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Hydrothermal troctolite alteration at 300 and 400 °C: Insights from flexible Au-reaction cell batch experimental investigations

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Abstract

Troctolites are increasingly recognized as a common rock found in association with oceanic core complexes. They are similar to komatiite in composition, and hence troctolite alteration may provide insight into H_2 production on Early Earth. We investigated the hydrothermal alteration of olivine-rich troctolites in two batch experiments (300 °C, and 400 °C – 40 MPa) by reacting forsteritic olivine and anorthite-rich plagioclase with salt solutions. The alteration process was evaluated based on concomitant fluid samples and solids retrieved upon the termination of the experiments. In both experiments, the initial rock powder was turned into a hard, compact mass through cementation by secondary phases. The heterogeneity of this mass was documented using μ-computed tomography and electron microscopy. Thermodynamic computations were conducted to determine the equilibrium phase assemblages and fluid compositions with increasing reaction turnover.

Mineral zonation developed between the fast-reacting, fluid-dominated top portion of the solids and the more isolated portions at the bottom of the reaction cell. At 300 °C, the total reaction turnover after 1800 h was 77.5%. Serpentinization of olivine controlled the fluid composition after plagioclase had reacted away in the top layers. In contrast, a Ca- and Al-enriched assemblage of xonotlite and chlorite developed alongside unreacted plagioclase at the bottom. The porosity is very low in the top layers but high (around 15%) in the bottom part of the cemented mass. At 400 °C, the reaction turnover was only 51% as olivine was stable after plagioclase had reacted away. Clinopyroxene and andradite ± chlorite had formed in the top layers, whereas xonotlite, grossular, and chlorite had formed at the bottom. The permeability is more uniform and the mineral zonation less pronounced at 400 °C. These mineral zonations developed as a consequence of increased mobility of Ca, Al, Mg, and to a lesser extent of Fe in the experiment, which may be facilitated in the highly permeable granular materials when compared to a compact rock. Steady-state hydrogen concentrations were at least 20 mmol L^{-1} at 300 °C and <1 mmol L^{-1} at 400 °C. A lack of magnetite formation at the higher temperature is responsible for the low-H_2 yields.

Keywords: Troctolite alteration, experimental petrology/geochemistry, hydrogen, fluid-rock interaction