Kinetics of serpentinization in Aluminium- and carbonate-rich hydrothermal fluids

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The hydrothermal alteration of olivine is a widespread reaction that occurs wherever warm aqueous fluids react with ultramafic mantle rocks or olivine-rich magmatic rocks. Olivine is transformed into serpentine, plus variable amounts of magnetite and magnesium hydroxides. On Earth, the serpentinization reaction operates from deep subduction zones to shallow lithospheric environments where it alters significantly the physical and chemical properties of rocks. The deep biosphere may also benefit from this reaction. Serpentinization may also have key emerging societal implications, such as the production of hydrogen as a source of carbon-free energy. Although Al-bearing minerals and CO_2-rich fluids are ubiquitous in the relevant settings, the role of these elements on the kinetics of serpentinization has not yet been investigated. CO_2 or carbonate ions have sometimes been added at very high concentrations to simulate industrial CO_2 injections leading exclusively to carbonate mineral formation.

We measured the kinetics of olivine serpentinization in presence of dissolved Al, HCO_3^-, or Al + HCO_3^- in a low-pressure diamond-anvil cell at 200 °C, 350 °C, and 2 kbar. Follow-up of the reactions was realized using time-resolved X-ray diffraction at the beamline ID27 of the ESRF (Grenoble, France). Scanning electron microscope (SEM) was used to characterize solid reaction products. All reactions occured in less than two days, *i.e.* at least one order of magnitude faster that in previous studies. Serpentine and magnetite were formed in all experiments indicating that the Fe^{2+} of olivine has been oxidized by water resulting in H_2 production. Raman spectroscopy on solid products also showed the presence of magnesite in samples reacted in presence of HCO_3^-. Hence, we conclude that the presence of Al favours the serpentinization reaction and the production of H_2 that leads to favorable conditions for carbon reduction.