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Mechanism and kinetics of spinel-garnet lherzolite transformation: An experimental study

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The phase transformation from spinel lherzolite to garnet lherzolite occurs at around 2.0 GPa in the upper mantle, in which spinel reacts with pyroxenes to form garnet. Previous studies have reported the reaction textures of partially transformed natural peridotite rock samples (e.g., Obata and Morten, 1987), and the phase boundary of this transformation from high-pressure experiments (e.g., Walter *et al*., 2002). However, the kinetics of spinel-garnet lherzolite transformation has not been examined so far, which makes it difficult to discuss time-dependent processes of mantle flow across the phase boundary.

In order to study the kinetics of this reaction, high-pressure experiments were conducted in the garnet lherzoltite stability field (3.2 GPa and 1273-1473K for 0.6-30 hours) with a spinel single crystal embedded into powder mixture of orthopyroxene and clinopyroxene. We used crystals from San Carlos mantle xenolith as the starting material. In some experiments, spinel surface was deposited by platinum and half of the spinel was covered with olivine to know the direction of garnet growth.

Microstructural observations of recovered samples revealed that garnet reaction rim was formed between single crystalline spinel and polycrystalline pyroxenes. The width of garnet reaction rim (x)t linearly increase with the square root of time t. The growth of kinetics can be described by $[x(t)]^2 = 1.3*10^{-8}m^2s^{-1}\exp(-188kJmol^{-1}/RT)t$, based on the diffusion-controlled growth mechanism. This is much faster than lattice diffusion coefficients of divalent species in garnet which previous studies report. Because the platinum markers were at the spinel-garnet interface, it is thought that the garnet reaction rim grows toward the pyroxene region. This suggests that the rate-limiting process is the grain boundary diffusion of trivalent species in the garnet reaction rim.

Development of corona textures around spinel with garnet reaction rims from natural peridotite rocks has been reported in previous studies. We experimentally reproduced the formation of corona texture and clarified the kinetics of the diffusion-controlled garnet rim growth. Our results can be used to constrain their cooling rate or P-T-t paths, and to discuss mantle flow across the spinel-garnet lherzolite boundary.