

A billion years of metasomatic alteration of the Kaapvaal SCLM encapsulated in fibrous diamonds

Yaakov Weiss, Steven Goldstein, Cornelia Class, and Gisela Winckler

Lamont-Doherty Earth Observatory, Columbia University, New York, United States (yweiss@ldeo.columbia.edu)

Constraining the nature and timing of metasomatic events by C-O-H fluids in the sub-continental lithospheric mantle (SCLM) is an ongoing challenge in our understanding of the SCLM history. 'Fibrous' diamonds, which rapidly grow during such fluid-rock interaction, commonly encapsulate the C-O-H fluid metasomatic agents, which are trapped and encapsulated as μm -scale high-density fluid (HDF) inclusions and can be directly sampled. They thus offer a unique opportunity to investigate metasomatic events involving C-O-H fluids in the SCLM. We analyzed major and trace elements and the helium content and isotopic composition of the HDFs included in a set of diamonds from the DeBeers-Pool and Finsch kimberlites in the Kaapvaal craton, South Africa. Saline HDF micro-inclusions in 3 of the DeBeers diamonds and in 2 from Finsch have very similar major and trace element compositions, suggesting they formed in related metasomatic events. They are characterized by high alkalis (K, Rb and Cs), Ba and LREEs compared to Th, U, Nb and Ta, and by Ti, Zr, Hf and Y negative anomalies relative to REEs of similar compatibility. Their $^3\text{He}/^4\text{He}$ ratios vary between 3-4 Ra. Plotting the 3 DeBeers-Pool diamonds on an $^4\text{He}/^3\text{He}$ vs $^{238}\text{U}/^3\text{He}$ diagram defines an 'isochron' with an age of 96 ± 45 Ma. This result represents the first radiometric age reported for fibrous diamonds and the C-O-H mantle fluids they carry. In addition, 1 diamond from DeBeers-Pool has silicic microinclusion compositions while 2 diamonds from Finsch carry carbonatitic HDFs. These diamonds display more radiogenic $^3\text{He}/^4\text{He}$ ratios between 0.07-0.6 Ra, which suggests formation during earlier and different metasomatic events. Using the measured U, Th, ^4He and ^3He content of these diamonds, and the equation for ^4He production by U and Th, we calculate $^3\text{He}/^4\text{He}$ ratios as a function of time. Assuming that the HDFs initial R/Ra values varied between 3-11, representing common values for MORB, the SCLM and subducted components, the silicic and carbonatitic HDFs signify two older metasomatic events that took place in the Kaapvaal lithosphere at ~ 350 and ~ 850 Ma, respectively. Thus, our new data reveal 3 episodes of chemical changes in the Kaapvaal craton SCLM during the last ~ 1 Ga, each by a different metasomatic agent. The youngest episodes indicate direct relationships between highly-saline fluid metasomatism, fibrous diamond formation and late-Mesozoic kimberlite eruptions, while the older silicic and carbonatitic metasomatic events may be related to the regional Namaqua-Natal Orogeny and Damara Orogeny at ~ 1 Ga and ~ 500 Ma, respectively.