



Exploring the effect of fluid chemistry on carbonate failure strength

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In the Earth's brittle upper crust, reactive fluid-rock systems continuously alter the equilibrium between the rock's poromechanical, transport and elastic properties. Potential associated destabilization and damage of rocks can be rapid (e.g. earthquakes) or slow (e.g. creep, subsidence). In the context of geological CO₂ storage in deep saline aquifers or depleted hydrocarbon reservoirs, site injectivity and integrity should be guaranteed over the reservoir lifetime. To date, most experimental evidence into mechanical fluid-rock interactions considering storage safety has focussed on the effect of acidic pore fluids, but there is only few data available on the effect of different salt solutions on rock failure behaviour. In particular, recent work has shown that 0.4 M Na₂SO₄ facilitates time-dependent crack propagation in calcite single crystals, whilst a very similar salt, MgSO₄, does not. Yet both salts are common, and as such likely to be involved in mineralogical trapping of the injected CO₂ solution, also in carbonate-rich storage formations.

We present the first results of an on-going experimental study to determine the effect of these pore fluid chemistries on the dynamic failure of a carbonate rock. We used 54 mm diameter carbonate specimens from the Ragusa Formation (Sicily, Italy), composed of 98% calcite with 2% quartz, quantified with X-ray diffraction and X-ray fluorescence analysis. This isotropic carbonate rock has an average porosity of ~14% and density of ~2.3 g/cm³. Prior to testing, two sets of specimens were vacuum saturated with either 0.4 M MgSO₄ or 0.4 M Na₂SO₄ solutions for three different exposure times, namely 1, 50 and 200 days. Note that the solutions were pre-saturated with respect to CaCO₃ using powder from the same carbonate source. A reference set was pre-saturated with CaCO₃-solution only (1 and 50 days exposure). We performed drained, triaxial tests on the pre-saturated specimens at a constant strain rate of 1x10⁻⁵ s⁻¹, room temperature and three confining pressures (7, 30 and 70 MPa) to determine the failure envelope for the different fluid types. We monitored (i) axial and radial deformation, (ii) P- and S-elastic wave velocities, and (iii) acoustic emissions. We interpret the results using a micromechanical model based on microphysical mechanisms such as time-dependent crack propagation and instantaneous fracture. Quantitative microstructural analysis and post-test porosity measurements on targeted samples are expected to further support this study. Overall, these experiments aim at yielding how mechanical strength varies between salt types and saturation times, emphasizing the role of the geometry of the pore network.