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Insights from reactive percolation experiments on the geological storage of CO2 in natural serpentinites

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With global warming and increasing carbon dioxide concentrations in the atmosphere being probably one of the main scientific challenges of the XXIst century, the need to develop and implement Carbon Capture and Storage (CCS) technologies is more and more pressing. One possible solution which has been recently gaining momentum, is the storage of CO2 as solid carbonates, which offers a much safer solution than the classical option of deep saline aquifers. Carbon dioxide mineralization can be proceeded in a variety of settings, but the potential of mafic and ultramafic formations (i.e. natural formations composed mostly of magnesium silicate minerals) is particularly appealing because of the large storage capacities (e.g. 77000 GtCO2 in Oman ophiolites (Kelemen & Matter, 2008), even more if we consider the ultramafic content of the oceanic lithosphere), as well as the relatively short mineralization time (several years (Pogge Von Strandmann 2019)). When a carbonate rich fluid percolates in an ultramafic formation, the primary minerals dissolve, releasing their Mg2+, and potentially Ca2+ in solution triggering the precipitation of Mg-carbonates (Power 2013). Moreover, as these formations are commonly rich in reduced iron (Fe2+), the high temperature percolation of water can also trigger the oxidation of ferrous iron to ferric and the concomitant reduction of water to H2 (Klein 2013). This phenomenon which is commonly observed in nature (Charlou 2010) could also be leveraged to double the carbon dioxide sequestration with a H2 production scheme.

However preliminary experiments show that the precipitation of carbonates in the porosity has a potentially dramatic effect on the permeability and thus the injectivity. Moreover, precipitation of carbonates can also have a negative impact on the host rock reactivity by precipitating on the substrate surface and thus shield it from further attack from the injected fluid.

In this study, we present 2 result from flow-through carbonation experiments on natural serpentinites at respectively 160℃ and 280℃. Results show that precipitation of carbonates is responsible for a dramatic drop of permeability due to the clogging of the main percolation path. We interpret the final mineral assemblage as the result of the competition between mineral kinetics and fluid velocity scaled by the Damköhler and Péclet numbers. The reduction of permeability is due to the fast kinetics of carbonates, which allow them to precipitate locally and clog rapidly main flow pathways.

In light of these experiments, a successful development of carbon mineralization techniques needs to address the precipitation issue in order to prevent a premature and catastrophic loss of injectivity. Possible solutions are the control of carbonate nucleation and kinetics, targeted hydraulic fracturing of even the potential leveraging of reaction-induced fracturing and crystallization pressure where the precipitation of carbonates could generates stresses on the porous matrix high enough to fracture it and thus open new percolation paths.

Time Block Preference

Time Block A (09:00-12:00 CET)

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