層状はんれい岩の加水反応に起因したき裂形成に関する数値シミュレーション
Numerical simulations for reaction-induced fracture formation of layered gabbro during hydration process

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Serpentinization of oceanic lithosphere is important for various geological processes, including magmatism and earthquake at subduction zone, and generation of hydrogen and hydrocarbon at seafloor. For understanding the extent of the water infiltration into mantle within the oceanic lithosphere, permeability of the lower crust is an important factor, since gabbro has low permeability at high confining pressure (Katayama et al., 2012). In natural olivine-bearing gabbro, serpentinization of olivine grains produced radial fractures within the plagioclase matrix, which can potentially enhance the permeability (Jamtveit et al., 2008). Based on the numerical simulations using discrete element method (DEM), Jamtveit et al. (2008) shows that fracture network is produced by the volume expansion of olivine grains during hydration. However, their model dos not treat the advective fluid flow explicitly, it is not clear how permeability evolves during such processes. In this study, inspired by the natural textures of olivine gabbro taken from CM1A-7A (Wazi Zeeb, Oman Drilling Project), we conducted the DEM simulation for understanding the feedback of the fluid flow –olivine hydration –fracturing to the layered gabbro, which consists of olivine-rich layer and olivine-poor layer alternately. In particular, we focus on the contrasting fracture patterns between olivine and plagioclase, the evolution and anisotropy of permeability produced by the reaction-induced fracturing within the layered gabbro.

We conducted the two-dimensional DEM model, and the details of the model follows Okamoto and Shimizu (2015) and Shimizu and Okamoto (2016). We consider a simple volume increasing hydration reaction (A + H_2O →B; 50% volume increase), and the reaction rate is defined as a linear function of fluid pressure. In the model, advective fluid flow occurs through apertures between particles, in response to difference of fluid pressure of individual domains. The rock model is consist of reactive part (it can change from olivine to sperneitne) and non-reactive part (e.g., plagioclase and clnopyronene). The reaction rate constant and aperture width of matrix and fracture are defined based on the non-dimensional numbers based on Shimizu and Okamoto (2016).

Firstly, we conducted the simulations for the model in which a single olivine exists in non-reactive matrix. When fluid is supplied through matrix, hydration of olivine starts, which produces the mesh-like textures inside the olivine grain and radial cracks within the unreactive matrix, which is consistent with those observed in the gabbro sample from CM1A. Second, we conducted a case where several olivine grains exist in matrix. In this case, we found the formation of fracture network that connects among the olivine grains, and positive relationship between the reaction rate and permeability. Finally, we tested the case of the layered structure that consists of olivine-rich layer and olivine-absent layer, and that fluid flows in

direction perpendicular to the layers. The results of the simulations reveals that the development of vertical fractures in both olivine-rich and non-reactive layers, whereas the horizontal fractures are only developed in the olivine-rich layers. These features of fracture orientation are consistent with the natural observations and indicate that he reaction-induced fracturing could significantly enhance the fluid infiltration through layered gabbro.

References

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