The possibility of the depleted mantle being a high $^{3}He/^{4}He$ reservoir

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The origin and composition of the high-$^{3}He/^{4}He$ reservoir in the Earth's deep interior have long been debated, and ocean island basalts (OIB) and Baffin Island picrites with high $^{3}He/^{4}He$ ratios (>20 Ra) remain significant research focus. Incompatible trace element ratio and Sr, Nd, and Pb isotopes in high-$^{3}He/^{4}He$ OIB and Baffin picrites are known not to be primordial and commonly show the depleted nature compared to chondrites and estimated bulk silicate earth, suggesting that incompatible element 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], it remains unclear whether residual peridotites can accommodate high $^{3}He/^{4}He$ ratios within the mantle. In order to verify the possibility that the ancient depleted mantle is a high $^{3}He/^{4}He$ reservoir, we performed He isotope analyses of olivines extracted from peridotite xenoliths from Oahu Island (Salt Lake Crater) and Kaula Island, Hawaiian Islands. These peridotite xenoliths show unradiogenic Os and radiogenic Hf isotopic compositions. It suggests being recycled lithospheric mantle depleted by ancient (>1 Ga) melting, independent of modern igneous activity in the East Pacific Rise [3]. The result demonstrated that the $^{3}He/^{4}He$ ratio of the mantle xenoliths shows a wide variation from 2.4 Ra to 9.5 Ra, indicating the radiogenic ingrowth of ^{4}He from U and Th. The $^{3}He/^{4}He$ ratio is significantly correlated with the depletion indices of peridotites such as whole-rock Al_2O_3 and Yb contents, and the more depleted peridotite shows a lower $^{3}He/^{4}He$ ratio. This implies that He is more incompatible than U and Th during mantle melting, inconsistent with the prediction of laboratory experiments [2, 4]. In contrast, the correlation line between $^{3}He/^{4}He$ ratio and whole-rock Al_2O_3 deviates from the value of depleted MORB mantle, and the olivine from fertile peridotite xenoliths tend to have higher $^{3}He/^{4}He$ ratios than that of MORB. This suggests that unradiogenic He has survived from homogenization processes and can be retained in the ancient depleted mantle.

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