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Serpentinization of sintered olivine during seawater percolation experiments

L. Luquot (1), M. Andreani (2), M. Godard (1), P. Gouze (1), and B. Gibert (1)

(1) Université Montpellier 2 - CNRS, Géosciences Montpellier, Montpellier, France (luquot@idaea.csic.es), (2) Laboratoire des Sciences de la Terre, Université Lyon 1, F- 69622 Villeurbanne

The mantle exposed at slow to ultra-slow spreading ridges is pervasively and variably serpentinized down to depth of 4-8km according to available geophysical data. The onset and durability of this hydration process require efficient penetration and renewal of fluids at the mineral-fluid interface. Moreover, serpentinization is exovolumic if a mass-conservative system is assumed, or chemical elements have to be leached out to conserve rock volume. Thus, the extent of serpentinization depends of the system capacity to create space and/or to drive mass transfers. In order to investigate these coupled hydrodynamic and chemical mechanisms, we did a laboratory experiment during which seawater was injected in a sintered San Carlos olivine sample at conditions representative of low temperature, ultramafic-hosted, hydrothermal systems. The percolation-reaction experiment was carried out at 19 MPa and 190°C; the initial water flow was set at 0.2 mL/h then decreased down to 0.06 mL/h after 8 days. During experiment, permeability decreases continuously although the high Si concentrations in outlet fluids indicate steady olivine dissolution. Fluids are also depleted in Fe and Mg, suggesting precipitation of Fe- and Mg-rich mineral phases. SEM and AEM/TEM analyses of the reacted samples allowed to characterize hematite and poorly crystallized serpentine, both formed at the expanse of olivine. Mass balance calculations indicate that, ca. 8 wt. % olivine was dissolved while the same mass of serpentine (+/- brucite) was formed finally resulting in a porosity decrease from $\sim$ 12% to 5 %. We infer that the structure of the newly formed serpentine resulted in the clogging of fluid paths and explain the decrease of permeability during experiments. Hematite (<1 wt.%) is also observed, indicating redox reactions. We observed that the outlet fluid composition is not modified by changes in the fluid flow. These experimental results are used better understand the scale and efficiency of serpentinization at the onset of the alteration reactions (effective reaction rates in porous/fractured media).