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Hydro-mechano-chemical coupling in rock failure

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Understanding rock failure is key for the safe and efficient development of the subsurface. Gas storage (CO_2, H_2 or CH_4), production of geothermal energy and the traditional extraction of hydrocarbons means fluid injection or extraction. These processes change the local stress state, but also local temperature or chemistry. Such use of the subsurface is about either keeping fluid where it is (storage) or making sure fluids come out with a sufficient but still safe rate. Since fault rocks are in many cases important fluid transport pathways, this needs a careful and complete understanding of how rocks fail. Therefore, a thorough understanding of the stages of deformation leading to failure is key, as well as any potential differences for different rock types and failure modes. We performed uniaxial compressive and triaxial experiments on limestone and sandstone to investigate the hydro-mechano-chemical coupling in rock failure, using active and passive acoustics to monitor the failure behaviour. All experiments are done at room temperature.

Using active acoustics for first arrival times is an established technique. We use here the more novel coda-wave interferometry technique to track deformation in triaxial tests at different confining pressures in sandstones and limestone, which deform respectively in a fully brittle or a semi-ductile manner. This shows that the first signs of failure can be picked up before the yield point, i.e. before the time it is picked up by any of the traditional bulk stress-strain signals used in experimental rock deformation. In uniaxial compressive experiments on the same brittle sandstone samples we show that the loading pattern can affect the final strength but also the maximum acoustic emission amplitude. Cyclic loading tends to systematically reduce the magnitude of the largest induced seismic event, whilst simultaneously also promoting more complex fracture patterns and disintegration. This implies that the risk of induced seismicity can be mitigated by changing the loading pattern in subsurface operations. Finally, we show that for reactive rocks under the right pressure and temperature conditions, changing the chemistry can have an effect on rock strength, where the effects depend on the internal rock structure. This research increases the understanding of rock failure and show the potential of monitoring for a safe and efficient development of the subsurface.