Helium Isotope Variations in Basalts Along Gakkel Ridge and Heterogeneity of the Arctic Upper Mantle

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We report helium isotope compositions, determined by crushing in vacuum to release the gas trapped in vesicles, for 57 basalt glasses from the ultra-slow spreading Gakkel Ridge. Other geochemical data, especially radiogenic isotopes (Pb, Nd, Sr) reveal the presence of an isotopic boundary in the mid-section of this ridge that separates basalts in the west (west of 14°E longitude) having “Indian Ocean” (Dupal) isotopic signatures, from basalts in the east which resemble the North Atlantic/Pacific domain (Goldstein et al. 2008). This boundary reflects heterogeneity in the underlying mantle related to the tectonic history of continental land masses surrounding the Arctic Ocean. In the west there is a narrow range of $^{3}He/^{4}He$ with lower values (7.0-7.9 R_A), while in the east there is a wider range of $^{3}He/^{4}He$ with higher values (7.9-9.3 R_A) and effectively no overlap with the western group. Off-axis lavas do not fit this simple picture however, revealing some systematic temporal variability, perhaps associated with mantle flow beneath the ridge. All Gakkel Ridge basalts are deeply erupted and most have high helium contents, in some cases at the upper end of the MORB range (>50 µccSTP/g). The few exceptions, having He contents below 0.1 µccSTP/g, have the highest $^{3}He/^{4}He$ (>8.8 R_A). This effect appears to reflect earlier (recent) melting of isotopically heterogeneous mantle, during which the initial melt fractions were slightly enriched in ^{4}He, perhaps due to a larger modal contribution of clinopyroxene and/or garnet to those melts. The temporal variability and the melting effects, while significant, do not account for the large $^{3}He/^{4}He$ signal observed along the ridge axis. Overall, $^{3}He/^{4}He$ shows systematic covariation with other isotopic indicators of mantle heterogeneity (Pb, Nd, Sr and Hf), indicating that the helium isotope variations are a long-lived feature of the Arctic upper mantle. The $^{3}He/^{4}He$ ratio is as effective a discriminant of eastern and western Gakkel Ridge groups as is Δ8/4Pb. In contrast, this is not true of Indian Ocean ‘Dupal’ basalts, which exhibit the full MORB range of $^{3}He/^{4}He$ (i.e., from ~6.5 to 9.7 R_A away from island hotspots carrying elevated $^{3}He/^{4}He$)