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Carbon dioxide sequestration in different geological reservoir: New insights from lab-scale flow-through experiments.

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Geological carbon storage (GCS) is one of the portfolio solutions for mitigating greenhouse gases emissions. The last decade has experienced substantial and worldwide research and demonstration efforts in relation to storage of CO_2 . Substantial progress has been achieved in field of characterization in many types of deep geological formations (such as depleted oil and gas reservoirs or deep saline aquifers) and in the understanding of the interactions between the injected CO_2 , the formation fluid and the rock-forming minerals. New models have been developed for various relevant time and space scales, geological and geometrical configurations.

 CO_2 underground storage is an industrial technology that requires predictive modeling tools for assessing feasibility and risks. It means that the controlling mechanisms and the effective parameters (i.e. that will be used at the Darcy scale) as well as the uncertainties must be identified. However, dissolution-precipitation processes involve complex coupled mechanisms, strongly controlled by the hydrodynamical and chemical variability of the system at all scales. Specifically, the upscaling from pore-scale to Darcy scale is challenging, not only because of the hydrodynamical and mineralogical heterogeneities, but also because of the strong thermodynamic disequilibrium and the relatively high flow rate expected in the vicinity of the CO_2 injection. Reproducing such processes at lab scale where conditions are fully controlled is probably the only means for investigating mass transfers, developing pertinent transport-reaction models and measuring the effective parameters.

Here we present three set of lab experiments during which CO_2 -saturated brine is injected into (i) peridotites, (ii) zeolite-rich sandstones and (iii) limestones.

Results show that mass transfers are heterogeneous at pore scale due to the high variability of the flow velocity, leading to the development of distinctly different chemical microenvironments: (i) in peridotites, Ca-magnesite and talc precipitate in low flow zones while Si-rich layer develop at olivine surface in higher flow zones, which provide the mechanism of a constant permeability; (ii) in sandstones, chlorite dissolution induce locally redox reactions and precipitation of graphite and magnetite, while precipitation of Ca-rich carbonates and kaolinite is associated to laumontite dissolution and results a strong decrease of the permeability, although porosity remains high (10%); (iii) in limestone different dissolution processes are characterized depending of the local velocity and the injected fluid. Efficiency of these processes (dissolution/precipitation) is highly sensitive to small changes in local parameters: initial structural and mineralogical heterogeneities, fluid velocity and composition (pE, pH,...). At the scale of these microenvironments, fluid speciation is controlled by the renewing rate of the solutes at pore scale and the effective kinetics; thus, it can be significantly different from bulk fluid concentrations.