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K and U budget in the mantle

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K, U and Th concentrations in bulk silicate Earth (BSE) are significant for isotope geochemistry, including noble gases and Pb isotopes, as well as for geothermal study as internal heat sources. While the concentration of U in BSE has been estimated from the chondritic value, K concentration of BSE is poorly constrained due to its volatility during formation of the Earth. Instead, K concentration in BSE has been calculated using U concentration in BSE multiplied by the canonical K/U ratio (13000) deduced from the relatively uniform K/U of crustal and mantle-derived rocks (e.g., O'Nions and Oxburgh, 1983). However, if subducted and dehydrated slab with low K/U occupied a considerable volume in the mantle, the presence of this "hidden" reservoir would result in a significant reduction in K/U, and hence in the total amount of K, in BSE compared to the previous estimates (Lassiter, 2004). This hypothesis has been debated (Arevalo et al., 2009). However, He-Ne-Ar isotope systematics of the HIMU reservoir, which was produced from subducted old oceanic crust, demonstrate that K/U of this reservoir should be much lower (3000) than the canonical K/U ratio (Hanyu et al., in submission), supporting Lassiter (2004)'s hypothesis.

In this presentation, I discuss the impact of subducted oceanic crust on the K and U(+Th) budget in the mantle. Since the subducted oceanic crust is enriched in U, but not in K by dehydration, the preservation of the subducted oceanic crust in the mantle, that is HIMU reservoir, affects the K and U budget in the silicate Earth. Mass balance calculations of K and U were conducted, assuming four major reservoirs, continental crust, depleted mantle reservoir, primitive mantle reservoir and subducted oceanic crust, after Lassiter (2004). The differences between the model presented here and that presented by Lassiter (2004) are twofold. (1) We assume variable U concentrations in the subducted oceanic crust, from U-poor dehydrated N-MORB (0.05 ppm) to U-rich bulk crust observed in natural eclogite (0.12 ppm). (2) We assume some depletion in U and K for primitive mantle reservoir, because it is not necessarily unmodified BSE, but may be moderately depleted due to it making a small contribution to the formation of continental crust (Class and Goldstein, 2005).

The estimated K/U of BSE is modified from canonical value of 13000 down to 8000-10000 by taking the presence of subducted slab into consideration, irrespective of the values chosen for the compositions of the abovementioned reservoirs, if all the oceanic crust ever subducted has accumulated, occupying 6-9 % of the mantle. In this case, K concentration in BSE is also lower than the previous estimate of 250 ppm. The fraction of primitive mantle reservoir in the silicate mantle is also estimated from the mass balance calculations. It is highly dependent on the concentration of U in the subducted crust. In particular, if U concentration in the subducted oceanic crust is relatively low (0.05 ppm), the primitive mantle reservoir should occupy at least 30% in the mantle to balance the K and U budget in the silicate Earth. This suggests that considerable amount of primitive mantle reservoir has been unmixed and isolated in the convecting mantle.

References -

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