The Gakkel Ridge – A smoking gun for an origin of DUPAL mantle

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The ultra-slow spreading Gakkel Ridge, under the Arctic ice cap, is a remarkable microcosm of global MORB physical and chemical variability, providing special opportunity for geochemical mapping of the upper mantle and investigating mantle flow and origins of mantle heterogeneity. Key features include: (1) isotopic variability covering nearly the range of global MORB, (2) robust western and eastern volcanic segments separated by a "sparsely magmatic zone" (SMZ), (3) distinction of the W Gakkel volcanic zone as the only significant DUPAL ocean ridge segment outside the Southern Hemisphere, and (3) a sharp transition from DUPAL to "Pacific-Atlantic-type" mantle, occurring in the middle of the SMZ, reminiscent of the Australian-Antarctic Discordance (common features include great bathymetric depths and low magma production associated with a mantle boundary).

While the origin of DUPAL mantle has been a matter of major debate, here we have a *smoking gun* identifying its source. (1) Spitsbergen Quaternary alkaline basalts (SQB), showing DUPAL character, plot as the enriched endmember to western Gakkel lavas for combinations of all isotopes and some trace elements (e.g. Th,U,La), strongly indicating that the component causing the "DUPAL-like" characteristics in the sub-Gakkel mantle is also the source of the SQB. (2) The SQB in turn are derived from melting of subcontinental lithospheric mantle (SCLM), indicated by strong evidence for melting in the presence of residual amphibole (reflected by low Ba/Th and Rb/Th in SQB), unstable in asthenosphere p-T conditions. (3) It follows that the DUPAL signature in Gakkel lavas reflects delamination of Spitsbergen SCLM and dispersal into the convecting asthenosphere.

Further consideration of Arctic tectonic history, and comparison of western and eastern Gakkel lava chemistry, indicates that this process accompanied propagation of N Atlantic mantle into the Arctic during Cenozoic separation of Greenland and Svalbard. The abrupt isotopic boundary in the "sparsely magmatic zone" thus represents the surface manifestation of the physical boundary between distinct North Atlantic and Arctic upper mantle regions. The Gakkel data show the close relationships between ridge structure, bathymetry, and mantle convective processes.

Quantifying Late Quaternary changes in MOC intensity from circum-Antarctic Nd isotopes

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The Circum-Antarctic plays an important role in the ocean circulation system, connecting the three major ocean basins and acting as the intermediary of global water-mass exchange. As the main "blender" of water masses, the vigor of the meridional overturning circulation (MOC) is reflected by changes in its tracer inventory through time. For example, weak export of NADW (or GNAIW) would result in a reduction in North Atlantic chemical signatures in deep Circum-Antarctic water masses. Hence, constraints on the inventory of appropriate tracers in the Circum-Antarctic over time can be a key for better understanding of MOC changes and its relation to global climate. Nd isotopes in authigenic phases of deep sea cores provide the possibility to quantify past ocean circulation changes, as a quasi-conservative tracer.

We present a ~30 kyr record that we interpret to represent this "global blend", allowing a first order quantification of the variability of the export of North Atlantic waters to the Circum-Antarctic. The core, V19-188 from the Indian Ocean, shows coretop ε_{Nd}= -8, in argeement with ambient seawater and consistent with a Circum-Antarctic provenance. Throughout the entire record, ε_{Nd} remains more Pacific-like than our previous Cape Basin record [2], consistent with the Cape Basin Nd isotopes representing intermediate mixtures of components from the North Atlantic and Circum-Antarctic.

The record indicates large variations MOC intensity over the past ~30 kyr. A conspicuous feature is Pacific-like ε_{Nd} values during Heinrich 1 and the early part of MIS 2 at >23 kyr, indicating absence of any NorthAtlantic-derived component and implying shut-down of the global MOC during these intervals. The Younger Dryas also imparts a significant but smaller magnitude MOC weakening. However, the MOC is moderately strong during the LGM around ~20 kyr. The record is strikingly similar to the North Atlantic $^{231}Pa/^{230}Th$ record of McManus *et al.* [1], from the Holocene through the LGM at ~20 kyr where that record ends. We suggest that further comparison of ε_{Nd} and Pa/Th can be an important means of gaining new insights into MOC history and its impact on climate.

[1] McManus *et al.* (2004) *Nature* **428,** 834-837.
[2] Piotrowski *et al.* (2005) *Science* **307,** 1933-1938.