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Hf-Nd-Pb isotope systematics in MORB from the Mid-Atlantic ridge, 22-35°N

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Systematic Sr-Nd-Pb isotopic studies of MORB have shown that the terrestrial upper mantle is chemically and isotopically heterogeneous on various scales, from thousands of kilometres to decimetres. Due to the larger fractionation between Lu and Hf relative to the fractionation of Sm and Nd during magmatic processes, the application of combined Lu-Hf and Sm-Nd isotope systematics may provide a unique perspective on the origin of upper mantle heterogeneities. Currently, however, no Hf isotope data are available to study mantle heterogeneities in detail on a small sample scale (~1000 km).

Here, we present new results from Hf, Nd, and Pb isotope analyses of 22 MORB (bulk rocks and glasses) along a small segment of the Mid-Atlantic ridge, between 22°N and the Oceanographer fracture zone (35°N). With these data, we attempt to establish the possible effects arising from tectonics, such as fracture zones, plume-ridge interaction (e.g., influence of the Azores hotspot located to the north of our ridge segment), as well as passive mantle source heterogeneities (e.g., ''marble cake''mantle).

Our results show significant Hf isotope variations with $^{176}Hf/^{177}Hf$ ratios ranging from 0.283112 to 0.283365, as well as large Pb isotope variations ($^{206}Pb/^{204}Pb$=18.080-19.372, $^{207}Pb/^{204}Pb$=15.438-15.573 and $^{208}Pb/^{204}Pb$=37.526-38.912). The range in $^{143}Nd/^{144}Nd$ (0.512953-0.513258) is comparatively more restricted. Even though Nd and Pb isotope ratios display a clear negative correlation, no general relationship can be observed between Hf and Nd (or Hf and Pb) isotopes at the scale of the sampling zone. However, based on average isotopic compositions, two domains divided by the Hayes fracture zone (33.5°N) can be distinguished. In addition, a weak Hf-Nd trend is observed for basalts located between the 30 and 33.5°N transform faults, directly south of the Hayes transform fault. The apparent decoupling between Hf and Nd (or Hf and Pb), already observed at a larger sampling-scale, will be discussed in terms of mantle heterogeneities.

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Mantle source heterogeneity recorded in olivine-hosted melt inclusions from the FAMOUS zone, Northern Mid-Atlantic Ridge

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Melt generation below mid-ocean ridges involves polybaric melting of an adiabatically upwelling mantle source region. Isotopic variations in MORB have revealed that the upper mantle is chemically heterogeneous on various scales, from thousands of kilometres to decimetres. Even though variation in major and trace element compositions of MORB is generally attributed to the effects of partial melting, melt extraction, migration towards the surface and differentiation at shallow depths, it is also possible that part of this variation directly reflects compositional variation of the source. It is thus important to decipher the chemical fingerprint of each process, in order to constrain mantle heterogeneity. A direct approach is to characterize the composition of instantaneous melts preserved as inclusions in early-formed minerals. Melt inclusions may sample a range of primary liquids, and could therefore be used to obtain information on possible variation in source composition and extent of melting.

For the present study, melt inclusions hosted by high-Mg olivines (Fo_{88-91}) from a single MORB sample (ARP73-10-03) from the FAMOUS zone were analysed for major and trace elements by electron microprobe, ion probe and LA-ICP MS. The compositional variation in the near-primary melts cannot be explained by progressive melting of peridotite at a constant pressure, nor by polybaric melting of an adiabatic upwelling mantle. In contrast, the large range in trace element compositions and in highly incompatible element ratios can be accounted for by considering a mixing relationship between two mantle components. This result indicates that melts derived from different mantle sources can co-exist in the ridge plumbing system before melt aggregation takes place and that they may be preserved at the scale of a single sample. It raises the question of how mantle melts are collected beneath mid-ocean ridges.