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Healing and sliding stability of simulated anhydrite fault gouge: effects of water, temperature and CO_2

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Anhydrite-bearing faults are currently of interest to 1) CO_2-storage sites capped by anhydrite caprocks (such as found in the North Sea) and 2) seismically active faults in evaporite formations (such as the Italian Apennines). In order to assess the likelihood of fault reactivation, the mode of fault slip and/or fault leakage, it is important to understand the evolution of frictional strength during periods of no slip and upon reloading (healing and relaxation behavior) and of the velocity dependence of friction of anhydrite fault gouge. Therefore, we performed slide-hold-slide experiments combined with a velocity-stepping sequence using simulated anhydrite fault gouge (>95wt% CaSO4). Vacuum-dry and wet experiments were performed at a temperature range of 20-150°C, an effective normal stress of 25 MPa, and if pore fluid was present, a fluid pressure of 15 MPa. We also performed tests using dry CO_2, water-wetted CO_2 and CO_2-saturated water as pore fluid, but only at 120°C. Our results show healing even for vacuum-dry samples, but healing is significantly enhanced in wet samples. Dry samples exhibit velocity-weakening behavior at $T \geq 120$°C, and wet samples exhibit velocity-strengthening behavior over the full temperature range. The presence of CO_2 does not influence the healing behavior or the velocity-dependence of friction. Samples containing water-wetted CO_2 exhibit behavior similar to wet samples. We infer that the healing in dry samples is controlled by plastic asperity creep (Dieterich-type), probably through dislocation creep. In wet samples healing is inferred to be controlled by pressure solution. Extrapolation of the experimental results to natural reservoir conditions for wet anhydrite fault gouges using a pressure solution rate law shows that complete healing will occur within (tens of) days.