; Dickson et al., 1988), historical (e.g. Little Ice Age; Lamb, 1979), and ancient Holocene hydrographic anomalies (Bond et al., 1997). Their interplay with the main core of Atlantic drift water along western Europe is still a matter of debate. The manifestations and pace of these hydrographic instabilities are investigated using high resolution sediment cores collected off both northern (MD99-2269) and southern (MD95-2015) Iceland, below the present path of the Arctic and Subarctic fronts, respectively, as well as off Norway (MD95-2011) under the influence of the Norwegian Current. Coccolith species diversity and concentrations are used as proxies of surface water circulation changes.

Millenial-scale oscillations linked with periodic advection of cool ice-bearing polar waters are particularly well depicted by the inferred productivity changes of the dominant and opportunistic species Emiliania huxleyi, as well as of specific North Atlantic Drift index species. These rapid, almost periodic changes call for a common origin and forcing mechanism. The frequent lack of synchronism of these oscillations in the studied sedimentary archives however suggests a complex pattern of transmission of these anomalies to remote areas of the boreal North Atlantic. The manifestation of the 8.2 cal. ka event around Iceland and off Scandinavia will be given a special attention, and will be compared with the impact of the other Holocene climate oscillations.

GC13A CC: 524 C Monday 1330h

Impact of Ice Surges and Major Drainage Events on Thermohaline Circulation and Climate: Geologic Records and Numerical Simulations III *(joint with OS, C)*

Presiding: **D C Barber,** Bryn Mawr College**; H Rashid,** Massachusetts Institute of Technology

GC13A-01 1330h INVITED

Spatial and Temporal Patterns of IRD Provenance in Glacial North Atlantic Sediments

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A full picture of ocean-atmosphere-ice sheet interactions awaits a thorough assessment of the array of different types of IRD layers with observations as well as models. Factors that must be considered in the observational studies are provenance (including geographic region of origin and whether icebergs or sea ice was the transporting agent), flux, relationship to sedimentological patterns such as grain size variations, and lateral sediment redistribution on the seafloor. We focus here on the provenance observations and their implications during the intervals of Heinrich layers H3 through H2, approximately 31 to 20 kyr. During the last glacial interval and prior to H3 (ca. 60-31 kyr), ice sheets had not achieved their maximum positions, and the abundance of IRD in marine sediments was generally lower as evidenced by standard measures such as %IRD and number of lithic grains per gram. H3 appears to be related to a modest IRD flux and it has been inferred to be a low foraminifera zone more than and IRD event. The map pattern of provenance variation within the H3 interval appears to be clearly relatable to surface current patterns and a significant portion of the continental derived detritus in eastern North Atlantic cores must have a European and/or Iceland+Greenland origin. In eastern Atlantic core VM28-82, the provenance varies abruptly across the low foraminifera interval of H3. In the Labrador Sea H3 has a composition like those of H1, H2, H4 and H5, suggesting a Hudson Strait source. Accordingly, the evidence appears to favor multiple sources of detritus (none of which overwhelmed the sediment load in the IRD belt) with a depositional pattern that is consistent with known surface currents. H1, H2, H4 and H5 can be traced far across the Atlantic to near Britain and Iberia based on the overwhelming Hudson Strait provenance. A difficulty in assessing geographical variations in the precursory intervals of Heinrich events is the rapid temporal variation in composition combined with the generally low resolution sampling. Hornblende 40Ar/39Ar ages within H2 cluster at 1.8 Ga (75%), with most other grains being older. Below H2 in cores from Orphan Knoll (GGC31), off Newfoundland (VM23-14), in the Heinrich layer thickness maximum (SU90-11) the ages are much more scattered. Although more data are needed to make a firm conclusion, it appears that the interval just below the Hudson Strait provenance has a large Paleozoic source and just below that appears to be a mixture of Cenozoic (Icelandic hot spot) and ancient (Greenland?) grains. These observations are consistent with published petrological and Nd isotope evidence in the precursory interval of H2. Published evidence indicates a contrast between the precursory intervals of H2 and H4, consistent with the glaciers' not being at their maximum positions until after H3. It is expected that the precursory interval in eastern North Atlantic sources might be composed of largely different sources, similar to the implied provenance from the H3 map pattern.

GC13A-02 1355h

Large and Rapid deglacial Changes in the Atlantic Meridional Circulation Recorded in sedimentary 231Pa/230Th

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The ocean's meridional overturning circulation (MOC) is an important mechanism for heat transport and inter-basin exchange of water and salt. Changes in the rate of the Atlantic MOC are widely believed to affect climate but a direct link with past climate variability has been difficult to demonstrate. Although past changes in Atlantic MOC have been inferred from changes in deep water chemical composition derived from sedimentary nutrient proxies, these reconstructions provide insufficient constraints on the rate of overturning to establish their climatic impact. Here we report measurements of 231Pa/230Th, a kinematic proxy for MOC, in a high accumulation-rate sediment core from the subtropical North Atlantic. The record reveals that large and rapid variations in the rate of Atlantic MOC occurred in concert with millennial-scale climatic events during the last deglaciation. Meridional overturning was nearly or totally eliminated during the coldest deglacial interval in the North Atlantic region, which coincided with the catastrophic iceberg discharge Heinrich Event H1, and declined sharply but briefly into the Younger Dryas cold event. The deglacial accelerations in MOC following these cold intervals were associated with the two most abrupt regional warmings recorded in Greenland ice cores and North Atlantic sediments and coincided with accelerations in sea level rise.

GC13A-03 1415h

Potential Paleocirculation Implications by Coupling Pb and Nd Isotope Analyses on Different Grain-Size Fractions From Labrador Sea Sediments

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In Labrador Sea, we have emphasized that Nd and Pb isotopes measured on clay-size fraction are suitable tracers of deep circulation changes through time. Nd and Pb are indirect paleocurrent tracers for reconstruction of sedimentary material driven by these currents (e.g., Fagel et al., 2003). Indeed, clay particles behave cohesively and are less sensitive to current winnowing after deposition. However, if the clay-size fraction gives informations about the inception and presence of a deep current, it does tell nothing about the strength of this current. Moreover, clays are not likely to be deposited in case of high-strength deep current, resulting in an uncomplete and/or biased reconstruction of deep current evolution. To overcome this problem, it is necessary to look also at coarser fractions, as demonstrated (e.g., Revel et al., 1996). Pb and Nd isotope compositions were thus analysed by MC-ICP-MS on different grain-size fractions on Last Glacial and Holocene sediments from the Labrador Sea. Four grain-size fractions were investigated for a set of samples from core MD99-2227 (Greenland Rise). Our results show a clear variation of Nd and Pb concentration according to grain-size. In addition, the Nd and Pb isotopic signatures are different from one grain-size to another. For Nd isotopes, such a fractionation was more or less expected, as it had been already evidenced in previous studies (McLennan, 1989; Revel et al., 1996; Innocent et al., 2000). The observed shifts between the four investigated grain-size fractions are interpreted in terms of changes in deep current strength. This approach allows to monitor the deep current changes through time, whatever the strength of the paleocurrent. References: Fagel et al., 2003. Geochim. Cosmochim. Acta 66, 2569-2581. Innocent et al., 2000. Mar. Geol. 168, 79-87. McLennan et al., 1989. Nature 337, 547-549. Revel et al., 1996. Mar. Geol. 131, 233-249.

GC13A-04 1430h

Detecting the source of Heinrich layers: an organic geochemical study.

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There are controversies regarding the origin of Heinrich layer 3, the massive ice-rafting and meltwater event in the North Atlantic Ocean during the last glacial cycle spanning the time between 28 and 29 ka BP. Some argue in favor of a North American Laurentide Ice-Sheet (LIS) source similar to other Heinrich layers while a contending view argues for European ice-sheet sources. Existing geochemical proxies such as $^{40}Ar/^{39}Ar$, $^{207}Pb/^{20}6Pb$, etc., could not be used to distinguish between different sources for H3 due to its low content of ice-rafted debris (IRD). In order to circumvent this problem we have used organo-geochemical tracers to characterize the sediment provenance of Heinrich layers 2 and 3 as well as samples between Heinrich layers. The samples analyzed are from cores covering a wide range of geographic locations from the mouth of the Hudson Strait at 62°N to 50°N in the Labrador Sea, the former main conduit of the LIS iceberg discharge, to as far south as the Bermuda Rise and to the east side of the Atlantic Ocean. Samples were analyzed for saturated and aromatic hydrocarbons by Gas Chromatography-Mass Spectrometry. Mature biomarkers such as hopanes and steranes in their thermodynamically stable configuration, and aromatic hydrocarbons such as aromatic steroids, aryl isoprenoids and aromatic hopanoids were detected. This assemblage of mature compounds is incompatible with recent and shallow surface sediment. Presence of such hydrocarbon compounds can be explained by the transportation of organic matter due to the glacial erosion of organic-rich source rocks. Our findings clearly demonstrate no appreciable differences in biomarkers distributions in sediments within H2 and H3 in the Labrador Sea. Biomarker patterns similar to those of the Labrador Sea sediments within H2 and H3 are present in the western Atlantic cores VM23-14 [43.24°N, 45.15°W] and-16 [46°N, 45°W]. The same signatures of biomarkers were also identified in core Hu89038-008 [33.69°N, 57.61°W] from the Bermuda Rise as well as in cores BOFS-5K [50.68°N, 21.86°E] and-8K [52.51°N, 22.07°E] from the eastern North Atlantic. Our data suggest that during the deposition of both H2 and H3 in the Labrador Sea as well as in the North Atlantic Ocean, sediments were delivered by icebergs that originated from the LIS. It also implies that the fine-grained sediments distinctive of the LIS source reached as far as 20oE in the North Atlantic, which is in agreement with the earlier findings of Rosell-Melé et al.(1997) in core BOFS-5K. Our results are in contrast to the existing paradigm that H3 only originated from a European source. The presence of similar mature biomarkers indicative of the LIS source in the Bermuda Rise core suggests that during the Heinrich and other stadial events LIS detritus were carried to the site by the Western Boundary Undercurrent (WBUC) and deep Gulf Stream circulation.

GC13A-05 1445h

Laminated deposits in Quaternary sediments of the Bay of Biscay as a recurrent phenomenon of glacial cycle terminations: the global perspective of a local seasonal deglacial pattern

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