Barite scaling in fractures simulated with nucleation and crystal growth kinetics

Morgan Tranter¹,², Marco DeLucia¹, and Michael Kühn¹,²
¹GFZ German Research Centre for Geosciences, Fluid Systems Modelling, Potsdam, Germany (mtranter@gfz-potsdam.de)
²University of Potsdam, Institute of Geosciences, 14476 Potsdam-Golm, Germany

Deep hydrothermal systems in fractured media are a potential source of geothermal energy. A key problem prevails as a consequence of utilisation that the geochemical system is perturbed and scaling may build up over time. Barite stands out as one of the most ubiquitous scaling agents in deep geothermal systems. It causes irreversible efficiency loss and may be responsible for geothermal power plants to become non-profitable. Due to complex parameter interplay and underlying uncertainties, it is imperative to utilise numerical simulations to investigate temporal and spatial precipitation effects.

In this work, the impact on fracture permeability in the near field of the injection well is assessed. A one-dimensional reactive transport model is set up with heterogeneous nucleation and crystal growth kinetics. In line with potential target hydrothermal systems in the North German Basin, the following parameters are considered in a sensitivity analysis: injection temperature (50 to 70 °C), pore pressure (10 to 50 MPa), fracture aperture (10⁻⁴ to 10⁻² m), flow velocity (10⁻³ to 10⁰ m s⁻¹), molar volume (50.3 to 55.6 cm³ mol⁻¹), contact angle for heterogeneous nucleation (0° to 180°), interfacial tension (0.07 to 0.134 J m⁻²), salinity (0.1 to 1.5 mol kg⁻¹ NaCl), pH (5 to 7), and supersaturation (1 to 30).

Nucleation and consequently crystal growth can only begin if the threshold supersaturation is exceeded. Therefore, contact angle and interfacial tension are the most sensitive in terms of precipitation kinetics. If nucleation has occurred, crystal growth becomes the dominant process, which is mainly controlled by fracture aperture. Results show that fracture sealing can happen within months (33 days) and the affected range can be in the order of tens of metres (10 m).

Predicting the threshold supersaturation is a crucial point in this context, as it essentially determines if barite precipitation becomes relevant. The uncertainty of parameters influencing nucleation at in-situ conditions is high, emphasising the need to investigate these in more detail. The presented models suggest that barite scaling must be recognised as a serious threat if the supersaturation threshold is exceeded, in which case, larger fracture apertures could help to minimise kinetic rates.