Feedback among reaction, mass transport and fracturing during metamorphism: controls and and pattern formation

*Atsushi Okamoto[1], Hiroyuki Shimizu[2]

1.Graduate School of Environmental Studies, Tohoku Univ., 2.Institute of Fluid Science, Tohoku Univ.

Analyses of equilibrium phase relations with recently-developed thermodynamic dataset of rock-forming minerals has provided us significant information on distributions of stable mineral assemblage and water content within the Earth's interiors. However, based on the petrological observations of metamorphic rocks and serpentinites, thermodynamic equilibrium is not always attained during metamorphism at individual P-T conditions, and unreacted parts often remain. To understand the dynamic behavior of the Earth's interior, it is important to investigate essential controls on the progress of metamorphic reactions. We have developed a novel model for the coupled processes of surface reaction, fluid transport and fracturing during metamorphic reactions by a distinct element method (DEM) (Okamoto and Shimizu, 2015). This model considers a reaction rate as a function of fluid pressure, and revealed that contrasting fracture patterns are produced between volume-decreasing dehydration (typical in prograde metamorphism) and volume-increasing hydration reactions (retrograde metamorphism, or serpentinization).

In this contribution, we focus on the relative rate of fluid transport and surface reaction on the fracture pattern during the volume-increasing hydration reaction. The new DEM model treats transport of water in two ways; flow along the fractures and flow through matrix. The latter has the similar effects to diffusion. For evaluate the system, we introduce two nondimensional parameters; the ratios of the rates of fracture flow (Y_F) and diffusion (Y_D) to the surface reaction rate. We found systematic changes in fracture pattern and system evolution as a function of Y_D and Y_F. In the first case that reaction is faster than water transports (Y_D <1 and low Y_F <1), the reaction proceeds from the boundaries and forms fine fractures layer-by-layer. In the second case that reaction is faster than diffusive transport of water but much slower than flow along the fracture (low Y_D<1 and high Y_F >1000), the reaction proceeds inward effectively to form hierarchical fracture networks. In the third case with high diffusion rate (Y_D >10), the reaction tends to proceed from the boundaries without fracturing. The dependence of the fracture pattern on Y_F and Y_D suggests the importance of the rates of water transport relative to the surface reaction rate in studying the mechanism and overall rate of water-rock reactions. The fracture pattern generated in the second case is similar to mesh texture found in the partly serpentinized peridotite in oceanic peridotites. We also discuss the effects of grain boundaries and will develop the model to more realistic reaction system which incorporate element diffusion such as silica.

Okamoto and Shimizu (2015) Earth Planet Sci Let, 417, 9-18.

Keywords: reaction-transport-fracturing feedback, distinct element method, serpentinization

