

For understanding supercritical water-rock interaction and hydrothermal metamorphism in the geothermal fields

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Recently, the deep drilling projects targeting the frontier of the geothermal resources have been greater attentions in the worlds, including Island, Italy, as well as Japan. For example, on January 2017, the Iceland Deep Drilling Project (IDDP-2) reached the condition of 426 degreeC and 34 MPa, which exceeded the critical points of seawater (Frioleifsson et al., 2017). At such supercritical conditions, the rocks were suffered from intense water-rock interactions producing the mineral assemblage of greenschist to amphibolite facies; in other words, the deep drilling of the geothermal areas provides us in-situ laboratory of active metamorphic processes. Metamorphic petrology has been constructed based on the thermodynamic equilibria among minerals within rocks for low-water-to-rock ratio and high temperature environments, whereas water-rock interaction, which has been commonly applied to low-temperature environments (< 300 degreeC) with high water-to-rock ratio, is mainly analyzed based on the equilibria among the chemical species in the solutions. The most serious problem in application of the solution analyses at high-T conditions is a lack of thermodynamic data of the charged aqueous species at low H₂O density region (i.e. vapor, or vapor-like supercritical) and around critical points (Johnson et al. 1992).

For understanding the dynamic reaction systems of fluid-rich crustal environments, we have conducted several series of hydrothermal experiments under sub to supercritical conditions. Beyond the predictions of conventional petrological analyses, we found that two important aspects of the water-rock interaction. One is the common appearance of metastable minerals. We conducted the flashing experiments of silica-saturated solutions, which were prepared by dissolution of granite or basalt in pure water, from sub to supercritical conditions. In all cases, we found that the precipitates are not quartz, but spherical particle of metastable amorphous phases with size of 0.1-2 μ m. In the cases of basalt, some columnar crystals were also formed (mainly albite). The amorphous silica particles produced by the flashing were transformed into more stable phases (to cristobalite to quartz) only in a few days at the supercritical conditions by dissolution and precipitation processes. The formation and transport of silica nanoparticles play essential roles on the evolution of permeability within the supercritical reservoirs. The other aspect is strong effects of preferential dissolution of specific minerals. We conducted a hydrothermal-flow through experiments of basalt (from Island) at 410 degreeC and 35 MPa for 34 days with flow rate of 0.01 ml/min. We found remarkable variation of the product minerals along the flow path, as well as the local variation among phenocrysts and groundmass parts. At the upstream, grossular and anorthite was formed by preferential leaching of albite component of the plagioclase, whereas amphibole and chlorite are mainly formed in the downstream, with increasing pH. Such complex phenomena with intense element transfer are difficult to predicted by P-T pseudosection with assumption of an "average" bulk composition. For comprehensive understanding of the chemical processes of the supercritical water-rock interaction in open system, we need to develop new approaches which combine petrology, solution chemistry and statistical analyses of high dimensional data, as well as the establishment of the thermodynamic data for supercritical conditions.

Frioleifsson GO, Elders WA, Zierenberg RA et al., 2017, Scientific Drilling, 23, 1-12.

Johnson JW, Oelkers EH, Helgeson HC, 1992. Geochim Cosmochim Acta, 7, 899-947.

Keywords: supercritical water-rock interaction, phase petrology, solution chemistry, metastable mineral, preferential leaching of elements