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Frictional properties of basalts in the presence of water: role of fault displacement

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Assessing the seismic potential stemming from the injection of pressurised fluids into shallow and deep basaltic formations suitable for carbon sequestration is of paramount importance for the safe and worldwide exploitation of any in-situ CO_2 storage method. Although a few studies have been carried out to investigate the frictional properties of basalts interacting with H_2O- and CO_2- rich fluids, very little is known about the evolution of the frictional behaviour of basalt-built faults with cumulated slip.

To investigate the role of liquid water and cumulated slip on faults cutting basaltic sequences, we performed friction experiments with the rotary-shear apparatus SHIVA (INGV- Rome). Pre-cut experimental basalt-built faults were sheared by imposing a constant displacement rate of 10 μm/s and an effective normal stress σ'n between 7.8 and 8.8 MPa. The tests were conducted at: (1) room humidity, (2) water-saturated and, (3) water-pressurized, Pf, conditions. The latter were performed from sub-hydrostatic (Pf/σn = 0.22) to supra-hydrostatic (Pf/σn = 0.50) conditions. To approach a reproducible condition for the frictional interface, at the beginning of each experiment, the fault was slid ("run-in phase") for 2 mm at room-humidity conditions and the steady state friction coefficient was 0.62$\pm$0.03. Then, the samples were unloaded and sheared again in a sequence of shear load-unload cycles intended to monitor the frictional behaviour with increasing cumulated slip: 2 mm of sliding at 10 μm/s was followed by 2 min of hold time, until the fault cumulated 8 mm of slip. Afterwards, the fault was slid steadily at 10 μm/s until the achievement of 48 mm of displacement. Finally, the same sequence was reiterated to achieve a target shear displacement of 56 mm.

At the end of each cycle we measured the steady state friction coefficient μss. Compared to the friction coefficient measured during the running-in phase (room-humidity conditions), μss (1) decreased slightly (0.05-0.15) in the presence of water after 4 mm displacement and, (2) increased slightly (0.05–0.1) at the end of each experiments regardless of the experimental conditions. While (1) can be explained by the lubricating effect of water, (2) may be the result of fault gouge produced during the 56 mm of accumulated slip.

These preliminary mechanical data suggest that the presence of water renders the fault more prone to slide, whereas wear production and thus hypothetically fault maturity tends to hinder fault sliding. To deepen our knowledge on fault stability for CO_2 storage, further experiments are planned to test the effect of fault slip in basalts in the presence of H_2O- and CO_2- rich fluids and their rate and state behaviour.