

Elemental partitioning between olivine grains and grain boundaries in mantle rocks

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The concentration and location of incompatible elements, which strongly partition into the fluid phase (melt and/or volatile) in fluid-bearing rocks, provide essential constraints on the geochemical and geodynamical processes in Earth's interior. However, a fundamental question remains: Where do the incompatible elements reside prior to formation of the fluid phase? To answer this question, we investigated partitioning of Ca between the grain interiors and grain boundaries of olivine in natural and synthetic olivine-rich aggregates. We found that the partitioning follows a thermodynamic model for equilibrium grain boundary segregation driven by misfit strain energy in grain matrix. The behavior of other elements present in detectable concentrations at grain boundaries (K, Cr, Ti, Al, Mn, Ni) indicates that differences of ionic radius relative to the host elements (Mg and Si) control the concentration of these minor elements at grain boundaries. Our simple model for the segregation depending on ionic radius predicts that olivine grain boundaries can be the main storage sites for the solutes with ionic radius larger than 0.11 to 0.12 nm depending on the grain size (0.1 to 10 μm) for aggregates simply composed of olivine grains.

The grain boundaries have well-defined thermodynamic properties and that they can store significant amounts of incompatible elements. This observation provides a new framework for interpreting geochemical signatures in polycrystalline rocks.