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$^3He/^4He$ >65 times the atmospheric ratio measured in Baffin Island lavas: Evidence of core-mantle exchange?

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The observation that some mantle plumes have higher $^3He/^4He$ ratios than mid-ocean ridges implies that plumes tap reservoirs that are less outgassed than the upper convecting mantle. In olivines from Baffin Island lavas associated with the Iceland plume, we measured the highest magmatic $^3He/^4He$ ratios found in terrestrial igneous rocks (>65 times the atmospheric ratio, Ra), as well as neon more primitive than in mid-ocean ridge basalts. Here, we explore whether the core might be the source of these very high $^3He/^4He$ ratios. We estimate that preserving $^3He/^4He$ >65 Ra requires ~8 x 10^{-11} cm^3/g STP ^3He in the core, assuming a closed system. This is less than experiment-based predictions for nebular helium partitioning into the metal segregates that formed the core [1]. We also calculate that 4.5 Gyr of nucleogenic neon production would not detectably influence the $^{20}Ne/^{22}Ne$ and $^{21}Ne/^{22}Ne$ ratios of the core. If core-derived oxides mix into the mantle, they might be too poor in lithophile elements to influence the lithophile element isotopic ratios of the mantle. If so, the depleted $^{87}Sr/^{86}Sr$, $^{143}Nd/^{144}Nd$, and $^{206}Pb/^{204}Pb$ ratios of the highest $^3He/^4He$ Baffin Island lavas may reflect the composition of depleted mantle (e.g., mantle lithosphere in a slab graveyard) into which core material mixed. For these reasons, the core is a viable source of high-$^3He/^4He$ helium and primitive neon. This idea potentially eliminates the constraint—based on high $^3He/^4He$ ratios—that parts of the mantle escaped degassing. But for unknown reasons, helium-neon systematics [2,3] show that the Baffin Island mantle source has a higher time-integrated $^3He/^{22}Ne$ ratio (7.3–8.6) than primordial mantle (<2) and Iceland mantle (~2). We speculate that the high $^3He/^{22}Ne$ composition of the Baffin Island mantle source is the result of faster helium than neon diffusion in lower mantle silicate phases. Core-derived oxides might transfer neon and helium into mantle domains that are also enriched by helium diffusion out of the core.

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