Coupled flow, transport, and geochemical processes in fractures/fissures with a focus on geothermal and karstic systems.

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This research project focuses on the investigation of coupled processes occurring similarly in two different application topics: karstic systems and geothermal systems. In karstic systems, the team aims at exploring an extension to current karstification theories. This extension proposes that the dissolution of calcium carbonate in caves during certain periods and under certain conditions is driven by the replenishment of CO_2 due to density-driven dissolution of CO_2 [1]. This theory could be a complementary explanation for the process of speleogenesis in karst formations. Meanwhile, in geothermal systems, the team is investigating the operation of geothermal energy plants in fractured rock and simulating the alteration of fractures due to geochemical processes during operation and hence their consequences.

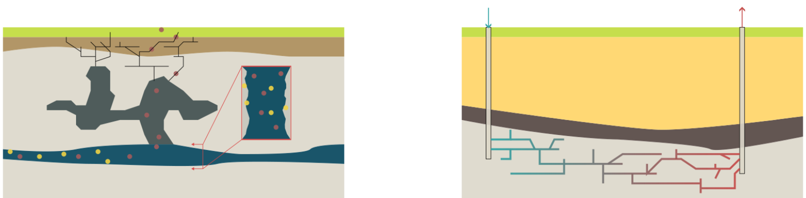

Figure 1: Applications of reactive-transport in fractures/fissures:
Left: Proposed mechanism of karstifaction due to enhanced density-driven CO_2 dissolution.
Right: Geothermal energy plant in fractured rock.

To study density-driven CO_2 dissolution in a karstic cave, an experiment employing a stagnant water column inside a cave with CO_2 sensors placed at different depths was conducted. Additionally, a series of experiments in an artificial fracture is currently conducted to measure reaction rates on the limestone surface. The data gathered from these experiments are used to calibrate a reactive-transport model, which is then used to gather data on the single-fracture scale for various fracture geometries and flow conditions. The gathered data allow to determine effective quantities on the single-fracture scale. Currently a field-scale model using the effective quantities from the pore-scale is being developed and will be later tested against field-scale data provided by operations of existing geothermal-energy plants.

Data on the single-fracture scale are gathered and reprocessed in a published paper and two data sets (DaRUS), including CO_2 concentrations in cave-air and inside stagnant water bodies [2, 4, 3]. Measurements of chemical species in an artificial fracture during the reaction with calcite are currently performed to generate more data sets. However, complementary to the experimental work, the numerical simulation of CO_2 density-driven dissolution proved to be challenging. We are confident that the calibration of reaction-rates and simulation of reactive-transport on the single-fracture scale for various scenarios will be successful. A concept for the data-based scale bridging (i.e., using an up-scaled model on geothermal system) is currently under development and will include intermediate steps, like the identification of dimensionless numbers or analytic approximations to smaller scale processes to be included on the scale of application.

In summary, this project investigates coupled hydraulic and geochemical processes in different Re-number regimes and in two different topics of application: karstic-systems and geothermal systems. A particular influence on the coupling is also due to the flow regime, which may be approximated with a Darcy model if Re numbers are sufficiently small or with a Navier-Stokes model. The different model complexity will, of course, also affect the computational effort. The contribution will provide preliminary results of the ongoing research project and outline the challenges and strategies to address them.

References

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