Development of reaction-induced stress and permeability in $MgO-H_2O$ system

*笠原 久夢[1]、宇野 正起[1]、岡本 敦[1]、土屋 範芳[1]
*Hisamu Kasahara[1], Masaoki Uno[1], Atsushi Okamoto[1], Noriyoshi Tsuchiya[1]

1. 東北大学大学院 環境科学研究科
1. Graduate School of Environmental Studies, Tohoku University

Fractures are dominant flow path of fluid transport in the crust, and fluid flow through the fractures is important for the progress of fluid-rock interaction and material transport in the crust. The fractures enhance permeability in rocks, which has significant effects on the efficiency oil mining, geothermal development and Carbon dioxide Capture and Storage (CCS). Thus, the research on the fracture formations and associated permeability developments are increasingly important for geoscience and engineering.

Especially during fluid-rock interactions in the crust, hydration reactions increase solid-volume and generate stress. Recently such reaction-induced stress has been investigated as a new fracture generation process. For example, the fractures associated with reaction-induced stress are observed in serpentinized olivine (Jamtveit and Austrheim, 2010). In addition, the stress exceeding rock strength is reported from thermodynamic prediction (Kelemen and Hirth, 2012) and experimental measurements (e.g., Lambart et al., 2018). However, the existence of non-fractured rocks despite the volumetric expansion reaction (Centerrea et al., 2015) and the discrepancies between the experimental and theoretical values of reaction-induced stress have not yet been clarified. To understand the causes of these phenomena, it is important to constrain the controlling factors and the generation processes of reaction-induced stress. Therefore, we conducted direct measurements of reaction-induced stress and permeability development during hydration reactions, to clarify the relation between the reaction, stress generation, fracturing and permeability developments.

In our previous study, we measured the reaction-induced stress in $MgO–H_2O$ system, and observed stress generation of approximately 40 MPa, exceeding common tensile strength of rocks. It is indicated that temperature dependence exists in stress generation behavior: the higher the temperature, the higher stress are generated and the stronger stress relaxation are observed after a peak stress. We also showed that this behavior can be explained by competition between reaction and deformation strain rate. This result was consistent to a certain extent with the result of $CaSO_4$・$1/2H_2O–H_2O$ system reported by Skarbek et al. (2018).

In this report, we aimed to clarify the influence of reaction and deformation rate on stress generation and the permeability development during volumetric expansion reaction. We conducted two experiments, the stress measurement experiments and the permeability experiments. In the former, experiments were conducted using pellets (ϕ=45–55%) of MgO powder as a starting material under conditions of approximately 80 to 120 °C and fluid pressure of approximately 0.100 MPa. The developments of reaction-induced stress were measured as a function of temperature. In the same experimental systems, the reaction and deformation rate were determined by measuring the strain and the reaction rate. In the latter, the experiment was conducted using the sintered MgO as a starting material under the conditions of approximately 100 to 300 °C, a fluid pressure of 0 to 10 MPa, and a confining pressure of 0 to 50 MPa. The permeability developments were measured under conditions of various temperatures, confining

pressures and fluid pressures. From the results, we consider the relation between stress, fracturing and permeability and discuss the modes of rock fracturing and fluid transfer enhancement during hydration reactions in the crust.

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