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Reactive transport modeling to quantify swelling of clay-sulfate rocks

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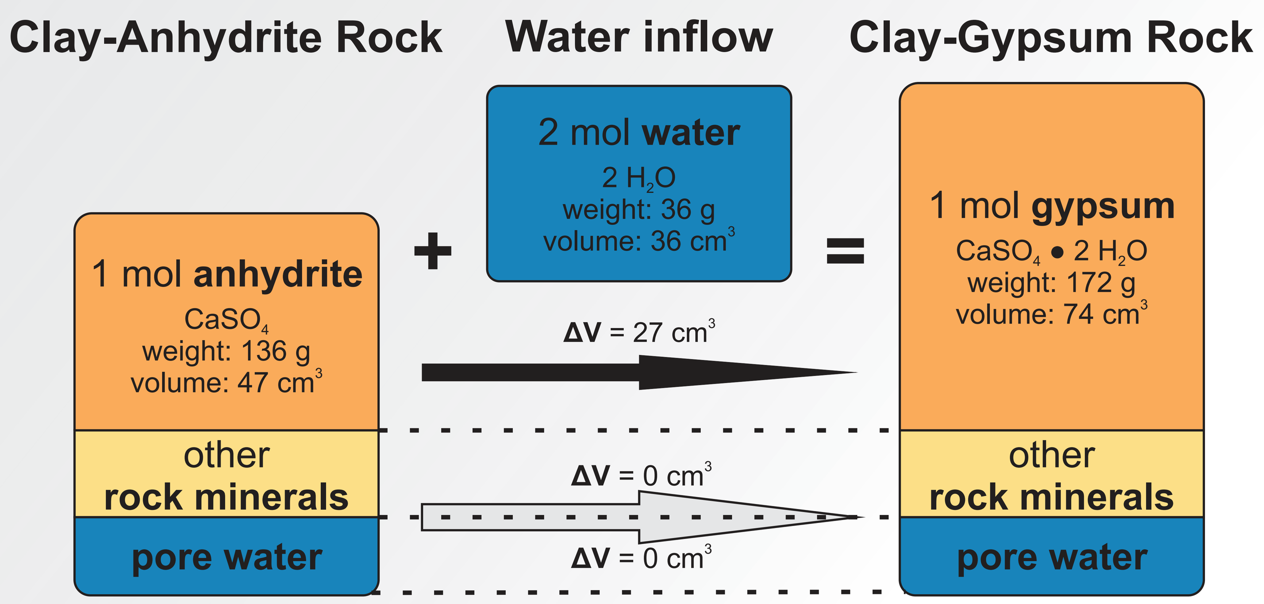
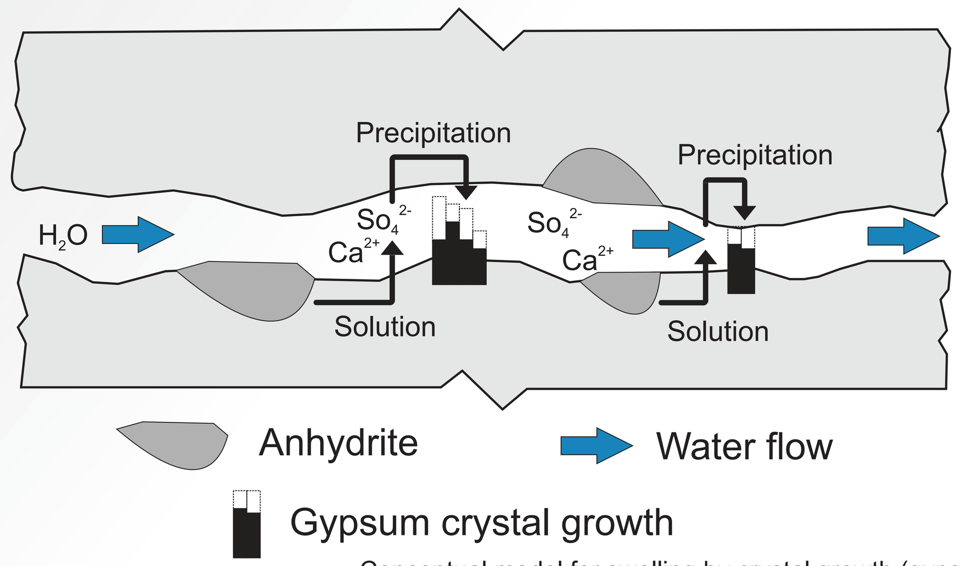
Staufen im Breisgrau, damaged houses as a result of ground heave after thermal drillings.

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.

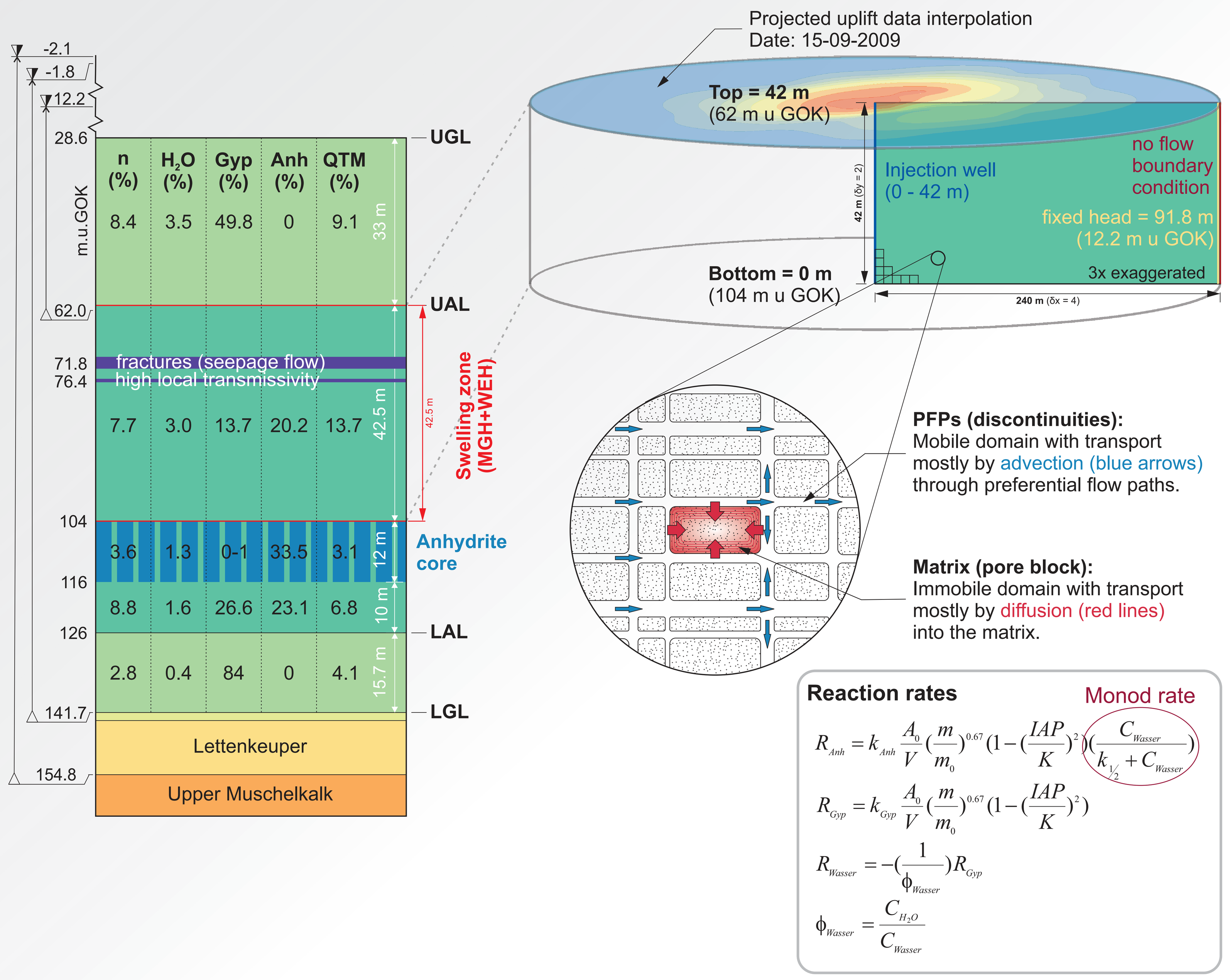


Conceptual model for swelling by crystal growth (gypsum precipitation) (from Alonso 2011; Ramon 2014, modified)

② Hypotheses

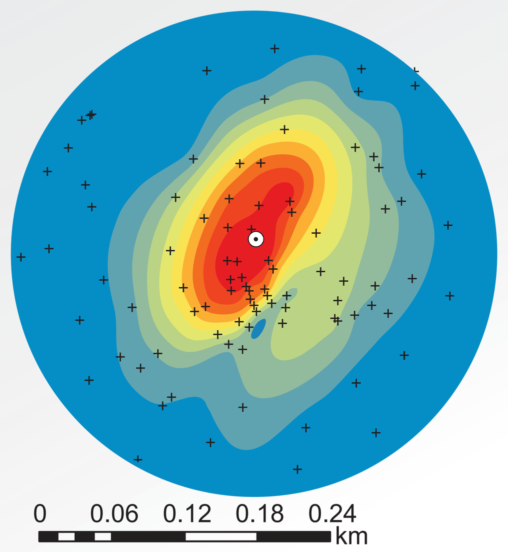
- Swelling of clay-sulfate rock is mainly controlled by anyhdrite dissolution and gypsum precipitation.
- Changes in hydraulic conditions by human activities can lead to geochemical changes in sulfate rocks, triggering swelling.
- Field scale swelling reaction rates may differ from those determined in the laboratory.
- A quantitative description of groundwater flow and reactive transport can explain and possibly predict the swelling phenomena.

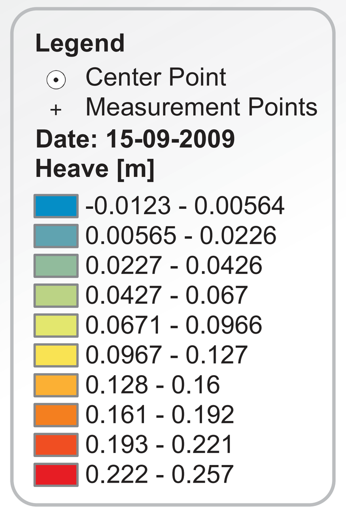
③ Reactive Transport Model

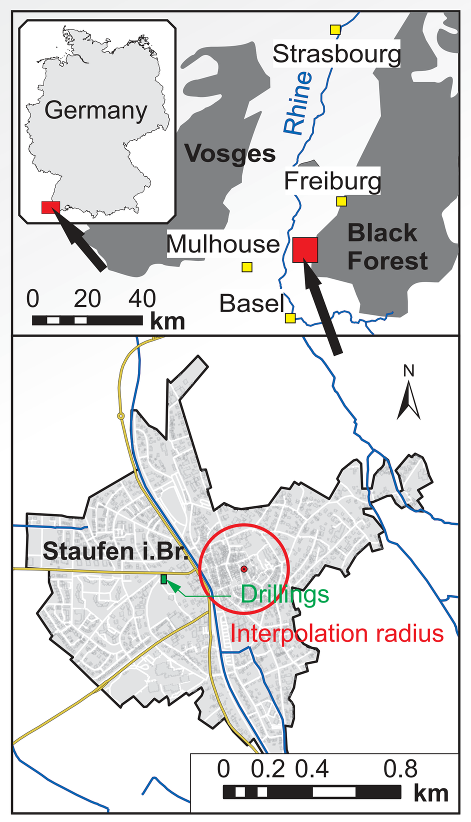


④ Geodetic Uplift Data

The model is calibrated against uplift data obtained from a dense network of geodetic measurement points on site.







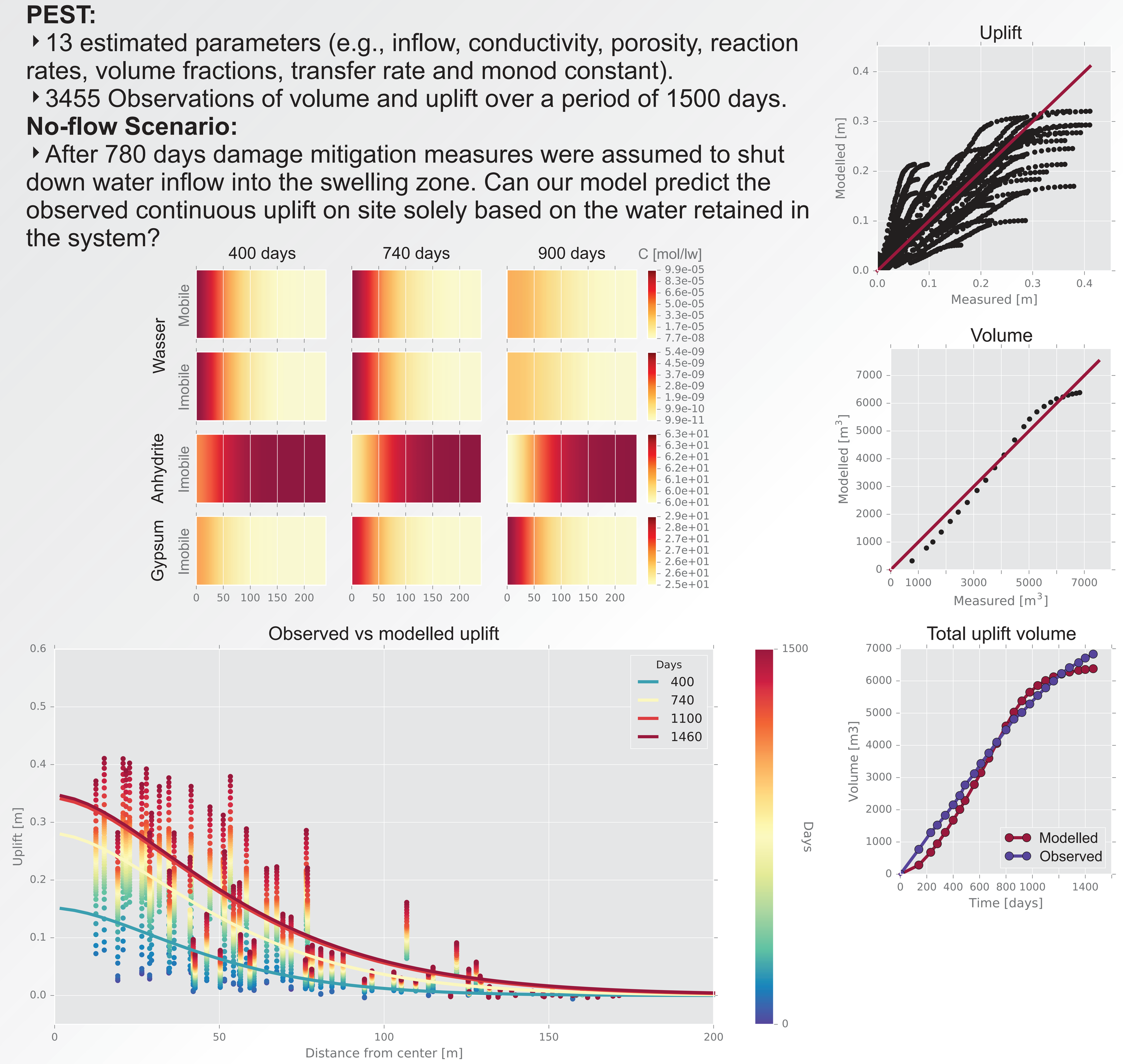
⑤ Parameter Estimation (PEST)

PEST:

- 13 estimated parameters (e.g., inflow, conductivity, porosity, reaction rates, volume fractions, transfer rate and monod constant).
- 3455 Observations of volume and uplift over a period of 1500 days.

No-flow Scenario:

- After 780 days damage mitigation measures were assumed to shut down water inflow into the swelling zone. Can our model predict the observed continuous uplift on site solely based on the water retained in the system?



⑥ Summary

- Preferential flow paths as well as the mass transfer between the mobile and immobile domains - and therefore water availability - impose a strong control on the magnitude and spatial extent of the simulated swelling process.
- A no-flow szenario underestimates uplift after mitigation measures.

⑦ References

- Alonso E.: Crystal growth and geotechnics, Paper presented at the Arrigo Croce Lecture, 15 Dec 2011, Rome, Italy, pp 46.
- Ramon A.: Expansion mechanisms in sulphated rocks and soils, PhD thesis, Universitat Politècnica de Catalunya, Barcelona, 2014.
- Butscher, C., Mutschler, T., and Blum, P.: Swelling of Clay-Sulfate Rocks: A Review of Processes and Controls, Rock Mech. Rock Eng., 49, 1533–1549, 2016.