Role of serpentinite dehydration for production of isotopic heterogeneity in the mantle

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It has been widely accepted that chemical modification of oceanic crust due to dehydration reaction played an essential role for the production of isotopic heterogeneity of the mantle. However, most of water in oceanic crust is released beneath forearc area (< ~ 80 km depth) at relatively low temperature at ca. 500 °C. Because of low solubility of elements to dehydration fluids at such low P-T conditions, dehydration at shallower depths could not modify chemical composition of residual oceanic crust significantly. Accordingly, an additional process other than dehydration of oceanic crust is required to fully explain the isotopic diversity in the mantle. One of the possible processes to induce large chemical fractionation could be fluid-rock reaction caused by serpentinite dehydration, because water content of serpentinite is up to 13% and thickness of serpentinite layer was inferred to be up to 40 km, meaning that serpentinite layer can be a major water reservoir in a subducted slab.

In this study, we conducted geochemical modeling of the isotopic evolution of subducted oceanic crust taking into account the effect of the fluid-rock reaction induced by serpentinite dehydration and dehydration of oceanic crust itself, and examined the suitability of our model for generating the high-μ (HIMU), focal zone (FOZO) and prevalent mantle (PREMA) mantle components. The results suggest that dehydration of oceanic crust alone cannot produce isotopic variation beyond the bounds of PREMA compositions. The wider range of isotopic diversity from PREMA to FOZO can be accounted for by various degrees of element partitioning between subducted oceanic crust and fluids (aqueous or supercritical) released by slab serpentinite dehydration. The extremely radiogenic Pb isotopic signature of HIMU can be produced only by extensive reaction between subducted oceanic crust and slab serpentinite-derived fluids along the specific geothermal gradient resulting from the relatively slow descent of moderately old slabs. The rarity of such tectonic conditions can explain the scarcity of HIMU.