Knockout seawater –basalt experiments and its implications to hydrothermal alteration in midocean ridges

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Midocean ridge is one of the most active sites of water-rock interaction because of its high temperatures and high fluid flux. The hydrothermal alteration there provides significant impacts on various processes including elements exchange between hydrosphere and lithosphere, global circulation of H_2O, mineralization, and at the bottom of hydrothermal system at least reaches at supercritical conditions exceeding 400 degreeC. Seawater is characterized by high concentration of Na, Cl as well as Mg, Ca and SO_4(Antonelli et al. 2017). In spite of many experiments on basalt-seawater interaction, most of basalt-seawater experiments are limited to batch-type and/or at low temperature (<350 degreeC). Therefore, our knowledge on controls the type and extent of hydrothermal alteration of oceanic crusts is still limited. In this study, we conducted the supercritical flow-through experiments on basalt-water interaction. By Knockout seawater experiments, which uses the solutions extracting individual elements from seawater, we revealed the essential factors of seawater on the alteration of oceanic crust.

P-T conditions of the flow-through experiments are 400-410 degreeC and 38-39 MPa and with flow rate of 0.025 –0.1 ml/min. Four series of experiments were conducted with different starting solutions; (1) distilled water, (2) NaCl aqueous solution, (3) NaCl + $MgCl_2$aqueous solution, (4) analogue sulfate-precipitated seawater (hereafter, analogue seawater). The composition of the analogue seawater was set based on the fact that CaSO4 precipitates during the heating of seawater above 150 degreeC. We enclosed the power of basalt taken from Iceland. The contrasting behaviors in the evolution of solution chemistry and product minerals were found between experiments with distilled water and analogue seawater system. In the basalt-distilled water experiments, the concentrations of Si, Na and Al increased and pH (room T) increased from 6 to 9. The plagioclase grains (An60-80) is replaced by anorthite (An100) with abundant pores preferentially near inlet, and a small amount of chlorite formed downstream. These features indicates that preferential leaching of albite components occurred, and the other elements are small. In contrast, basalt-analogue seawater experiments, the Mg concentration decreased and Fe, Ca and Si increased, and pH decreased from 8 to to 3. In this experiments, Mg-chlorite replaced pyroxene and plagioclase throughout the reaction tube, and Fe-Ti oxide precipitates at downstream. The extensive chloritization is similar to those found in chloritites in Oman ophiolites. The PC scores plot based on the principal component analyses of the solutions of four types of Knockout experiments reveal that NaCl,aq is similar to distilled water, but NaCl+MgCl2,aq is similar to seawater. These features means that Mg, not NaCl, is a key factor controlling the extent of hydration and element budget during the hydrothermal alteration of midocean ridges.

References

Antonelli, M.A., Pester, N.J., Brown, S.T., DePaolo, D.J., 2017. Pros. Nat. Ac. Sci., 114, 12413-12418.

Keywords: basalt-seawater experiments, hydrothermal alteration of midocean ridge, chloritization

