5.6.48

Hf isotopes and mantle melting along the Southeast Indian Ridge

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The Southeast Indian Ridge (SEIR) provides a unique opportunity to study the consequences of along-axis variations in upper mantle temperature, and to test global models that link regional and segment scale petrologic and isotopic variations to axial depth and crustal thickness. The axial depth increase from 2300 m to 5000 m over a distance of 2500 km along the SEIR, from 86°E to 120°E, is similar to the global range for spreading ridges away from hotspots, making it a regional-scale analog of the 60,000 km-long global ocean ridge system. The SEIR depth gradient occurs at intermediate and constant spreading rate (70-75 mm/y full rate) and in the absence of large transform offsets and nearby hotspots. Local variability is significant along several SEIR segments, but to first order the major element systematics follow global trends, consistent with mantle temperature having a dominant control on extent and depth of melting. Previous work has also established that He, Pb, Sr and Nd isotope variations along the SEIR may be controlled by changes in the depth of melting of isotopically heterogeneous mantle. As well, all SEIR lavas west of the Australian-Antarctic Discordance are true “Indian type” as indicated by their high $^{208}Pb/^{206}Pb$ ratios. New Hf isotope results (ε_{Hf} =+9.5 to +14.6) reveal a marked difference from the global trend of axial depth - $\delta_{Lu\text{-}Hf}$ (deviation in Lu/Hf of the melt compared to a reference mantle source, computed from the measured $^{176}Hf/^{177}Hf$ and Lu/Hf). Along the SEIR, $\delta_{Lu\text{-}Hf}$ shows a narrow range of 0.35-0.50 (for a 2 Gy reference isochron). Such high values indicate recent enrichment of Hf relative to Lu, likely due to melting that initiates in the presence of garnet. The absence of a $\delta_{Lu\text{-}Hf}$ - axial depth trend is contrary to model predictions involving only garnet peridotite, unless the mantle reference isochron for the shallowest parts of the SEIR is >1.5 Gy younger than it is for the deepest parts. Alternatively, melting of garnet pyroxenite plays a role. If so, then larger amounts of garnet pyroxenite must be present beneath shallower sections of the SEIR, otherwise $\delta_{Lu\text{-}Hf}$ would covary with axial depth. This suggests a link between lithologic heterogeneity, mantle temperature and axial depth: heat production from radioactive decay of U, Th and K in garnet pyroxenite may exert some control on mantle temperature and axial depth in this region of the Indian Ocean.

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Isotopic evidence of large-scale mantle stretching and refolding beneath the Mid-Atlantic Ridge

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Although it has long been understood that mapping the isotope geochemistry of mid-ocean ridges would reveal features of mantle convection, it is only recently that a massive coverage of the ridge system by high-density and high-precision isotope data has become possible thanks to progress in mass spectrometry. We here report new Hf and Pb isotope data for about 300 basalt glasses dredged along the entire Mid-Atlantic Ridge from 55°S to 78°N. These data have been combined with other recent high-precision Pb and Hf isotope data and compared with literature values of Nd and Sr isotope compositions, such that ~400 data points are available for Pb and Hf, while more than 500 data points are applicable for Sr and Nd. The spatial coordinate used for the present calculations is the latitude of the samples in the North America – Europe eulerian reference system. Periodograms, which are simply a fit of the data by periodic functions of the latitude and the most adequate tool of Fourier analysis for unequally spaced data, have been calculated for wavelengths down to 2 degrees. Strong peaks significant at a >99 % confidence level are found for a surprisingly large number of wavelengths. The well-known hemispherical asymmetry is clearly visible in the spectra. Two new and intriguing results further emerge: 1. Two groups of wavelengths dominate, one at short wavelengths (2-5°) and one at planetary-scale wavelengths (15-60°). We consider that this dichotomy reflects the stretching-folding processes associated with mantle mixing on two contrasting length scales: the short wavelengths characterize strong vertical mixing in the upper mantle, whereas the long wavelengths attest to the presence of movements at the scale of the whole mantle. 2. The long wavelengths for Hf and Nd are mutually consistent and regularly distributed with wavenumbers spaced by $0.01^{\circ -1}$. This indicates that ancient chemical patterns are neatly refolded by mantle convection over long periods of time (>10 convection cycles) and argues against wholesale delamination of subducted lithospheric plates. Sr lacks the long wavelength harmonic content. Despite some common wavelengths at ~20 and 30°, Pb does not strictly follow Hf and Nd. Why this is so is not yet understood, but may prove of geodynamic significance.