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SPECIAL COLLECTION: MECHANISMS, RATES, AND TIMESCALES OF GEOCHEMICAL TRANSPORT PROCESSES IN THE CRUST AND MANTLE

Influence of grain size, water, and deformation on dolomite reaction rim formation

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ABSTRACT

Solid-solid mineral reaction rates are influenced by the microfabrics of reactant phases and concurrent deformation. To investigate this interplay in carbonate systems, we performed annealing and deformation experiments on polycrystalline and single-crystal calcite and magnesite, forming dolomite (Dol) and magnesio-calcite (Mg-Cal). At a fixed temperature of $T = 750$ °C and confining pressure of $P = 400$ MPa, samples were either annealed for 29 h, or deformed in triaxial compression or torsion for 18 h using a Paterson-type gas deformation apparatus. At the contact interface of the starting reactants, Dol reaction rims and polycrystalline Mg-Cal layers were formed. The widths of the layers were in the ranges 4–117 and 30–147 μm, respectively, depending on the microstructure of starting materials and experimental conditions. Annealing experiments with polycrystalline reactants in contact with each other resulted in a ~22-fold increase in Dol rim thickness compared to a contact between two single crystals and a larger Mg-Cal layer width by a factor of 5 (cf. Helpa et al. 2014). This suggests that the microstructure of magnesite controls migration of the reaction front. For polycrystalline starting materials, axial stress accelerated Mg-Cal growth rates but not Dol growth rates. Highly strained torsion samples showed Dol formation along grain boundaries in Mg-Cal as well as in the polycrystalline calcite reactant. A reduction of Dol rim thickness between polycrystalline reactants deformed in torsion is possibly caused by concurrent grain coarsening of polycrystalline magnesite. Dol and Mg-Cal growth kinetics between single crystals were unaffected by the addition of ~0.3 wt% water.

The experiments demonstrate that Dol reaction kinetics strongly correlate with magnesite reactant grain sizes, while Mg-Cal growth depends on the calcite reactant grain sizes. The dolomite-forming mineral reaction kinetics are not significantly affected by concurrent deformation. In contrast, deformation enhances Mg-Cal formation, especially at small calcite grain sizes that promote efficient grain boundary diffusion.

Therefore, the fastest reactions forming Dol and Mg-Cal in nature are expected to occur in very fine-grained reactants. Concurrent deformation may drastically enhance reaction kinetics if grain size reduction of the reactants occurs by, for example, cataclasis or dynamic recrystallization.

Keywords: Rim growth, carbonates, diffusion, deformation, water