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Fracture-related fluid migration and fluid-rock interaction in outcrop analogues of Buntsandstein reservoir rocks (southern Thuringia and northern Hesse)

Norbert Kasch (1), Jonas Kley (1), Jens Köster (1), and Jens Wendler (2)

(1) Jena University, Institute for Geosciences, Jena, Germany. e-mail to: norbert.kasch@uni-jena.de, (2) Now at Smithsonian National Museum of Natural History

Suitable reservoir rocks for carbon capture and storage (CCS) in saline aquifers must be porous, permeable and reside at depths below c. 800 m in structurally simple, preferrably unfaulted settings. In central Europe, the Lower and particularly Middle Buntsandstein are regionally extensive stratigraphic units which often meet these requirements. While often deeply buried, the Buntsandstein is exposed at the surface and easily accessible in other areas. We have studied the evidence for natural fluid flux in Buntsandstein reservoir outcrop analogues and drill cores of southern Thuringia and northern Hesse. The clearest sign of fluid-rock interaction is local bleaching of the red sandstones. In the field and on drill cores we did not observe bleaching along faults, but commonly along joints. There, the bleached fringes may have sharp or diffuse boundaries and can be traced along individual joints for a few dm to m. They are most often observed on small joints and fine cracks. Using 3D laser scanning, photo-stereogrammetry and manual measurements we established the geometric properties of the joint systems. The joint systems always comprise several joint sets, but in southern Thuringia bleaching is restricted to one north-trending set. Mining reports and geological maps show that basalt dikes of Tertiary age in this region also trend north. In the underground salt mines of the Werra potassium district, potassium salt minerals show bleaching at the contacts with the dikes. Also, CO2 is found trapped within rock salt along north-trending fractures, sometimes causing violent gas eruptions during mining operations. Taken together, these observations suggest that the bleaching along north-trending joints in the Buntsandstein is causally related to the migration of CO2-bearing fluids associated with the basalt volcanism. However, the Fe-releasing process may depend on admixtures of other phases, most likely hydrocarbons released from bituminous Zechstein carbonates. Geochemical analyses show that bleaching is related to a decrease in Fe and Mn reflecting hematite dissolution. Using cathodoluminescence microscopy and –spectroscopy combined with electron microprobe analysis and stable carbon isotope study, two major fluid-mineral interactions probably involving CO2 were detected: (1) precipitation of zoned, joint-filling calcites and zoned pore-filling calcite cements, the latter replacing an earlier dolomite, and (2) alkali-feldspar alteration. We interpret Fe-rich calcite crystal cores to reflect incorporation of iron released by coeval bleaching during the dolomite-calcite transformation. This recrystallisation was associated with a volume increase. The related decrease in permeability implies some degree of sealing and possibly enhanced retention of CO2. On the other hand, feldspar alteration reflected by the modulation of a brown-luminescence emission peak ($\sim$620 nm) has a destructing effect on the feldspars implying the possibility of diminished rock integrity due to bleaching.