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Integrated hydrogeological and geochemical processes in swelling clay-sulfate rocks

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The swelling of clay-sulfate rocks is a well-known problem in tunnel engineering where it poses a severe threat to important infrastructure. However, recently it was also encountered in an entirely different setting: The inaccurate implementation of geothermal installations in the town Staufen, Germany, led to water inflow into clay-sulfate rocks, resulting in heavy swelling. The swelling caused uplift rates of the ground surface exceeding 1 cm month-1, and severely damaged over 250 houses. The underlying processes of clay-sulfate rock swelling are complex and not yet sufficiently understood. In particular, hydraulic and geochemical processes in the zone of swelling are difficult to assess and the additional impact of constructional measures, such as borehole drilling, remains mostly unknown.

The transformation of anhydrite into gypsum as a result of water influx is considered to be the main mechanism contributing to the swelling process, leading to an increase in volume of up to 60 Additionally, reaction rates of anhydrite dissolution and gypsum precipitation at the field scale are to be compared with reaction rates determined in laboratory experiments.

This study investigates the significance of (1) the local geological setting, (2) hydrology and geochemistry of the swelling zone and (3) their modification upon human activities (drillings), as well as (4) the reaction kinetics of the anhydrite-gypsum-water system at the field scale. It incorporates 3D geological modelling, reactive transport modelling and model validation, with a focus on the reactive transport model. The models are based on the case study of Staufen, which provides an excellent data set for model development and comparison of the model results to the actual observed swelling processes in the field. Forward modelling with validation via iterative calibration is chosen as a methodological approach. The validated models represent the geological, hydrological and geochemical conditions which cause the swelling of the clay-sulfate rocks. They also quantify the reaction kinetics, characterizing the anhydrite dissolution and gypsum precipitation during the swelling process under field conditions.

In this contribution, the extensive datasets from the test site of town Staufen and their relevance for the individual model development steps are presented. They comprise geological, geophysical, hydrological, geochemical, geomechanical and geodetic information providing an excellent data basis. Furthermore, a conceptual overview of the methodology for the geological and reactive transport model, as well as model validation using the presented data, is outlined.

The expected results of the study will lead to a better understanding of the hydrological and geological processes that trigger the swelling of clay-sulfate rocks.