Investigating volatile cycles in the terrestrial mantle by incorporating He and Ar isotopes into geodynamical models of mantle convection

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The dichotomy in $^{3}He/^{4}He$ isotopes ratios between mid ocean ridge and ocean island basalt samples (MORB and OIB) has provided a fundamental cornerstone in defining the need for a long-lived, volatile rich, and possibly primordial, geochemical reservoir within the deep mantle. However, this is somewhat at odds with evidence from other radiogenic isotope systems (e.g., U-Th-Pb, Lu-Hf, Sm-Nd, Rb-Sr), as well as geophysical evidence, for recycled surficial/crustal material in the deep mantle. Geodynamic models of mantle convection have been developed to incorporate earth-like phase and viscosity changes and can reproduce earth-like surface heat flow and plate motion. When such models take into account the higher density of the subducting oceanic crust, compared to the surrounding mantle, it provides a mechanism of retarding convection in the deepest mantle and reproduces observed geochemical distributions in multiple isotope systems (U-Th-Pb, Rb-Sr, Sm-Nd, Lu-Hf and Re-Os) that define the DMM, HIMU and EMI mantle endmembers (Brandenburg et al., 2008, Jones et al., 2017). Here we use a geodynamical model of mantle convection (Brandenburg et al., 2008), and combine it with geochemical input parameters, to investigate whether the subduction of dense eclogite can retard lower mantle convection sufficiently to explain the observed differences in $^{3}He/^{4}He$ obtained for MORB and OIB. We go on to analyse the effect of ^{3}He outgassing from the Earth’s core and early recycling of extra-terrestrial material containing high ^{3}He (e.g., interplanetary dust particles (IDPs)) into the mantle. The K-Ar system is also incorporated into the model and earth-like ^{40}Ar planetary degassing from the mantle is reproduced. We explore the impact of ^{36}Ar recycling on the $^{40}Ar/^{36}Ar$ compositions of MORB and OIB. The results suggest recycling of atmospheric Ar can produce the observed $^{40}Ar/^{36}Ar$ compositions of the upper and lower mantle.

Brandenburg, J.P., Hauri, E.H., van Keken, P.E., Ballentine, C.J., 2008. Earth and Planetary Science Letters 276, 1-13.

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