Si-metasomatism during sea floor serpentinization and estimation of its kinetic parameters

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Water-rock interaction is dominant process at the Earth surface and its kinetics is important for understanding geological, climatic, and biological process of the planet. Kinetic parameters of chemical reaction were usually determined by laboratory experiments; however, due to its sparseness and noise, estimating exact parameter is often difficult. To estimate the parameters exactly, machine-learning algorism were proposed (Omori et al., 2016): however, such machine-learning algorism for water-rock interaction has not been tested with real experimental data.
In this study, we applied machine-learning algorism to extract the kinetic parameter of water-rock interaction. Serpentinization is representative hydration process at slow-spreading ridge and play crucial roles on rheological, magnetic, seismic and thermal properties of sea floor. Hydrothermal experiments (230-degree C, 2.80MPa) were carried out in olivine (Ol)–quartz (Qtz)–H_2O system, as analogues of crust-mantle boundary. By using unique tube-in-tube type hydrothermal experiments vessel, spatial and temporal data were obtained.
After the experiments, the mineralogy of the reaction products in the Ol-hosted region changed with increasing distance from the Ol–Qtz boundary, from talc to serpentine + magnetite. On the other hand, in Qtz-hosted region, talc was also formed. Talc zone was formed 1.0 mm from the boundary in Ol-hosted region, whereas it also formed 0.5 mm from the boundary in Qtz-hosted region.
The observed mineral distribution was modeled by reaction-diffusion equation. To model our experiments, we set eight reaction rate constants; diffusion constant for $SiO_{2(aq)}$ and rate constants for olivine→talc, olivine→serpentine, olivine→brucite, serpentine→talc, talc→serpentine, serpentine→ brucite, and brucite→serpentine. Firstly, Markov Chain Monte Carlo (MCMC) method were used to calculate the rate constants. This method was tested with artificial data and estimates the true value of kinetic constants with <0.5 % error. However, application of MCMC method to experimental data failed in estimating kinetic parameters, probably because the system studied here is expected to have several local minima. Here, to overcome this problems, we use an optimization algorithm of the exchange Monte Carlo method (Hukushima and Nemoto, 1996) and rate law during serpentinization will be discussed.

References

Hukushima, K., and Nemoto, K., 1996, Exchange Monte Carlo Method and Application to Spin Glass Simulations: Journal of the Physical Society of Japan, v. 65, no. 6, p. 1604–1608, doi: 10.1143/JPSJ.65.1604.

Omori, T., Kuwatani, T., Okamoto, A., and Hukushima, K., 2016, Bayesian inversion analysis of nonlinear dynamics in surface heterogeneous reactions: Physical Review E, v. 94, no. 3, p. 33305, doi: 10.1103/PhysRevE.94.033305.

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