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Chemistry of grain boundaries in mantle rocks

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ABSTRACT

The compositions of olivine grain boundaries have been analyzed with scanning transmission electron microscopy (STEM) via energy dispersive X-ray (EDX) spectrum profiling in three specimens: a peridotite ultramylonite, olivine phenocrysts in a basaltic rock, and synthesized compacts of olivine + diopside. Composition profiles across grain boundaries in both natural and synthetic samples exhibit a characteristic width of 5 nm and a depletion of Mg and concomitant enrichments of Ca, Al, Ti, and Cr. Chemical segregation is known to affect grain boundary processes such as grain boundary diffusion, sliding, fracture, and migration, all of which influence the rheological properties of polycrystalline aggregates. Also, because grain boundaries are enriched in trace elements, the boundaries can be important storage sites for such elements in mantle rocks. Mantle-derived melts with unusual compositions, such as those rich in Ca and/or Ti, might be explained by preferential melting of olivine grain boundaries enriched in these elements. The common chemical signatures at grain boundaries in all samples indicate that chemical segregation is an energetically favorable phenomenon and thus should occur elsewhere in Earth's mantle. Segregation of trace elements to grain boundaries may play an important role in dynamical and geochemical processes in Earth's mantle.