Nitrogen isotope biogeochemistry of the South Atlantic

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The South Atlantic at 40°S is a highly productive region of the open ocean marking the transition between the Sub Antarctic Zone (SAZ) and the South Atlantic gyre. We present a high resolution depth transect of $\delta^{15}N_{NO3}$ from the sub-tropical front to elucidate the contrasting nutrient regimes in water masses of subtropical (Agulhas Current, South Atlantic Central Water (SACW)) and Antarctic origin (Antarctic Intermediate Water (AAIW) and Sub Antarctic Mode Water (SAMW)). The preferential uptake of ^{14}N by biota leaves NO_3 enriched in ^{15}N as it is utilised; therefore, $NO_3/\delta^{15}N$ relationships in combination with nutrient stoichiometry can describe the history of water mass formation at the surface and transformation during transit [1].

The SAMW supplies high nutrient waters to the low latitude Atlantic, fuelling primary productivity [2]. A greater variation in SAMW NO_3 and $\delta^{15}N_{NO3}$ values compared to previous studies [3,4], may result from incorporation of the underlying AAIW and overlying surface waters during transport. At the surface, we estimate isotope fractionation during NO_3 utilization of ε ~9 ‰, which is consistent with previous SAZ estimates [3]. However, this fractionation effect is diluted in most profiles by the influence of the nutrient poor SACW.

Tropical surface waters are identified between 50-53°W, with $\delta^{15}N_{NO3}$ values in the range of 4-6‰. These depleted $\delta^{15}N_{NO3}$ signatures suggest the influence of N-fixation in this water mass. Similarly, the Agulhas leakage into the South Atlantic is characterised by low $\delta^{15}N_{NO3}$ signatures because it is sourced from the combination of tropical and Southern Ocean water masses of the Indian Ocean. These datasets will be modelled in an attempt to quantify the extent of N fixation, NO_3 utilization and water mass mixing that has occurred in these water masses, to address their role in nutrient transport and productivity within the ocean.

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Volcanism on Mars controlled by early oxidation of the upper mantle

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We investigated the genetic relationships between Martian meteorites and the surface rocks of the Gusev Crater analysed by MER Spirit. The SNC meteorites, with crystallisation ages mostly in the range 1.4Ga-180 Ma are likely derived from young volcanic regions such as Tharsis Plateau. They are enriched in volatiles and depleted in Ni and other chalcophile elements relative to terrestrial igneous rocks of similar composition[1]. Surface rocks from the Gusev crater are much older (~ 3.7 Ga) and are substantially richer in Ni and S with lower Mn/Fe ratios than the meteorites[2]. These observations lead to doubts that surface rocks and SNC meteorites have similar mantle source regions.

We started with the Dreibus and Wänke (DW) estimate of Martian mantle composition and experimentally-produced partial melts of this mantle at 1.5 GPa ([1,3]). Martian mantle Ni and S contents (up to 3000 ppm) were varied and the Ni and S contents of the melts calculated assuming sulphide saturation at low f_{O2} (FMQ- 2 log units). The melts were allowed to fractionally crystallise the liquidus mantle phases (olivine, orthopyroxene, clinopyroxene spinel and sulphide), using the crystallisation program 'Petrolog'[4]. This yielded the correct SNC trends of Ni-Mg and Mn-Fe for melts and cumulates with mantle Ni content of 1800 ppm. We repeated the procedure at high f_{O2} (FMQ+3 log units), conditions where sulphide is unstable. Partial melts are much richer in Ni and S and reproduce the Ni-Mg trend of the Gusev crater rocks. Furthermore, magnetite, found in the recently described "Gusev-like" meteorite NWA7034[5] becomes the liquidus phase and extracts Mn from the differentiates, consistent with observations of surface rocks. Our results demonstrate that the surface basaltic rocks of the Gusev crater and the igneous SNC meteorites are consistent with partial melting and fractional crystallisation from the same DW-like source but under different fO_2 conditions. The implications are that Mars' surface oxidised early in its history and that oxidised material was recycled into the upper mantle.

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