Episodic mantle convection inferred by the differentiation ages of depleted suboceanic mantle

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Depleted mantle comprises 50–70 % of the Earth’s mantle and is considered to be the residue after extraction of continental crust [1]. The depleted mantle resides in the subcratonic lithosphere and suboceanic convecting asthenosphere. It is critical to understand the evolution of the Earth’s mantle when and how the depleted mantle differentiated from the primitive upper mantle (PUM).

Re-depletion ages of residual peridotite assume perfect Re fractionation from the residual peridotite upon melting, so that Os isotopic ratio of the residue is suppressed to low values. As peridotites derived from the subcratonic lithospheric mantle have low $^{187}Os/^{188}Os$ ratios with late Archean to early Proterozoic Re-depletion ages, they are interpreted to be the residue of PUM that suffered a large degree of melting and were isolated from the convecting mantle since then [2,3]. Meanwhile, depleted MORB mantle (DMM) has a wide range in Os isotopic ratio from 0.116 to 0.135, with much younger Re-depletion ages <1.0 Ga, and is considered to have formed by partial melting, mixing and stirring through the ages. However, unlike the subcratonic lithosphere mainly consisting of highly depleted harzburgite, most DMM suffers only 3–4 wt% melt extraction compared to the PUM, and hence, a fairly large amount of Re is left in the DMM when differentiated from the PUM. This in turn means that the differentiation age of DMM from PUM is much older than it used to be considered.

To compromise the difficulty in adapting Re-Os isochron to residual mantle peridotites, we developed a method to estimate the initial Re/Os ratio of the residual mantle by using the coexisting melt compositions [4]. The degree of melting of the residual mantle can be modeled by REE abundance of the melt in equilibrium with the residue. Based on the estimated degree of melting,the original Yb content of the source mantle prior to melting is restored. Assuming the source mantle was formed by partial melting of the PUM, the initial Re/Os ratio of the source mantle is estimated, and then the differentiation age of the source mantle can be determined. Source mantles for the primary boninites from the Izu-Ogasawara-Mariana forearc are thus estimated to have differentiated from the PUM at 3.7–3.2 Ga and 1.7–1.5 Ga. Likewise, the average DMM with Os ratio of 0.125 fractionated from the PUM at 2.6–2.2 Ga, which coincides with the Re-depletion age of subcratonic lithosphere. These three ages also coincide with the periods of continental crust formation [5]. We suggest that the climax of mantle convection that resulted in the continental crust formation is also responsible for the evolution of the mantle and differentiation of the DMM.

Keywords: Re-Osisotope, Depleted MORB mantle, Indian MORB mantle, Izu-Ogasawara-Mariana forearc, Oman Ophiolite, boninite