# He and Ne diffusion in bridgmanite and lower mantle structure

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Low proportions of radiogenic He and nucleogenic Ne in basalts formed from deep-rooted plumes indicate sources with time-integrated low (U+Th)/(He+Ne) ratios. The outer core, primordial mantle and dense thermochemical piles in the large low S-wave velocity provinces of the D"-zone have been suggested as candidate reservoirs. We determined the diffusion rates of He and Ne in bridgmanite (bm, pure $MgSiO_3$) and periclase (pc) by ab initio molecular dynamics, and found marginally lower diffusion rates in pc relative to bm and for Ne relative to He.

The diffusion rates decrease with increasing pressures, and below we refer to 80 GPa, which corresponds to a neutral buoyancy level between $MgSiO_3$-dominated bm and liquid and solid peridotite [1]. In bm crystals formed in a basal magma ocean (BMO), He and Ne would diffuse over length scales of 0.5-6 mm in 2 min to 1 hr. At 100 K below the peridotite solidus during the first 100-500 My after BMO solidification, the diffusion lengths would be 2-9 km (a well insulated BMO might possibly have lasted into the Archean). Refractory and U-Th-poor bridgmanitic domains could therefore be efficiently charged, and possibly saturated, with He and Ne in less than 500 My. Such domains include early magma ocean cumulates, primarily in the 1600-2200 km depth range, as well as residues from deep plume melting shortly after BMO solidification. Large volumes of refractory bm-dominated material may have been formed by extensive core-BMO chemical exchange, involving transfer of silica from the core to the BMO and Fe-oxides in the opposite direction [1,2]. Refractory bridgmanitic domains with high viscosity and neutral buoyancy in the middle of the lower mantle would likely be convectively aggregated into large bodies and survive convective shearing and mixing [3,4].

Diffusion lengths at 100 K above the present adiabat are insufficient for effective dilution of primordial He and Ne isotopic signals during the last 3 Gy. Hot and vigorous plumes may entrain some of the bridgmanitic material, which becomes pyroxenitic and less refractory in the upper mantle. The refractory bm-dominated material may also explain the $^{182}W$-$^{142}Nd$-$^{129}Xe$ isotopic heterogeneities recorded by basalts from the Iceland and Ontong Java plume heads [5].

[1] Trønnes et al. (2018) *Tectonophys.*, accept. [2] Brodholt & Badro (2017) *GRL* **44**, 8303. [3] Becker et al. (1999) *EPSL* **171**, 351. [4] Ballmer et al. (2017) *Nature Geosci*. **10**, 326. [5] Rizo et al. (2016) *Science* **352**, 809.