Mantle degassing, 'missing' ^{40}Ar, and volatile rich reservoirs: A geodynamical view

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The observation that only ~50% of the ^{40}Ar produced by the decay of ^{40}K in the Earth's mantle is present in the atmosphere has been used as a fundamental line of evidence for both the extent of mantle outgassing and, in the absence of high concentrations in the mid-ocean ridge basalt (MORB) source mantle, the presence of an undegassed reservoir in the mantle. Here we apply a combined geodynamical-geochemical modelling approach, co-developed by Erik Hauri [1], to investigate the origin/location of the 'missing' ^{40}Ar and the observed differences in the $^{40}Ar/^{36}Ar$ compositions of the MORB (~44,000) and ocean island basalt (OIB; <10,000) mantle source.

The geodynamical model incorporates Earth-like phase and viscosity changes, and reproduces Earth-like surface heat flow and plate motion. Geochemical information has been combined with the model and the role of oceanic and continental crust formation/recycling on the production of different geochemical compositions in the mantle has been investigated - the model reproduces observed geochemical distributions for multiple radiogenic isotope systems (U-Th-Pb, Rb-Sr, Sm-Nd, Re-Os and Lu-Hf) that define different mantle endmember compositions (e.g., DMM, EMI, HIMU; [1], [2]).

Building on this base model, we extend the model to investigate the K-Ar isotope system. The model reproduces Earth-like ^{40}Ar planetary degassing from the mantle (~50% of ^{40}Ar in the atmosphere). We show that the deep subduction and long residence time of incompatible trace element (e.g., K) enriched oceanic crust in the deep mantle also accounts for the 'missing' ^{40}Ar. When atmospheric Ar recycling is incorporated into the model, the $^{40}Ar/^{36}Ar$ and $^{38}Ar/^{36}Ar$ compositions of the MORB and OIB source mantle can also be reproduced. However, a higher subduction recycling flux is required than has previously been invoked, providing evidence for more recycling of atmospheric (or seawater derived) noble gases into the deep mantle than previously recognised.

[1] Brandenburg et al, 2008. EPSL, 276, 1-13.
[2] Jones et al, 2017. AGU Fall Meeting Abstracts.