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A “lab-on-a-chip” experiment for assessing mineral precipitation processes in fractured porous media

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The understanding of dissolution and precipitation of minerals and its impact on the transport of fluids in fractured media is essential for various subsurface applications including shale gas production using hydraulic fracturing (“fracking”), CO₂ sequestration, or geothermal energy extraction. The implementation of such coupled processes into numerical reactive transport codes requires a mechanistic process understanding and model validation with quantitative experiments. In this context, we developed a microfluidic “lab-on-chip” of a reactive fractured porous medium of 800 μm × 900 μm size with 10 μm depth. The fractured medium consisted of compacted celestine grains (grain size 4 – 9 μm). A BaCl₂ solution was injected into the microreactor at a flow rate of 500 nl min⁻¹, leading to the dissolution of celestine and an epitaxial growth of barite on its surface (Poonoosamy et al., 2016). Our investigations including confocal Raman spectroscopic techniques allowed for monitoring the temporal mineral transformation at the pore scale in 2D and 3D geometries. The fractured porous medium causes a heterogeneous flow field in the microreactor that leads to spatially different mineral transformation rates. In these experiments, the dynamic evolution of surface passivation processes depends on two intertwined processes: i) the dissolution of the primary mineral that is needed for the subsequent precipitation, and ii) the suppression of the dissolution reaction as a result of secondary mineral precipitation. However, the description of evolving reactive surface areas to account for mineral passivation mechanisms in reactive transport models following Daval et al. (2009) showed several limitations, and prompt for an improved description of passivation processes that includes the diffusive properties of secondary phases (Poonoosamy et al., 2020). The results of the ongoing microfluidic experiments in combination with advanced pore-scale modelling will provide new insights regarding application and extension of the description of surface passivation processes to be included in (continuum-scale) reactive transport models.

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