Water in Rim Growth Experiments: Big Effect, but Hard to Detect

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The growth of polycrystalline layers of orthopyroxene (Opx) between olivine (Ol) and quartz (Qtz) has become the model system of choice for the study of the mechanisms and the kinetics of diffusion-controlled rim growth, and thus an important model for mineral reactions in water-poor systems in general. Here we present results from an improved technique in piston-cylinder press experimentation that allows extending the practical range of experimental conditions to lower temperatures. Our investigation aims at rim growth kinetics at very low water fugacity and the detectability of very small amounts of water in the reactants after experiment. We place a pile of double-sided polished Ol and Qtz single crystal plates in a thermal gradient, such that each run comprises an entire set of Opx rim growth experiments at different temperatures. By this set-up, the rim growth rates from one single run yield the apparent activation energy and the pre-exponential factor for the bulk diffusion process behind Opx rim growth, that is closely tied to Mg-Si interdiffusion through the Opx layers. The reactant crystal plates are mounted with controlled crystallographic orientation. This allows to precisely measure the OH content in the nominally anhydrous phases Ol and Qtz after experiment using polarised FTIR spectroscopy. For the first experiment we used synthetic forsterite (Fo) ($<<$1 ppm H_2O) and natural Qtz and for the second experiment we used natural Ol (69+-20 ppm H_2O) and natural Qtz. Boron-nitride was used as pressure medium surrounding the gold capsule that contained the reactant plates, and natural fluoride was used for the exterior part of the assembly. The reactant samples were dried at 600 °C for 1 hour before cold-sealing the capsules. At 1.9 GPa in the temperature range of 900 to 750 °C and with the running time of 72 hours. All these parameters are identical for both experiments. The apparent activation energy for the Opx-forming reaction in the first experiment is 105+/-15 $kJmol^{-1}$ and in the second experiment 236+/-39 $kJmol^{-1}$. Both the absolute bulk diffusion coefficients and their temperature dependence are close to an extrapolation of Yund's (1997) water-bearing experiments at 950 to 1100 °C. Extrapolations from really dry thin film experiments at 1300 to 1000 °C at 0.1 MPa total P (Milke et al. 2007) are slower by several orders of magnitude. Still, no increase in intracrystalline OH was detected in Fo after experiment. These findings suggest that very small amounts of water (probably originating from the pressure medium and diffusing into the gold capsule) have a very strong effect on the Opx rim growth rates, but are not traceable from the OH content of the reactant crystals.

References

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