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Microstructures and composition of brittle faults in claystones: Constraints on the barrier behavior

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Investigations of fault rocks are crucial to evaluate the barrier properties of clay rich formations used for the storage of hydrocarbons, carbon dioxide gas or for the storage of heat generating radioactive waste. Claystones are considered as a geological barrier. However, their barrier capability can be reduced if the claystones are cut by brittle faults.

Our study is focusing on the microfabrics and element mobility of artificially and naturally fractured claystones using a multi-method approach. Particular attention was paid to small scale lithological heterogeneities occurring in the clayey sequence. The microfabrics were investigated using SEM and optical microscopy. Geochemical and phase analyses were carried out using XRD, XRF and ICP-MS. In addition, organic (TOC) and inorganic carbon (TIC), total sulphur (TS) as well as the cation exchange capacity (CEC) were determined.

Macroscopic observations of fault zones on outcrops and drill cores indicate closely spaced planar and undulating discontinuities, including slickenside striations. The investigated fault zones are often accompanied by calcite veins and calcite enriched zones. The fault core is formed by a mm to cm thick clayey, fine grained, cohesionless fault gouge including reworked calcite fragments. Duplex-like domains are separated by discrete microshears, along which the rocks disintegrate. Calcareous fossils, common in undeformed claystones, appear in these zones fragmented and rotated. In contrast to calcite, quartz is more resistant to solution-precipitation processes. Rarely intracrystalline fracturing was observed.

The calcite mineralization in veins, and solution-precipitation processes of calcite, documented by stylolites, reflect enhanced palaeo-permeability and activity of Ca^{2+}- and CO_2-rich fluids inside some of the fault zones, mainly along fault parallel shear planes. Elevated Sr and Ba concentrations are bound to the tectonic, secondary calcite veins within and outside the investigated fault zone. The geochemical data presented in form of isocon diagrams suggest volume gain related to the opening of veins and pores, which are now filled with calcite.

Our results do not provide evidence for presently open pores or fractures, which might be related to non-artificial tectonic deformation. However, (micro)fractures as well as mineralized veins represent inherited damage in the rock, and are prone to brittle reactivation during fluid pressure increase or during the excavation of underground galleries. A complex, polyphase deformation history including a possible reactivation of older structures is supported by our observations.