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Permeability evolution during carbon mineralization in peridotite: an experimental determination of chemo-mechanical feedbacks

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Carbon Capture and Storage (CCS) aims to gather and store atmospheric $CO_{2,}$ often in geologic reservoirs, to mitigate the increasing atmospheric CO_2 concentrations that lead to climate change. While the majority of CCS projects to date focus on structurally trapping CO_2 in gaseous form in porous sedimentary rocks, carbon mineralization approaches storage from a much more secure perspective by storing CO_2 as a solid carbonate mineral phase.

During the carbon mineralization process, interactions between the host rock and the fluids flowing through the rock's permeable pathways exert a primary control on the evolution of permeability of the system. Precipitation of mineral phases within the fracture network can significantly reduce the permeability of the overall system (clogging), whereas mineral dissolution and volume positive mineral reactions (leading to cracking) can enhance permeability. The coupling between these competing processes dictates reservoir permeability and thus the long-term storage capacity and lifetime of CO_2 storage reservoirs. Experimental studies are therefore vital to understand the chemo-mechanical controls on dissolution, precipitation, and carbonation-induced cracking, as well as to quantify their effect on the permeability of the system.

In this study, we perform experiments using a new AutoLab triaxial deformation apparatus equipped with independently servo-controlled axial load, confining, and fluid pressures. Samples are prepared via cold press from Twin Sisters peridotite powdered to a mean particle size of 94 µm. Experimental conditions are set to reproduce shallow crust conditions at viable injection depths and are controlled at a confining pressure of 20 MPa and fluid pressures of 10 MPa. Experimental temperatures range from 20 to 150 °C. Pore fluids are mixed in a joint mixing vessel using deionized water and sodium bicarbonate forming a solution of 0.6 M concentration. The solution is then pressurized using CO_2 (99.9% purity) to a pressure of 3.5 MPa serving both as a vehicle for CO_2 transport and as pH buffer. Permeability, ultrasonic wave velocities, axial strain, pH and fluid composition are monitored during these flow-through experiments.

Preliminary results relate progress of the mineral carbonation reaction through the sample with a systematic decrease in permeability and an associated increase in P wave velocity. The results of this experimental study will be used to constrain the most favourable conditions for CO_2 storage in a solid form, which is fundamental to the upscaling of carbon mineralization as an innovative, efficient and safe method for CO_2 storage.