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Evidence for Stronger Thermohaline Circulation Prior to Northern Hemisphere Glaciation from Nd and Pb Isotopes in Ferromanganese Crusts

Martin Frank (frank@erdw.ethz.ch)[1], **Nicholas Whiteley** (nickw@earth.ox.ac.uk)[2], **Sabine Kasten** (skasten@geochemie.uni-bremen.de)[3], **James R. Hein** (jimh@octopus.wr.usgs.gov)[4] & **R. Keith O'Nions** (keitho@earth.ox.ac.uk)[2]

[1] Institute for Isotope Geology and Mineral Resources, ETH-Zentrum, NO C61, Sonneggstrasse 5, 8092 Zürich, Switzerland
[2] Department of Earth Sciences, University of Oxford, Parks Road, Oxford OX1 3PR, UK
[3] University of Bremen, FB5 Geowissenschaften, Postfach 330 440, 28 334 Bremen, Germany
[4] U.S. Geological Survey, 345 Middlefield Road, MS-999, Menlo Park, CA 94025, U.S.A.

The intensity of North Atlantic Deep Water (NADW) production is considered one of the key parameters controlling the global thermohaline ocean circulation system and climate. Reconstructions of the strength of NADW flow in the past have been derived from marine sediments, either using the carbon isotope composition of benthic foraminifera or changes of sedimentological parameters. Results of the reconstructions from these two sources have, however, not always been consistent. Sedimentological results have been interpreted in terms of a strengthening of NADW flow since the onset of Northern Hemisphere Glaciation (NHG). In contrast, stable carbon isotope data show that the isotopic difference between the Atlantic on the Pacific has increased over the past 3 Myr, suggesting that NADW production and global thermohaline circulation was significantly stronger prior to NHG.

We present an alternative approach to reconstruct the intensity of NADW production using Nd and Pb isotopes as water mass tracers, which have been recorded by ferromanganese crusts and nodules. Drastic shifts in the Nd and Pb isotope compositions of NADW starting between 2 and 3Ma ago, which were related to increased physical erosion on the adjacent continents, have been recorded in NW Atlantic crusts (Burton et al., 1997; O'Nions et al., 1998; Reynolds et al., 1999). For Nd, but at least partly also for Pb, the oceanic residence times are long enough to allow for the advection of such a signal to the southern Atlantic and Southern Ocean. The response of the Southern Ocean to this input signal should thus provide important information on the history and strength of circulation within the Atlantic basin over the last 10 Myr. We present new Nd (TIMS) and high-resolution and high-precision Pb-isotope time series (measured by multi collector ICPMS (Belshaw et al., 1998)) on 5 ferromanganese crusts from different water depths and locations in the Southern Ocean and a Mn-nodule from the Cape Basin. These were dated using profiles of $^{10}Be/^{9}Be$ ratios determined by SIMS. In marked contrast to the records from the NW Atlantic, the Southern Ocean records display basically invariant Nd isotope values over the past up to 14 Myr and a clear trend towards more Pacific-like Pb-isotope composition over the past about 3-4 Myr. The increasing difference between these trace metal isotopes in the NW Atlantic and the Southern Ocean over the past 3 million years gives thus clear evidence for an overall reduction of NADW input into the Southern Ocean since the onset of Northern Hemisphere Glaciation.

The Pb isotope records are clearly influenced by this decrease in NADW export but the short residence time of Pb does not allow its use for quantitative evaluations. Nd on the other hand has an average residence time of at least 600 years (Tachikawa et al., 1999) which corresponds to several residence times of water in the Atlantic Basin and it can thus be used as a quasi-conservative ocean tracer. Mass balance calculations from the NW Atlantic and Southern Ocean Nd isotope time series show that the volume of NADW flowing into the Southern Ocean decreased by overall 15-30 percent over the past 3.5 Myr.

Rather than a continuous general decrease of NADW with time this effect might alternatively be explained by the evolution of more pronounced glacial periods since the onset of NHG, during which NADW did not arrive in the Southern Ocean or was at least greatly reduced. Assuming a weak glacial/interglacial climate variability prior to the onset of NHG (0 percent of time without NADW arriving in the Southern Ocean), the Nd isotope time series would indicate a change from continuous supply of NADW before 3.5Ma to about 15-30 percent of time with no NADW arriving in the Southern Ocean over the past 100-200 thousand years. Prior to 3.5Ma back to about 14Ma the Nd isotope data indicate that there has been a relatively strong and constant supply of NADW or a precursor of it to the Southern Ocean in agreement with results derived from carbon isotopes.

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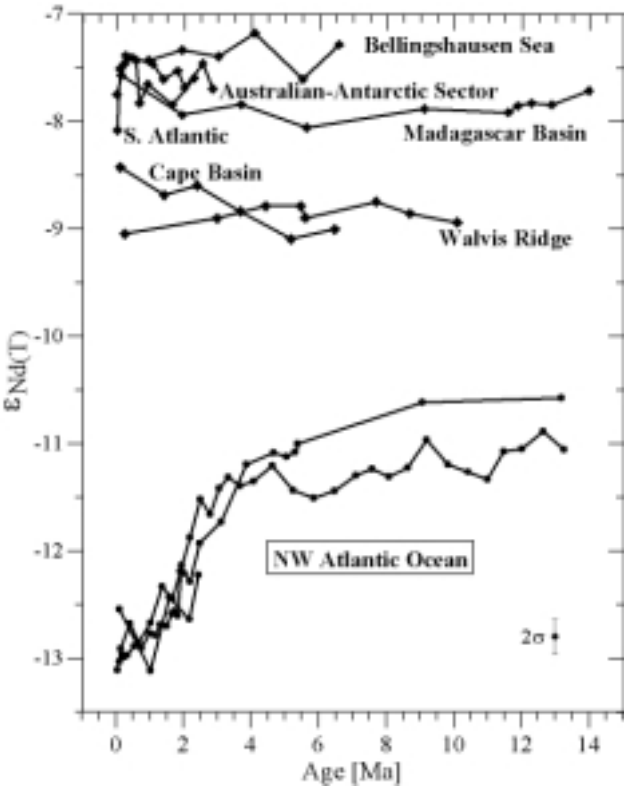

Figure 1: Nd isotope time series given as $\varepsilon_{Nd}(T)$from ferromanganese crusts in the NW Atlantic and the Southern Ocean. Error bar represents 2 σ external reproducibility.

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