Numerical prediction of effect of olivine content for proceeding of serpentinization

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The extent and progress of serpentinization within the oceanic lithosphere is a key to understanding global water circulation within the Earth's interior and seismicity at subduction zone. However, the mechanism to control the serpentinization rate of the oceanic lithosphere is still unclear. In this study, we reveals the importance of modal abundance of olivine grains on the feedback among fluid flow, fracturing and reaction based on the analyses of natural rocks and numerical modeling by distinct element method (DEM). The analyzed rocks are taken from Oman Drilling Project hole CM1A which through the crust-mantle transition zone. The analyzed rocks are olivine-gabbro, troctolite, dunite and wehrlite which show a large variation of the amounts of olivine. In troctolite and olivine gabbros, characteristic fracture patterns are observed: mesh-like texture within olivine grains and radial cracking around the olivine grains. Serpentine was observed along these fractures in olivine grains, it is suggesting that these fracture was a main fluid pathway during serpentinization. Moreover, a positive relationship was found between moral abundance of olivine and the extent of serpentinization.

The numerical simulation based on two-dimensional distinct element method (DEM) combining fluid advection and reaction (Shimizu and Okamoto., 2016) was conducted to examine the effect of amount of olivine grains to unreacted matrix. We consider a simple volume increasing hydration reaction (150% volume increase), and the rock model consist of reactive part (olivine) and unreactive part (plagioclase and pyroxene). We conducted five conditions varying distance between each olivine grains. As the result, the olivine grains made connected fracture network, which increase in permeability and reaction progress. However, when too low olivine content, it could not make enough fracture for reaction proceeding. In the other hands, when too much olivine amount condition, the permeability and bulk reaction progress become less because volume expansion caused fracture clogging which inhibited further fluid infiltration to fresh olivine grains.

These results suggest that (1) an increase of olivine amount results in development of fracture network to percolate fluids, but (2) too much olivine amounts prevent the fluid flow as volume-expansion close the fractures which obstruct fluid penetration. The discrepancy between natural observation and numerical modeling for dunite suggest the importance of other fluid pathways such as nano-scale pores in serpentine for complete serpentinization.

Shimizu, H., Okamoto, A., 2016. The roles of fluid transport and surface reaction in reaction-induced fracturing, with implications for the development of mesh textures in serpentinites. Contributions to Mineralogy and Petrology, 171, 73.

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