Controlling factors of reaction-induced stress and strain during hydration reactions: Experimental investigation in $CaSO_4$-H_2O system

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Dehydration and hydration reactions deep in the Earth control the water budget in the subduction zone system. Hydration reactions in particular, associate large solid volume changes. Such solid volume changes can induce large stress by the release of Gibbs free energy during the reactions, which can be larger than the strength of rocks and generate fracturing. However, whether volume change in hydration reactions causes fracturing, enhance fluid flow and promote further hydration reactions, or it fills in the pores, reduces fluid flow and suppresses further hydration, is largely unconstrained. Here we explored mechanical responses of polycrystalline rock through hydration reactions $CaSO_4 + 2\ H_2O \rightarrow CaSO_4{\cdot}2H_2O$, wich involves as much as +60% of theoretical solid volume change.

To understand the dependency of reaction-induced stress and strain on confining pressure and porocity, constant load experiments with various loadings (0.01–10 MPa), and constant volume experiments with various porocities (20–35%) were conducted. Reaction–induced strain and stress, and heat of reaction were measured during the experiments. Starting materials are pressed poweder of mixture of anhydrite and hemihydrate, with grain size of ~50–100 μm.

Although the samples have high porosity (ø = 24%), direct measurement of reaction-induced strain under constant load experiments revealed that reaction-induced bulk strain does occur under loadings of 0.01–10 MPa. The increase of loading enhances deformation mechanisms such as pressure-solution creep, and the amount of reaction-induced bulk strain decreases. Constant volume experiments revealed that reaction-induced stress increases linearly with reaction rate. These results suggest that the mechanical behavior during hydration reaction is primary controlled by the competition between the reaction rate and deformation rate.

Such competition of reaction rate and deformation rate may control whether the rock fractures during hydration reactions or not, and would have significant effect on the extent of reactions in wedge mantle or arc crust at subduction zones, where aqueous fluid is provided for hydration reaction.