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Origin of Mantle He and Implications for Mantle Fluid-flow

Minoru Ozima (ezz03651@nifty.ne.jp)

Senkawa 1-21-11, Toshima-Ku, Tokyo, 171-0041, Japan

The helium isotopic ratio in mantle-derived materials is now widely used as a tracer to investigate mantle dynamics and structure. The helium isotopic ratio is often discussed with other trace elements including heavier noble gases in the context of "He-trace element systematics". A fundamental assumption in the use of helium as a mantle tracer is that helium is the intrinsic component of the mantle like other trace elements. This has long been taken for granted. Anderson (1998) challenged this conventional wisdom. Recently Ozima and Igarashi (2000) concluded from an extensive compilation of mantle noble gas isotopic data that helium in the mantle is totally decoupled from heavier noble gases, and is likely to be "alien" to the mantle. In this paper I examine further the decoupling of mantle helium and its implications for mantle dynamics. $^{40}Ar/^{36}Ar$ in the Earth's atmosphere (295.5) is about 6 orders of magnitude larger than the primordial solar ratio (10^{-4}). This is due to elemental fractionation in K/Ar during the segregation of the solid Earth from the solar nebula (e.g. Ozima & Podosek, 1999). In the contrary, $^{4}He/^{3}He$ in the mantle (about 10^{5}) differs only by a factor of 50 from the primordial solar ratio (about 2.5×10^{3}). This enormous difference in isotopic evolution in the Earth between He and Ar indicates that the origin of mantle helium is not concomitant with the acquisition of heavier noble gases such as Rayleigh distillation from the solar noble gases (Ozima & Podosek, 1999), and may suggest an "alien" origin of helium in the mantle. This conclusion is also supported from the observation that variation in $^{4}He/^{3}He$ is much smaller than in $^{21}Ne/^{22}Ne$. Both ^{4}He and ^{21}Ne increase due to the addition of radio/nucleogenic isotopes from U-decays, and the effect should be much severer in $^{4}He/^{3}He$ than in $^{21}Ne/^{22}Ne$ in a closed system evolution. However, the contrary empirical observation mentioned above indicates that He and Ne have not evolved in a closed system. This observation, together with the decoupling of mantle He from heavier noble gases, also support the 'alien' mantle He. The uniformity of the mantle $^{4}He/^{3}He$ ratio can be best explained by the hypothesis that helium in the mantle was homogenized in the fluid phase. Complementarity in the helium content between MORB and OIB (Ozima & Igarashi, 2000) argues for transportation in the fluid phase. On the basis of these empirical observations and theoretical considerations, I propose that helium in the mantle is migrating from deeper to shallower regions together with hypothetical mantle fluids. I show that the existence of such mantle fluids appears to be in harmony with geochemical observations.

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