Grain boundary diffusion of Re, Os, Pt, and Pb, in olivine aggregate in presence of sulfide

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Upper mantle heterogeneity of the elements hosted by sulfide, such as Os, Pt, Pb, is expected to be controlled by the rate of grain boundary transport of these elements in olivine-rich mantle rocks. As a small quantity of sulfide minerals is dispersed within mantle peridotite, the diffusive homogenization through the grain boundary is the likely rate limiting process to exchange variable amount of trace elements hosted by sulfides, but not hosted in other silicate minerals in significant abundances. Specifically, highly siderophile elements are such elements hosted by sulfides but not in mantle silicate minerals. We have conducted piston cylinder experiments at 2.0 GPa and 1260 °C, designed to measure the olivine grain boundary diffusivity in presence of sulfide for Re, Os, Pt and Pb. Our results of the bulk diffusivity vary from ~10^{-11} m^2 s^{-1} for Re and Os to ~10^{-9} m^2 s^{-1} for Pt and Pb. These values represent the rate of exchange through a polycrystalline olivine aggregate. With consideration of the grain size and the grain boundary thickness, the grain boundary diffusion rate is deduced from the bulk diffusion values, and they range from ~10^{-8} m^2 s^{-1} for Re and Os to 10^{-5} m^2 s^{-1} for Pt and Pb. Surprisingly, the fast values are comparable to an olivine grain boundary diffusivity for hydrogen. Applying these diffusion coefficients to upper mantle conditions, the “rule of thumb” scaling model shows that the mantle peridotite hosting Pb for one billion years must have a kilometer-size homogeneous domain of Pb abundance and isotopes, while for Re and Os, the homogeneous domain can be as small as 50 m. This suggests significant decoupling of Pb and Os isotope signatures in mantle-derived materials (basalts and xenoliths) can be explained by variable extent of diffusive equilibration of sulfide grains.