Effect of Orthopyroxene on Kinetics of the Olivine-Spinel Phase Transformation

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Introduction

The kinetics of the phase transformations of olivine to its high-pressure polymorphs has attracted great interest over the last 30 years because of the geophysical and geodynamic consequences. Previous experimental studies have mainly involved single-phase aggregates (i.e., olivine). The effect of secondary phases on the kinetics has generally been ignored. A major portion of subducted lithosphere is harzbergitic; that is, olivine (ol) and orthopyroxene (opx) are coexisting in the slab, and opx can locally reach as high as 40%. It is necessary to conduct a kinetic study of olivine phase transformation in the presence of opx. We reported that opx has a significant effect on kinetics when ol and opx powdered mixtures were used as starting material. In this study, we use hot-pressed samples of pure ol and an ol+opx mixture as starting material because they are more relevant to the subducting lithosphere.

Methods and Materials

Experiments were carried out at beamline 13-BM. The starting materials included hot-pressed polycrystalline aggregates of San Carlos olivine and an ol+opx mixture (annealed at 6 GPa and 1300ºC for 3 h). A small chunk of each aggregate was embedded in NaCl powder in the same high-pressure assembly. Two samples were again separated by powder NaCl (mixed with BN), which was used as the pressure marker. After the target pressure (P) was reached by using the 250-ton large-volume press (LVP) coupled with a T-cup device, the temperature (T) was increased stepwise. The phase transformation was monitored by x-ray diffraction while the sample assembly remained under the desired P and T conditions. The pressure was calculated on the basis of Decker's equation of state (EOS) of NaCl, and the temperature was measured by a W/3%Re-W/25%Re thermocouple.

Results

The samples were first cold-compressed to 11.6 GPa. The temperature was then increased to 600ºC (11.7 GPa) within 10 min. The P and T remained constant for about 1 h. No phase transformation was observed in both samples. Temperature was increased again to 650ºC and maintained constant while pressure was increased to 17.2 GPa. The second compression lasted about 1 h. The samples remained at the final P and T conditions for 3 h. Diffraction peaks from both samples were not widened significantly during the course of the experiment, indicating that a nearly hydrostatic condition was obtained. The olivine-spinel phase transformation occurred in the mixture of olivine and opx, and a significant amount of spinel formed. However, no phase transformation was detected in the pure ol sample.

Discussion

The experimental results demonstrate that the kinetics of olivine-spinel phase transformation can be greatly enhanced by the presence of orthopyroxene. They strongly suggest that the phase transformation of olivine to its high-pressure polymorphs can readily proceed in the subducting lithosphere, and that there would be no metastable olivine in the slab.

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