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Implications for the deep Earth from the He-Ne-Ar isotope composition of earliest basalts from the Iceland plume

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Early Tertiary picrites from Baffin Island (BI) and West Greenland are the earliest eruptive products of the Iceland plume. Their major element composition is consistent with derivation from partial melts of mantle that is up to 200˚C hotter than normal. Olivine phenocrysts from these rock are characterised by the highest ^{3}He/^{4}He yet recorded on Earth; we have identified 29 samples with ^{3}He/^{4}He > 35 R_a. The high ^{3}He/^{4}He basalts have a range of incompatible trace element and lithophile radiogenic isotopic compositions that overlap the range of MORB and most northern hemisphere OIB (including Iceland). This is inconsistent with a discrete mantle reservoir with high ^{3}He/^{4}He that is a residue of ancient mantle depletion. The simplest explanation is that the early Iceland plume sampled an anomalously hot mantle reservoir that had a sufficiently high concentration of helium - with high ^{3}He/^{4}He - to dominate subsequent mixing in the plume head.

Despite the exceptionally high ^{3}He/^{4}He the Baffin Island picrite olivines have Ne and Ar isotope compositions that are similar to Iceland and Hawaii. ^{20}Ne/^{22}Ne ratios never exceed 12.3, and ^{38}Ar/^{36}Ar are indistinguishable from air values, providing no evidence that the Ne and Ar were directly acquired from the solar nebula. ^{40}Ar/^{36}Ar range up 6,300 and the average ^{21}Ne/^{22}Ne$_{ext}$ is 0.036 $\pm$ 0.003. Co-variation of ^{4}He*/^{40}Ar* and ^{3}He/^{36}Ar record significant elemental fractionation that occurred prior to melt inclusion trapping (i.e. before air contamination). The BI source has ^{3}He/^{36}Ar = 1.2-1.8

(calculated assuming $^{4}He^{*}/^{40}Ar^{*}$ production ratio of 2-3) that is significantly higher than measured in basalts from the convecting upper mantle (“popping rock”) and steady-state plume sources (e.g. Iceland-Loihi). However it is lower than the ratio of solar nebula gases ($^{3}He/^{36}Ar \sim 10$) and presents the intriguing possibility that the He enrichment may originate in a deep reservoir that is dominated by solar noble gases. The nature and location high-^{3}He reservoir is unclear as seismic evidence for the source of the Iceland plume is the subject of debate. However, it is clear that the earliest Iceland plume sampled a hot, He-rich reservoir that is not available to steady-state mantle plumes.