Helium Isotopic Textures in Earth's Upper Mantle

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We report $^3He/^4He$ for a suite of 150 mid-ocean ridge basalt (MORB) glasses, collected at 5-10 km intervals along the Southeast Indian Ridge (SEIR). Between 81-101°E, $^3He/^4He$ varies from 7.3 to 10.2 R_A, encompassing more than half the MORB range away from island hotspots. Abrupt transitions occur in $^3He/^4He$; in one case the full range occurs over ~10 km distance, indicating significant He isotope variability in the upper mantle at this scale. Melting of lithologically heterogeneous mantle, containing a few percent garnet pyroxenite, produces lower $^3He/^4He$ ratios; $^3He/^4He$ above ~9 R_A likely indicates a pyroxenite-free mantle source. Patterns in spectra of the length scale of variability represent a description of helium isotopic "texture". We use three complementary approaches; periodogram, red-noise spectral estimation ("Redfit"), and continuous wavelet transform (CWT). Long-wavelength "lobes" are present in the periodogram, similar to "hotspot type" spectra in the Atlantic. Redfit and CWT also reveal prominent and decreasing power at ~1000 km, ~500 km and ~250 km. The densely sampled region of the SEIR by itself shows significant power at ~30 km, similar to the scale inferred from Hf and Pb isotopes in the same suite. $^3He/^4He$ at intermediate scales may show overtones of the 1000 and 500 km fundamental periods, but they are not as well resolved. At 500-1000 km length scales, wavelet transform coherence reveals that $^3He/^4He$ varies in-phase with axial depth along the SEIR. This suggests a coupling between melt production and $^3He/^4He$, probably due to lateral variations in upper mantle potential temperature related to convective upwelling. Collectively, our results show that $^3He/^4He$ is controlled both by source heterogeneity associated with folding and stretching of material lines ("marble-cake" mantle) during plate-scale flow, and by variations in melting in response to secondary convection.