A relic of a planetary-like He-3/He-4 ratio in Archean komatiites

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Archean Komatiites (2.7 Ga old) from Munro Township, Ontario, Canada, was analyzed for helium isotopic composition in order to obtain helium signature of the Komatiite mantle source. Helium was extracted by sequential crushing method. Each crushing step yielded He-3/He-4 ratio of 12.4, 19.1, 30.7 and 13.8 Ra (Ra denotes the atmospheric He-3/He-4 ratio of 1.4 x 10-6). Such a variation can best be explainable with the contamination of radiogneic He-4 released from crystal structure during the crushing extraction. The estimated uncontaminated He-3/He-4 ratio is from 70 to 120Ra, indicating that the primordial component dominates helium in the Archean mantle.

An Archean Komatiite (2.7 Ga old) from Munro Township, Ontario, Canada, was analyzed for helium isotopic composition in order to obtain helium signature of the Komatiite mantle source. Helium was extracted by sequential crushing method (4 steps with 10, 300, 500 and 1000 strokes, sequentially). Each crushing step yielded He-3/He-4 ratio of 12.4, 19.1, 30.7 and 13.8 Ra (Ra denotes the atmospheric He-3/He-4 ratio of 1.4 x 10-6) with their absolute He-4 abundance varying from 0.5 to 3 x 10-8 cm3STP/g. In contrast, the analyses on the crushed grains by a total fusion gas extraction yielded no detectable He-3 with significantly large amount of He-4 (~10-6 cm3STP/g). This amount is roughly consistent with He-4 produced from decay of U in the sample (~20 ppb) over 2.7 Ga, suggesting that the radiogenic component dominates the helium trapped in structural sites. These indicate the presence of two distinct helium components. One component is trapped in fluid/melt inclusions which liberate their helium by crushing with high (but variable) He-3/He-4 ratios. The other is a radiogenic He-4 released from the lattice of grains.

Although the crushing gas extraction is meant to preferentially observe the pristine mantle helium signature in fluid/melt inclusions, it is often the case that noble gases trapped in structural sites are also released by this technique [1]. With the observed two orders of magnitude difference in He-4 amounts in lattice and inclusions, we suspect that radiogenic He-4 from the structural sites was also released by crushing, and that this is the primary cause of observed variation in He-3/He-4 ratios. We will discuss here, by constraining the possible release behavior of mantle-derived and radiogenic He-4 during the sequential crushing, fluid inclusions of the sample might have much higher He-3/He-4 ratio than observed.

The release behavior of the mantle component can be constrained by the release of He-3. Then, by assuming a uniform He-3/He-4 ratio in inclusions (i.e., ratio without contamination from the radiogenic component), amount of mantle-derived He-4 in each step can be estimated. The release behavior of radiogneic He-4 can, then, be obtained by subtracting the radiongeic He-4 from the total observed He-4 in each step. If the highest He-3/He-4 ratio observed at the third step is chosen as uncontaminated original ratio, then this would lead a quite unlikely consequence; that is, no radiogenic He-4 released at the third step. In order to have a reasonable amount of radiogenic He-4 during the sequential crushing experiment, much higher uncontaminated He-3/He-4 ratio is required to be trapped in inclusions. Indeed, Scarci [1] examined the release of structure-sited noble gas during a sequential crushing, and reported that the d[He-4]/dt decreased smoothly following the exponential function of crushing time (d[He-4]/dt and crushing time can be equated to the amount of He-4 released per one crushing stroke and cumulative crushing strokes, respectively). So the amount of radiogenic He-4 released (per a stroke) during the third step should be between those in the second and fourth steps. This limits the possible range of uncontaminated He-3/He-4 ratioto be between 70 and 120 Ra, which is indeed quite high compared with any mantle-derived samples so far measured (Fig. 1). Such a high He-3/He-4 ratio could be a relic of helium in the Archean mantle source for the Komatiite parent magma. If so, this suggests that the He-3/He-4 ratio in the Archean mantle had been maintained high without being significantly diluted by in situ radiogenic component. Perhaps, the decrease in He-3/He-4 ratio in the mantle by radiogenic He-4 production would be accelerated after 2 Ga as was predicted by our recent model calculation [2].

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