Evidence for decreased NADW flux during Glacial Stages 2 and 4 from Nd isotopes in Southern Ocean sediments

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It has been suggested that North Atlantic Deep Water (NADW) production was reduced during the Last Glacial Maximum thereby altering the distribution of heat around the globe, and the partitioning of CO_2 between the ocean and atmosphere (Broecker and Denton, 1989). Although the thermohaline circulation concept has great appeal in explaining much of the evidence for climate changes that have taken place in the past, currently employed proxies have produced conflicting results regarding the changes in NADW production in the late Quaternary. In the Southern Ocean δC measurements on benthic foraminifera have been interpreted to indicate a switching off of NADW during glacial times. However, this interpretation is in conflict with interpretations based on Cd/Ca measurements of benthic foraminifera (Boyle, 1992). In support of the Cd/Ca results, $^{231}Pa/^{230}Th$ data from core top and late glacial marine sediments have been interpreted to indicate that export of deep water formed in the North Atlantic was similar to modern conditions (Yu *et al.*, 1996). The conflicting interpretations based on commonly employed proxies highlights the need for new tracers. We report here on work in progress to validate and apply the Nd isotope composition of marine authigenic precipitates as a proxy for variation in deep water mass composition.

The Nd isotope composition of deep seawater varies systematically with water mass properties. The unradiogenic character of Nd in the North Atlantic reflects the ancient shield rocks surrounding the area of NADW formation. The very young rocks surrounding the Pacific Ocean impart a more radiogenic signature to Pacific waters. In the Atlantic Ocean the Nd isotope composition of today's deep water appears to be the product of mixing of Southern Component Waters and Northern Component waters.

The observation that the Nd isotope composition of present-day water conforms to water mass properties is an important line of evidence in evaluating the potential for Nd isotopes as a tracer of water mass mixing in the past. However, it is also necessary that there be some extractable phase that sequesters seawater Nd in marine sediment in order to make use of this observation. Published work has demonstrated that ferromanganese precipitates, specifically crusts and nodules, generally record the approximate ε_{Nd} of the bottom water mass that bathes them, with only a few exceptions (e.g. Albarède and Goldstein, 1992).

Although ferromanganese crusts have been demonstrated to provide a reliable measure of bottom water Nd composition, and recent studies have used these substrates to examine changes in seawater composition over time, crusts are limited in their availability and growth rate, generally integrating over 10 thousand to 1 million years per subsample. Accordingly, we are in the process of testing the application of leaching methods to extract the ferromanganese phase from marine sediments in order to examine secular variation in Nd isotope composition of seawater at glacial to interglacial timescales. A preliminary test of leaches from a suite of core tops has yielded positive results that are entirely overlapping with seawater measurements.

Core RC11-83 (41.36°S, 9.48°E, 4718 m) is located in the Cape Basin of the southeastern Atlantic Ocean. Extensive stable isotope data have been reported for this core (Charles *et al.*, 1996). Charles *et al.* (1996) have interpreted the large variations in the δC to reflect a reduced contribution of NADW to this region during Stage 2 and Stage 4.

RC11-83 also records a significant glacial to interglacial contrast in the Nd isotopic composition of the ferromanganese component (Fig. 1). A core top sample and a sample from isotope Stage 3 provide Nd isotope ratios similar to nearby water measurements. In contrast, values much closer to those of the modern Pacific are found in two samples measured from Stage 2. Two measurements come from samples that were taken from transitional intervals based on stable isotope measurements, and these samples also provide intermediate Nd isotope values.

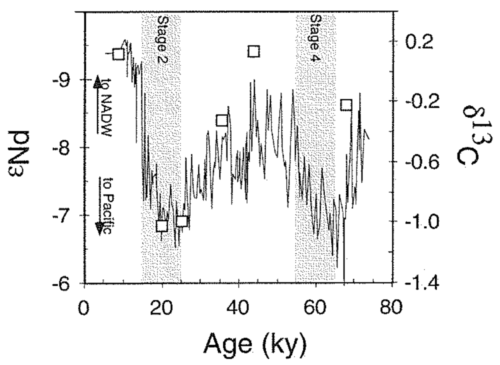

FIG. 1. ε_{Nd} (open squares) and $\delta^{13}C$ (solid line) plotted *vs* age. Holocene and Stage 3 ε_{Nd} values plot closer to the NADW endmember. Stage 2 values fall closer to the NADW endmember. This shift indicates a decreased flux of NADW to the South Atlantic during Stage 2.

These results are consistent with variability of the proportion of NADW in the southeastern Atlantic. Specifically, the results are consistent with shallowing or perhaps a complete shutdown of NADW. Results from previously published studies of the surface layers of ferromanganese crusts are also consistent with the results and interpretation presented here. Specifically, although there is a general agreement between the Nd isotope composition of ferromanganese crusts and seawater, crust are slightly more radiogenic than nearby seawater values in the region of the Drake Passage. Thus, Albarède and Goldstein (1992) reasoned that the observed offset could be interpreted as integrated measurement of the variable deep water composition in this region that produced by changes in deep water circulation on glacial to interglacial time scales.

As with all proxies, the Nd isotope proxy for deep water changes has its own set of potential complications. However, they are quite different and independent from those of δC or Cd/Ca which are nutrient and/or productivity tracers. Two lines of evidence support the hypothesis that the Nd isotope composition of the ferromanganese component from core RC11-83 provides a reliable estimation of the Nd isotope composition of seawater: (1) The $^{87}Sr/^{86}Sr$ of the samples is that of modern seawater; and (2) Core top measurements from a number of locations with different seawater chemistry and sediment substrate yield Nd isotope ratios that are consistent with those measured from seawater itself.

Variations in the Nd isotope composition in the ferromanganese component of deep sea sediment cores is shown to be a potentially powerful palaeoceanographic tool, providing directional information as to the origin of a water mass. Our supporting Sr isotope data from the same samples demonstrate that we are measuring a seawater signal. The observed variations suggests that, in agreement with δC data, the flux of NADW to the South Atlantic during Stage 2 and Stage 4 was reduced relative to Holocene and Stage 3.

References

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