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Recycle and fractionation of U and K in the mantle via slab subduction; noble gas isotopic evidence from Polynesian HIMU

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The abundance and distribution of U and K in the Earth are critical not only for isotope and noble gas geochemistry but also for internal heat production in the mantle. While the concentration of U in bulk silicate Earth (BSE) has been estimated from the chondritic value, K concentration in BSE is poorly constrained. K concentration in BSE has been estimated using U concentration in BSE multiplied by the canonical K/U ratio (13000) on the ground that crustal and mantle-derived rocks show uniform K/U. However, such theory might be uncertain if the subducted slab had fractionated K/U and it remained isolated as a hidden reservoir.

We present He–Ne–Ar isotopic compositions for Polynesian HIMU lavas with radiogenic Pb isotopic compositions. It has been widely accepted that the HIMU lavas are sourced from subducted ancient oceanic crust. K/U of the HIMU reservoir is constrained using the relative abundances of radiogenic and nucleogenic noble gases, because $^{40}Ar/^{36}Ar$ evolves by decay of ^{40}K while production of ^{4}He and ^{21}Ne is related with U and Th decay. In $^{4}He/^{40}Ar^{*}$–$^{4}He/^{21}Ne^{*}$ space (asterisks denote radiogenic component), the HIMU lavas define a trend that is parallel to, but offset from the trend previously observed for other ocean island basalts. Using $^{4}He/^{21}Ne^{*}$ as a monitor of elemental fractionation of noble gasses, fractionation-corrected $^{4}He/^{40}Ar^{*}$ is higher than that expected for the mantle with the canonical K/U of 13000. K/U of the HIMU reservoir converted from $^{4}He/^{40}Ar^{*}$ is approximately 3000. Low K/U of the HIMU reservoir is best explained by a model where this reservoir originates from subducted oceanic crust that preferentially lost K relative to U via dehydration during its subduction.

Since the HIMU reservoir, involving subducted oceanic crust, is enriched in U, but not in K, previous estimates of K/U and K concentrations for BSE, that did not take this reservoir into consideration, will be too high. The mass balance calculation, considering continental crust, depleted mantle, primitive mantle, and subducted crust, demonstrates that the estimated K/U of BSE may be modified from 13000 down to 8000–10000. Moreover, this calculation indicates that the subducted oceanic crust may make a significant contribution to the U mantle budget, requiring there to be less in the primitive mantle. However, a contribution from the primitive mantle is not ruled out entirely, unless the subducted oceanic crust had a relatively high U concentration and low K/U over geologic time and was totally preserved in a convecting mantle.