Hydration and development of fracture network within oceanic lower crust: an evidence from CM1A of Oman Drilling

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The rate and extent of hydration of oceanic lithosphere are of special importance for understanding of the global water budget, the physical properties of crust-mantle boundary and potential limit of microbial activities in the crusts. It has been suggested that Moho transition zone and uppermost mantle has been highly serpentinized. If the fluid source for serpentinization is seawater, the fluid infiltration through the “less permeable” lower crust should occur. In this study, we report the nature of serpentinization in olivine within the lower crusts that was recovered from the CM1A site of the Oman Drilling Project, and discuss the relationship between hydration, fluid flow and fracturing based on the modeling of distinct element method (DEM).

The gabbroic rocks of the lower crust showed layer structures composed of light and dark colored layers with few to several tens millimeter thickness. The former is mainly composed of plagioclase and clinopyroxnene and the latter is enriched in olivine. The olivine grains were serpentinized with forming mesh-like textures, and the extent of serpentinization increases with increasing the modal abundance of olivine. The serpentine veins within the olivine grains do not always contain brucite, and show the zoning of Al, indicating an influx of silica and aluminum from plagioclase during serpentinization. The large amount of magnetite was formed in the serpentine mesh veins, indicating that olivine with high Fe content (Mg# = ~0.82) effectively produce hydrogen compared to the common mantle peridotite (Mg# = ~0.9). Radial cracks, which are filled with chlorite, are also developed around the serpentinized olivine grains. These features indicated that the reaction-induced fracturing occurred as the force of crystallization exceeds the tensile strength of the matrix minerals as suggested by the previous studies (Jamtveit et al., 2008; Kelemen and Hirth, 2012). It is also noted that fractures in olivine tends to developed in horizontal direction (parallel to the gabbroic layering) whereas those with in the plagioclase developed in vertical direction.

We conducted the DEM simulation on serpentinization in layered gabbro, which treats the reaction, advective fluid flow and fracturing, and the reaction rate is defined as a function of fluid pressure (Okamoto and Shimizu, 2015; Shimizu and Okamoto, 2016). The model reproduces a simultaneous development of contrasting fracture patterns inside and outside of the olivine grains, and shows the development of fracture network connecting the olivine grains, and shows the positive feedback of serpentinization, fracturing and permeability enhancement in vertical direction. These results indicate that the reaction-induced fracturing play essential roles on the fluid infiltration through the lower crusts and mantle hydration.

References

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