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RECORD OF GLACIATIONS OFF THE EAST GREENLAND COAST OVER THE LAST 400 KYR: SM-ND ISOTOPIC SIGNATURE OF MARINE CLAYS

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Abstract

We use Nd isotope signature of the clay-size fractions of sediments from the Southern Greenland rise to track deep current changes over the last climate cycle. Fine particle supplies to the Labrador Sea by Western Boundary UnderCurrent (WBUC) were strongly controlled by proximal ice-margin erosion and thus echoed the glacial stage intensity. In contrast, distal WBUC-controlled inputs from NE Atlantic have been less variable, except for a marked increase in surface-sediments that suggests unique modern conditions

Introduction

The production of deep water in the North Atlantic is one of the puzzle in understanding the oceanic influence in climate changes. It is assumed that glacial to interglacial fluctuations in the exportation of North Atlantic Deep Water (NADW) to the Southern Ocean contributed to variations in atmospheric CO_2 concentrations during the Pleistocene. North Atlantic paleoceanography has been mainly investigated for the Last Glacial cycle, an interval may be not representative for the whole Pleistocene (Raymo et al., 2004). Most paleoceanographic reconstructions derived from biogenic proxies that are sensitive to ocean ventilation. Sedimentary abiotic components like magnetic properties (Kissel et al., 1997; Snowball and Moros, 2003), clay mineral assemblages (Bout-Roumazeilles, 1995; Fagel et al., 1997) or long period isotopic composition of clays (Bout-Roumazeilles et al., 1998; Frank et al., 2001; Fagel et al., 1999, 2004) were less investigated, even they bring indirect information on past circulation tracing the origin of the particles driven by the water masses. In this work, forty Sm-Nd isotope signatures were measured on the fine fraction of one sediment core (ODP Site 646) drilled in Labrador Sea, off Southern Greenland. Our aim is to record for the last four glacial/interglacial cycles (G-I) the relative contribution of fine particle supplies carried by the North Atlantic deep components into the Labrador Sea.

Material and method

Site 646 (58°12.56'N, 48° 22.15'W, water depth: 3460 m) was drilled in the Labrador Sea during Ocean Drilling Programme Leg 105 (Figure 1). Site 646 is located off Greenland on the upper northern flank of the Eirik Ridge sediment drift, below the high velocity axis of the WBUC. The WBUC drives NADW components overflowing the Denmark-Iceland-Faroe-Shetland sills (NSOW, ISOW) and the Denmark Strait Overflow Water (DSOW)] as well as a fraction of the Davis Strait Overflow, into a deep gyre in the Labrador Sea. The Labrador Sea Water (LSW) occupies the water column above NADW water masses. Surface waters are under the subpolar West Greenland Current (WGC) influence.

Sm-Nd isotopic signatures were determined in forty samples : we select 5 samples from each interglacial and glacial intervals. Sm-Nd concentrations and isotopic ratios were measured on the carbonate-free clay-size fraction. The < 2 µm fraction is the sedimentary faction that is the least affected by ice rafting and consequently more representative of the suspended particulate load of deep currents. The abundance of this clay-size fraction is slightly higher in glacials (mean = 6% ± 0.9) than in interglacials (mean = 3.7% ± 1.4). Sm-Nd data were measured using a VG-Thermal Ionisation Mass Spectrometer at GEOTOP.

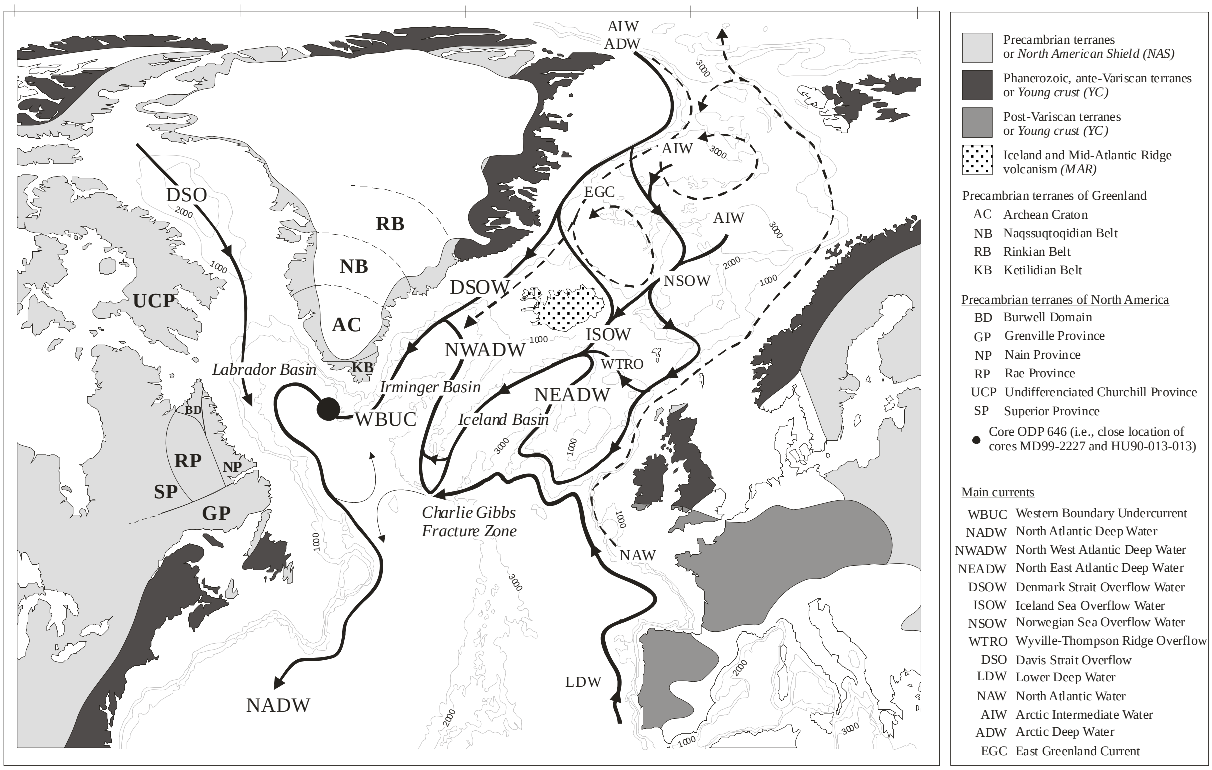

Figure 1 - Location of Site 646, Leg 105 ODP, Labrador Sea. The arrows indicate the pathways of deep or intermediate (plain line) and surface (broken line) currents. The structural terranes of the continental crust adjacent to the North Atlantic are indicated by grey levels and Iceland volcanism by dots (Fagel et al., 2004).

Radiogenic isotopic signature of marine clays: an indirect tracer for deep circulation Goldstein and O'Nions (1981) showned that detrital clays in marine sediments retain their Nd isotopic signature throughout the sedimentary cycle, that is, from continental weathering, through sediment transport to diagenesis. The radiogenic isotopic signature of the detrital sedimentary fraction can therefore be used to trace sediment provenance. In marine sediments crustal–derived material, mainly carried by rivers and dispersed by oceanic currents, is mixed with volcanically-derived material from oceanic crusts. In order to constrain sedimentary mixing, we must identified and characterized the isotopic composition of the potential geological sources of particles to the North Atlantic basins. Based on literature compilation (Innocent et al., 1997 ; Fagel et al., 2004), three main sources contribute to sediment mixture at core location: an old Precambrian crustal material from Canada and Greenland (NAS) ; a Paleozoic or younger crustal material from East Greenland, Europa, and Scandinavia (YC) and ; a volcanic source from Iceland, Faeroe and Reykjanes Ridge (MAR) (Figure 1). Based on Sm-Nd signatures, the relative contribution of each source will be estimated in each clay fraction. Then evolution of sedimentary mixings will be used to reconstruct past deep circulation changes.

Results and interpretation

On average for the last 360 kyr, the clay fractions from the glacial stages are characterized by the lowest Nd ratios (*i.e., unradiogenic* composition with more negative mean ε Nd = –15.7) than the fine material from the interglacial stages (mean ε Nd –11.5) (Figure 2). We calculated a mixing grid based on different proportions of the three end members using a standard Sm-Nd mixing pattern (Faure 1986). The mean Sm/Nd signatures for glacial intervals OIS2, OIS6 and OIS10 lay along a mixing line that is parallel to the NAS-MAR axis. Supplies characterized by young crustal Sm/Nd signature remain more or less constant (~40%) between those three glacial intervals; whereas mean volcanic contribution increases, relatively to old craton material, from OIS 2 to OIS6 and, OIS6 to OIS10. The glacial OIS8 displays a mean Sm/Nd signature close to the interglacials OIS1, OIS5 and OIS9. As an exception, the mean OIS7 value plots along the YC-MAR axis. Its high YC contribution is peculiar but it contains ~30% MAR like the other interglacial means.

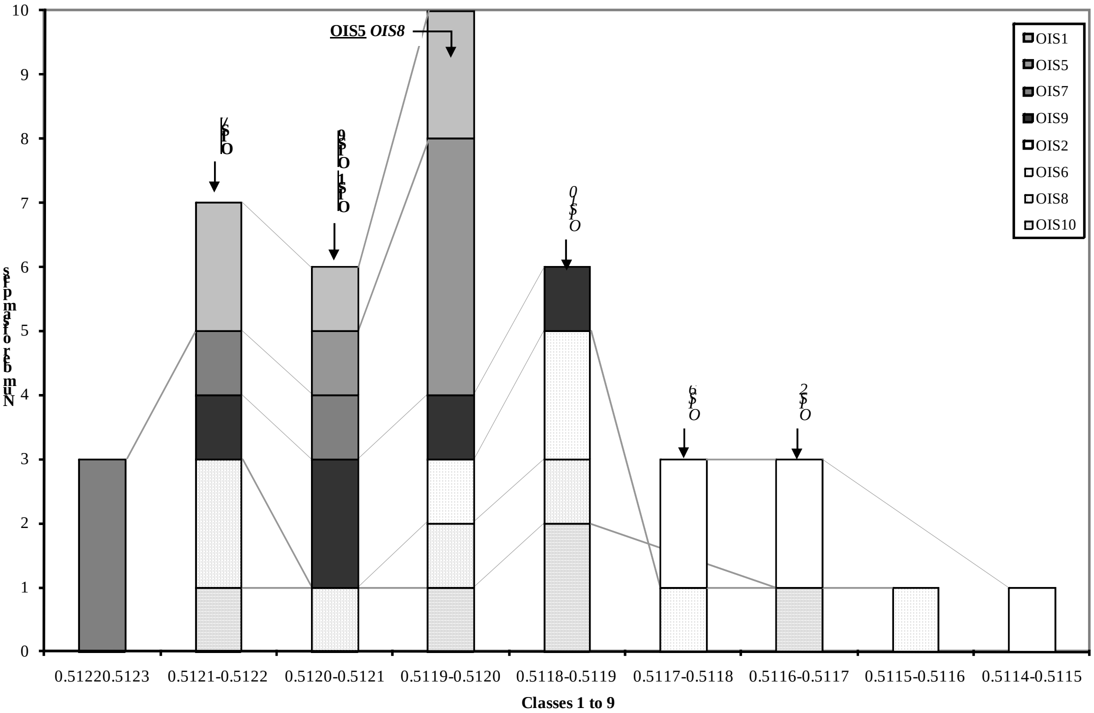

Figure 2 – Distribution of the $^{143}Nd/^{144}Nd$ ratios measured on the clay fraction. Nd data have been classed within 9 classes corresponding to a range of variation of 0.0001. Arrows indicate mean values.

In addition to internal variation within an OIS (probably underestimated by sampling resolution), the average contribution in NAS drops by a factor of 2 between a glacial interval and the adjacant younger interglacial. This evolution is mainly counterbalanced by higher mean MAR contribution within interglacials. Such evolution remains relative: any NAS drop could be due either to a decrease of NAS supplies or to higher supplies from the two others end-members (dilution process).

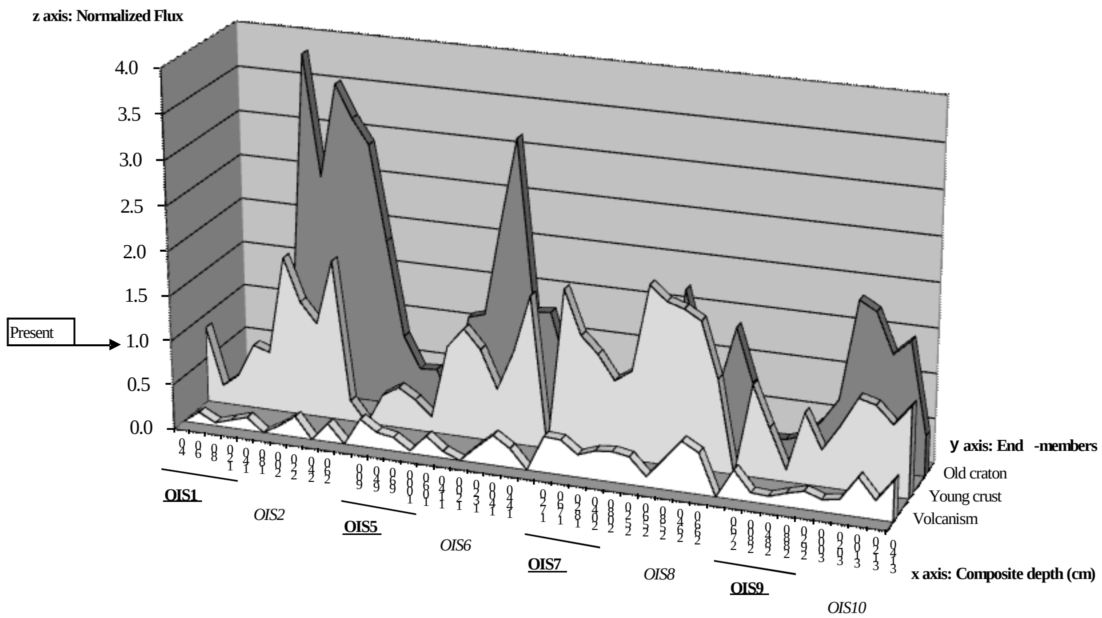

Figure 3 – Estimated contributions of the three identified end member NAS, YC, and MAR for the last four glacial/interglacial cycles. Each end member contribution has been normalized to surface representative sediment signature (vertical dashed line fixed at 1).

To decipher between higher supplies or dilution process, we estimate particle fluxes supplied by the end-members (Figure 3): NAS supplies are higher (relatively to the other end-members but also in absolute amount) during glacial intervals than during interglacials. The fine particle suppplies in Labrador Sea are therefore strongly controlled by proximal margin erosion: NAS supplies directly reflect the glacial stage intensity. MAR fluxes do not present significant G/I fluctuations for the last 360 kyr, except a marked increase in surface. The ODP646 Sm-Nd record confirms previous observations made from the study of nearby core MD99-2227: the late Holocene (i.e. < 3.1 kyr BP), characterized by an increase of MAR supplies, appear to be atypical with respect to the past 365 kyr. Peculiar recent conditions may be related to the unusual recent open sea ice conditions in Nordic seas favoring ocean convection, responsible for the observed anomalous large volumetric flux of NSOW today (Raymo et al., 2004) and/or the full appearance of the Labrador Sea Water mass.

Conclusion

The long-term evolution (i.e., over the last 365 kyr) of Sm-Nd ratios of fine particle fractions in deep Labador Sea sediments reflects changes in source provenance and deep-current paleointensity.

Glacial Sm-Nd signatures are characterized by systematically lower $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ ratios than interglacials, reflecting enhanced proximal supplies related to continental margin erosion. *The sedimentary Sm-Nd glacial signature can be used as a fingerprint of the local or regional intensity of glacial erosion.*

In terms of long-distance transport, the flux of distal fine particles transported by deep water masses from the Iceland Basin-Reykjanes Ridge-Iceland areas did not change significantly between glacials and interglacials, although an overall long-term reduction seems probable.

Late Holocene conditions seems quite peculiar with respect to the past 365 kyr.

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