Multiphase flow modelling of unstable calcite dissolution patterns from core scale to reservoir scale

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Injection of acids into carbonate formations can lead to unstable calcite dissolution fronts. For single phase aqueous flow this has been extensively studied, through experiments, theory and modelling, in the context of acid stimulation in the petroleum industry. Dissolution patterns, such as so-called wormholes (conduits of ~2mm diameter), are governed by the characteristic numbers for the convection to dispersion rates (Péclet number, Pe) and dissolution to diffusion rates (Dahmköhler number, Da). For well stimulation operations, Pe and Da numbers can be designed (injection rate; acid selection) to control the resulting dissolution patterns.

In recent years the topic has received significant interest in the context of CO_2 storage. Several groups have conducted core scale experiments and several of these have been succesfully modelled at core scale or pore scale. Most of the experiments were conducted in single phase mode, using carbonic acid. Wormhole formation is observed (depending on Pe, Da), and fully coupled flow-geochemical modelling (Reactive Transport Modelling) reproduces these results.

The question arises how these results relate to actual CO_2 injection operations, where CO_2 is injected as supecritical phase, and not as carbonic acid, i.e. not the acid is injected, but the acid forming agent. This might make a substantial difference as recently shown in [1]. Furthermore, field-application relevant length scales are not always accessible in experiments nor in fully coupled modelling due to too high numerical demands. Therefore an upscaling approach is needed for implementation of reactive transport and dissolution structure formation in field scale modeling.

We modelled core flood experiments in our in-house, fully coupled, reactive transport simulator, both for single phase and two-phase flow. We then formulated an upscaled description, based on existing models in the acid stimulation literature but generalised to the two-phase case. The upscaled approach was validated against the fully coupled approach, on the core scale. Then we applied the upscaled description to the field scale. This allowed us to semi-quantitatively predict the timing and spatial distribution of dissolution patterns, including their effect on well injectivity and CO_2 distribution.

[1] Ott & Oedai (2015), accepted for publication in *Geophysical Research Letters*. doi: 10.1002/2015GL063582