Systematics of helium in deep Earth diamond-hosted C-O-H fluids

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High-density super critical fluid (HDF) inclusions in 'fibrous' diamonds – a fast growing, volatile-rich form of diamond – are effectively the only available samples to directly investigate the composition and origin of deep H_2O- and CO_2-rich (C-O-H) fluids. These diamonds have very high He contents (up to ~10^{-5} ccSTP/g), ideal for He isotope studies, which provide basic geochemical information on mantle reservoirs and constraints on volatile and fluid cycling between the Earth's surface and deep mantle. But only few such diamonds have been analysed for their He compositions.

We report He contents and $^3He/^4He$ ratios of HDFs in 17 African diamonds that were previously analyzed for their major- and trace-element compositions. Excluding four diamonds having radiogenic $^3He/^4He<1$ Ra (where Ra is the atmospheric ratio of 1.39×10^{-6}), the new data reveal a compositional relation between $^3He/^4He$ ratios and the amount of K_2O and carbonate component of the HDFs: carbonatitic compositions are characterized by $^3He/^4He$=6.1-7.9 Ra, silicic by $^3He/^4He$=4.2-5.1 Ra, and saline $^3He/^4He$=2.6-4.3 Ra. These Ra values overlap with continental lithospheric mantle (CLM) peridotite (5.8±1.8 Ra) and alkaline lavas (5.9±1.0 Ra). Assuming the initial helium isotopic compositions of the CLM was MORB-like ($^3He/^4He$=8±1 Ra), the lower Ra range observed here may be explained through interaction with subduction-related 'low-$^3He/^4He$' saline-type C-O-H fluids.

One silicic and three carbonatitic HDF-bearing diamonds have radiogenic $^3He/^4He$ ratios between 0.07-0.69 Ra and associated aggregated nitrogen IaAB-type IR spectra with 25% and 32% B-centers, suggesting they formed during earlier and different metasomatic events than saline diamonds from the same kimberlite pipes. $^3He/^4He$ model ages for these events can be calculated using the U, Th, ^4He and ^3He contents of the HDFs. Assuming the HDF's initial Ra values varied between 3-11, representing common values for MORB, the SCLM and subducted components, the saline, silicic and carbonatitic HDFs represent three metasomatic events that took place at ~100, ~350 and ~850 Myr, thus revealing three episodes of lithospheric chemical changes by different C-O-H fluid types during the last ~1 Gyr.