

Integrated hydrogeological and geochemical processes in swelling clay-sulfate rocks

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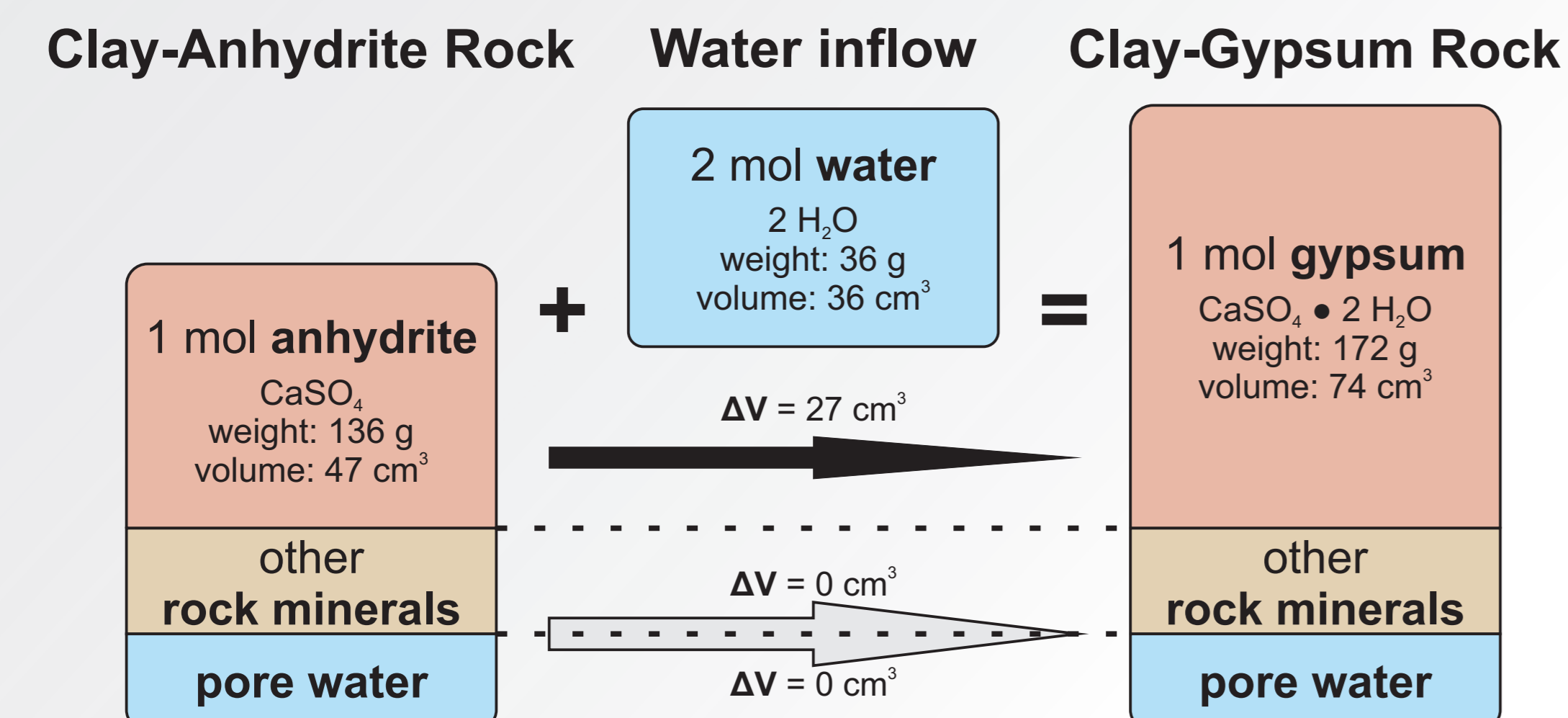
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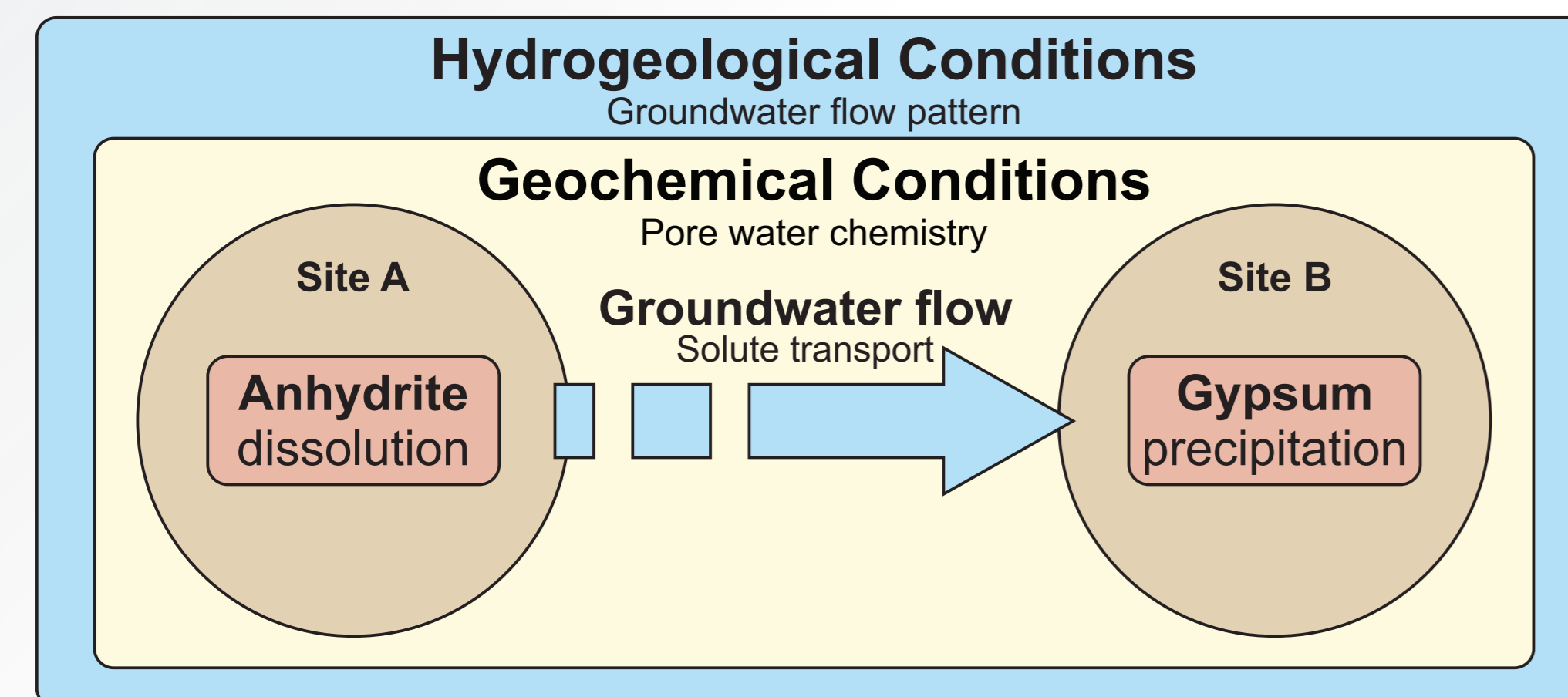
Staufen im Breisgau, damaged houses as a result of ground heave after thermal drillings.

① Background

The transformation of anhydrite into gypsum as a result of water influx is considered to be the main mechanism contributing to the swelling process of clay-sulfate rocks, leading to an increase in volume of up to 60 %.



Groundwater flow and its flow pattern together with geochemical conditions are key factors controlling dissolution and precipitation of sulfate minerals in clay-sulfate rocks, and thus swelling.



② Objectives

This study investigates the significance of:

- ▶ Local geological setting.
- ▶ Reaction kinetics of the anhydrite-gypsum-water system at the field scale.
- ▶ Hydrogeological and geochemical conditions of the swelling zone, and
- ▶ The effect of human activities (e.g. thermal drillings) on these conditions.

③ Hypothesis

- ▶ Swelling of clay-sulfate rock is mainly controlled by anhydrite dissolution and gypsum precipitation.
- ▶ Changes in hydraulic conditions by human activities can lead to geochemical changes in sulfate rocks, triggering swelling.
- ▶ Field scale swelling reaction rates may differ from those determined in the laboratory.
- ▶ A quantitative description of groundwater flow and reactive transport can explain and possibly predict the swelling phenomena.
- ▶ Numerical models for groundwater flow as well as reactive transport require an adequate geological site model.

④ Methods

Work packages

WP 1: 3D geological model GOCAD

- review of existing geological information
- interpretation, testing of different models

WP 2: Reactive transport model PHT3D (MODFLOW/MT3DMS coupled with PHREEQC-2)

- groundwater flow
- dissolved sulfate and heat transport
- geochemical reactions (kinetics)

WP 3: Model validation MODFLOW/MT3DMS, Abaqus CAE

- based on hydration heat
- based on geochemical strain

Forward modeling

WP 3: Iteration loop
(model adaption)

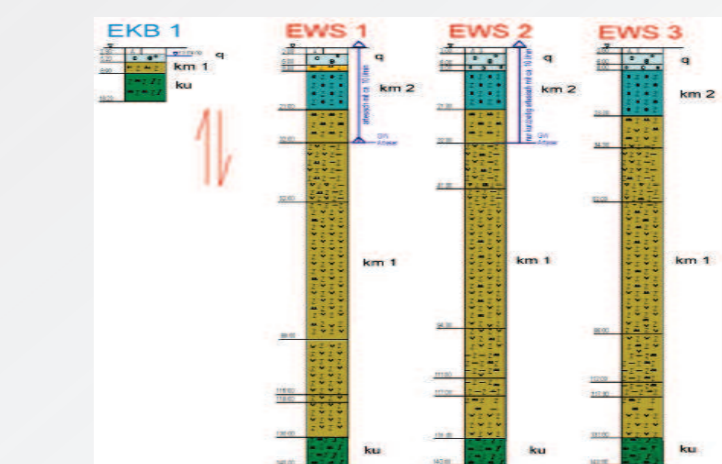
Forward modelling with validation via iterative calibration is chosen as a methodological approach. The validated models represent the geological, hydrological and geochemical conditions which cause the swelling of the clay-sulfate rocks. They also quantify the reaction kinetics, characterizing the anhydrite dissolution and gypsum precipitation during the swelling process under field conditions.

⑤ Input and Validation Data

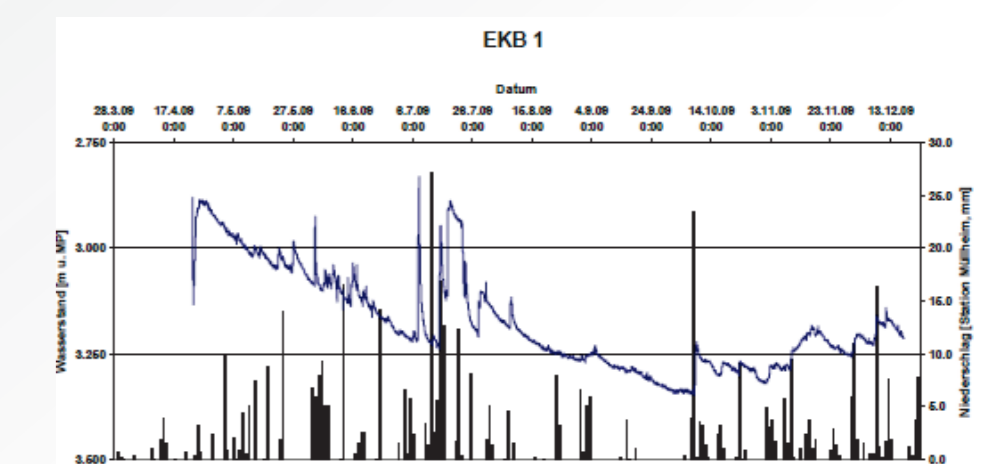
The models are based on the case study of Staufen, which provides an excellent data set for model development and comparison of the model results to the actual observed swelling processes in the field.



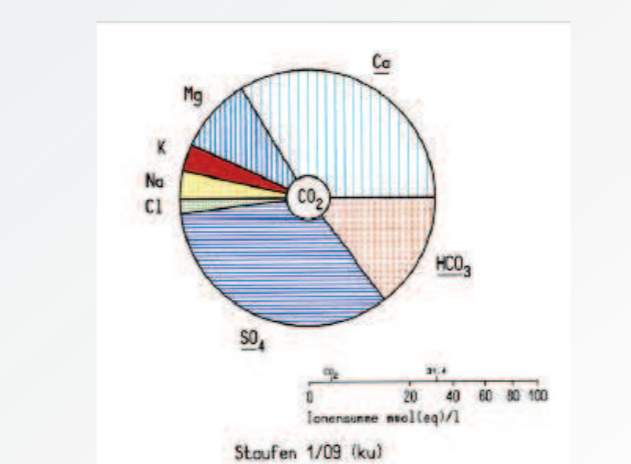
Geological map, Seismics



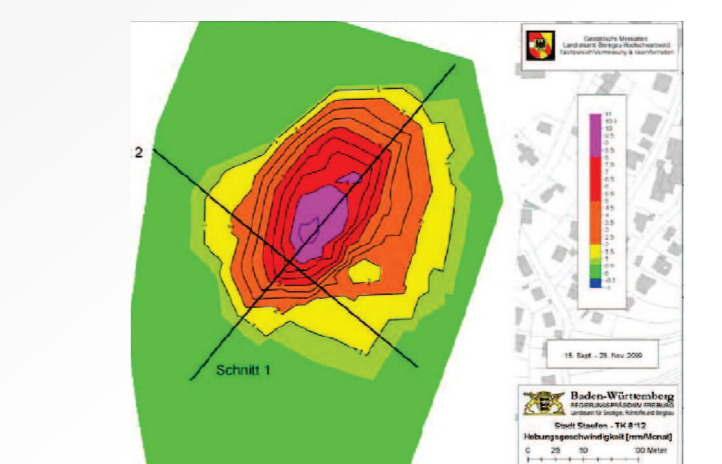
Exploration boreholes, geothermal drillings



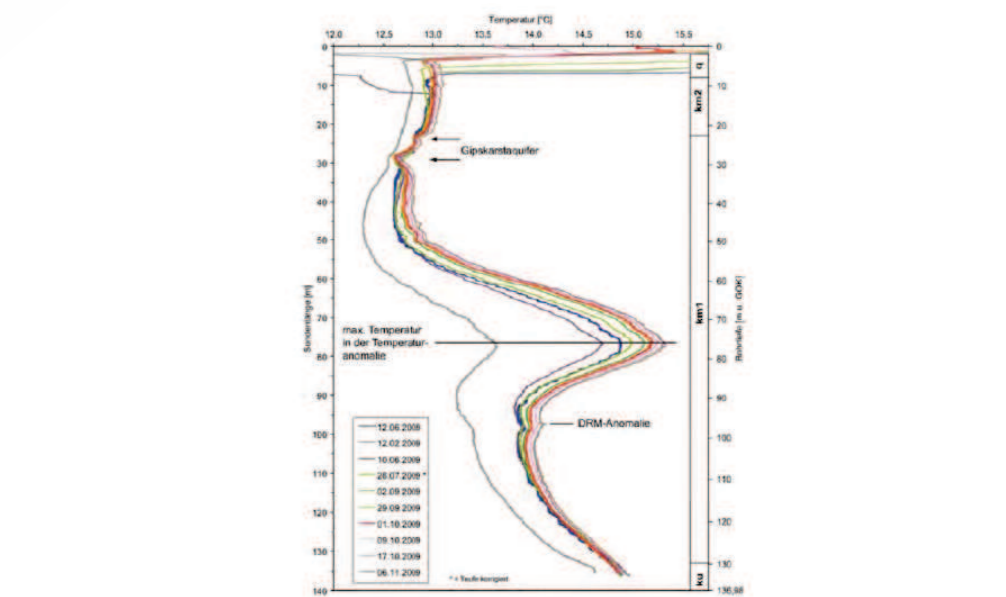
Hydraulics (transmissivities, head, pumping)



Geochemistry (concentrations and mineralogy)



Geodetic data (ground heave)



Temperature profiles of geothermal drillings

⑥ Outlook

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.

⑦ References

- ▶ LGRB, 2010. Geologische Untersuchungen von Baugrundhebungen im Bereich des Erdwärmesondenfeldes beim Rathaus in der historischen Altstadt von Staufen i. Br. Sachstandsbericht 01.03.2010, Landesamts für Geologie, Rohstoffe und Bergbau Baden-Württemberg (LGRB), Az.: 94-4763//10-563, Freiburg i. Br., 304 pp. Available at: <http://www.lgrb-bw.de/geothermie/staufen> (accessed 23.02.2015)
- ▶ LGRB, 2012. Zweiter Sachstandsbericht zu den seit dem 01.03.2010 erfolgten Untersuchungen im Bereich des Erdwärmesondenfeldes beim Rathaus in der historischen Altstadt von Staufen i. Br. Zweiter Sachstandsbericht 01.06.2012, Landesamts für Geologie, Rohstoffe und Bergbau Baden-Württemberg (LGRB), Az.: 94-4763//12-2487, Freiburg i. Br., 110 pp. Available at: <http://www.lgrb-bw.de/geothermie/staufen> (accessed 23.02.2015).