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Long-term effects of CO_2 on the mechanical behaviour of faults – a study of samples from a natural CO_2 analogue (Entrada Sandstone, Utah, USA)

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In an attempt to reduce CO_2 emissions, CO_2 capture and storage in depleted oil and gas reservoirs is seen as one of the most important mitigation strategies. However, in order to achieve safe storage on geological timescales, it is key to maintain integrity of the caprock and any faults penetrating the seal. One of the largest uncertainties lies in the prediction of the effects of fluid-rock interaction on the mechanical integrity and sealing capacity of the reservoir-seal system in the very long term, i.e. on timescales of the order of 103 or 104 years. As chemical interactions in the rock/CO_2/brine system are slow, their long-term effects on rock composition, microstructure, mechanical properties and transport properties cannot be properly reproduced in laboratory experiments.

One way of addressing this issue is to conduct experiments on reservoir, caprock and fault rock samples taken from natural CO_2 reservoir-seal systems, which can serve as natural analogues for CO_2 storage fields. The transport and mechanical properties of these rock samples, which have reacted with CO_2 over geological timescales, can then be compared with data obtained for laterally equivalent materials that are unaffected by CO_2. The observed changes in rock properties can subsequently be used as input for numerical models aimed at assessing the long-term effects of CO_2 on reservoir compaction, caprock damage, fault reactivation and fault permeability.

We assessed the mechanical behaviour and transport properties of fault rocks. To this end, we performed triaxial direct shear experiments at room temperature under nominally dry conditions, at normal stresses up to 90 MPa and shear velocities of 0.22 -10.9 μm/s. Simulated fault rocks were prepared by crushing material obtained from surface outcrops of the Entrada Sandstone, one of the CO_2-bearing formations from an analogue field under the Colorado Plateau, Utah, USA. Three types of starting material were obtained: 1) red-coloured samples consisting mainly of quartz and feldspar, some minor clay minerals and hematite/goethite grain coatings, 2) yellow-coloured, (so-called) bleached samples additionally containing various amounts of kaolinite, calcite and dolomite, and 3) heavily cemented samples from the surface outcrop of the fault core of the Little Grand Wash Fault, containing a high percentage of carbonates (> 40 wt%). Previous work demonstrates that the bleached samples and the material from the fault were altered as a result of interaction with CO_2-rich fluids.

Over the experimental range investigated, we measured friction coefficients of 0.55-0.85 for unbleached material and 0.55-0.80 for bleached material, while the fault core material showed higher friction coefficients (0.60-0.95), all showing a minor decrease with decreasing shear velocity and normal stress. Almost all samples showed velocity-strengthening slip behaviour. Overall, the frictional behaviour of Entrada Sandstone does not seem to be strongly influenced by CO_2/brine/rock interactions.