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The effects of supercritical carbon dioxide on the frictional behavior of simulated anhydrite fault gouge

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One option for mitigating climate change is to store anthropogenic CO_2 in subsurface reservoirs, particularly in depleted oil and gas fields. Reactivation of fault zones within and adjacent to potential reservoirs can lead to (micro)seismicity and to leakage of CO_2 due to enhanced permeability. To avoid these consequences, careful evaluation of the frictional properties of such faults is necessary. Both worldwide and in the Netherlands, anhydrite is a common caprock to many potential CO_2 storage sites. It is therefore likely that reservoir-bounding faults at such sites will contain anhydrite fault gouge. Against this background we investigated the effects of the presence of CO_2 on the frictional strength and on the rate and state dependent properties of simulated anhydrite fault gouge under dry and wet conditions.

Intact anhydrite core material, from the base of the Dutch Zechstein Group, was powdered and sieved to a grain size of $< 50\mu$m to simulate fault gouge. Experiments were conducted using a direct shear set-up placed in a triaxial testing machine, employing a 1mm thick gouge layer. A range of temperatures (80 - 150˚C) and sliding velocities (0.2-10μms^{-1}) was studied, at a fixed effective normal stress of 25MPa. The gouge was pressurized with dry supercritical CO_2, and with CO_2-saturated water. In both cases, the CO_2 pressure was 15MPa.

The results of the experiments on dry gouge pressurized with CO_2 show a friction coefficient (μ) of $\sim$0.65 at 80˚C, decreasing to 0.55 at 150˚C. Wet anhydrite fault gouge pressurized with CO_2 was slightly weaker at 80˚C, with μ=0.6 and a slight decrease in strength with increasing temperature, reaching 0.55 at 150˚C. Dry CO_2 saturated samples showed a transition from predominantly velocity neutral frictional behavior at temperatures of 80 and 100˚C to mixed behavior at the higher temperatures. Above 100˚C, the dry CO_2 saturated material shows velocity weakening (occasionally accompanied by stick-slip behavior) at low strains, and velocity strengthening behavior at high strains. In contrast, all wet experiments pressurized with CO_2 show velocity neutral to velocity strengthening behavior over the entire temperature range studied.

Since faults are expected to be water saturated under normal CO_2 storage conditions, our results imply that the presence of CO_2 is unlikely to significantly increase the (micro)seismic potential of anhydrite-filled faults under typical storage site conditions. To avoid fault reactivation during the injection phase it is useful to note that our results imply a slight decrease in the strength of faults containing anhydrite gouge at the in-situ temperatures (80-120˚C) compared with room temperature values.