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Can the slightly depleted mantle be a high $^{3}He/^{4}He$ reservoir?

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The origin and composition of the high $^{3}He/^{4}He$ reservoir, which is enriched in primordial He, in the Earth's deep interior are controversial. Ocean island basalts (OIBs) and Baffin Island picrites with high $^{3}He/^{4}He$ ratios (>20 Ra) remain the focus of significant research. However, incompatible trace element ratios, and Sr, Nd and Pb isotopes in high-$^{3}He/^{4}He$ OIBs and Baffin picrites are not primordial. They show slightly depleted geochemical signatures compared to chondrites and estimated bulk silicate earth. These results suggest that slightly depleted mantle is a discrete high $^{3}He/^{4}He$ reservoir [1]. Although several experiments have indicated that He might be more compatible than U or Th during partial melting of the mantle [2], whether residual peridotite can retain a high $^{3}He/^{4}He$ ratio has rarely been tested based on analysis of natural peridotites.

In order to verify whether ancient slightly depleted mantle is a high $^{3}He/^{4}He$ reservoir, we performed He isotope analyses of olivine extracted from 14 Hawaiian spinel peridotite xenoliths from Salt Lake Crater and Ka'ula Island. Xenoliths from these locals show unradiogenic Os and radiogenic Hf isotopic compositions indicating they are recycled lithospheric mantle depleted by ancient (>1 Ga) melting [3]. Our new results show a wide variation in $^{3}He/^{4}He$ ratio (2.4 Ra to 9.5 Ra). The $^{3}He/^{4}He$ ratio is correlate with the peridotite depletion indices (Al_2O_3 and Yb). The low $^{3}He/^{4}He$ ratios of depleted (low Al_2O_3 and Yb) samples indicate ingrowth of radiogenic ^{4}He from U and Th decay, implying He is more incompatible than U and Th during mantle melting. The correlation between $^{3}He/^{4}He$ and Al_2O_3 may be related to ancient melting (>1 Ga), suggesting that He within the mantle is not completely homogenized even after a billion years. In particular, the slightly depleted mantle may retains the relatively primordial $^{3}He/^{4}He$ ratio due to the less radiogenic ^{4}He. Then, the mantle, slightly depleted by the melting in the early earth, can be the primordial helium reservoir.

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[2] Parman et al. (2005). *Nature*, *437*(7062), 1140-1143.
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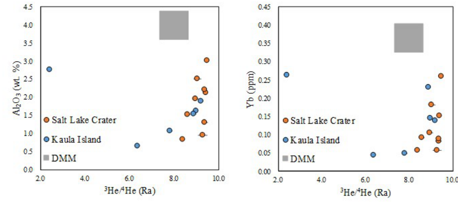

Fig. 1 Plot of $^{3}He/^{4}He$ ratio versus the depletion indices of peridotites (Al_2O_3 and Yb) of the Hawaiian peridotite xenoliths showing the fields for the depleted MORB mantle. The range of $^{3}He/^{4}He$ ratios in the DMM shows the variation of $^{3}He/^{4}He$ ratios of typical mid-ocean ridge basalts (Graham, 2002). The data of whole-rock Al_2O_3 and Yb contents in the DMM shows the estimated value of Workman and Hart (2005).