Institute of Fluid Mechanics
and Environmental Physics
in Civil Engineering

MA/IP - Thermohaline convection next to salt domes - a sensitivity analysis of groundwater flow, heat and mass transport parameters

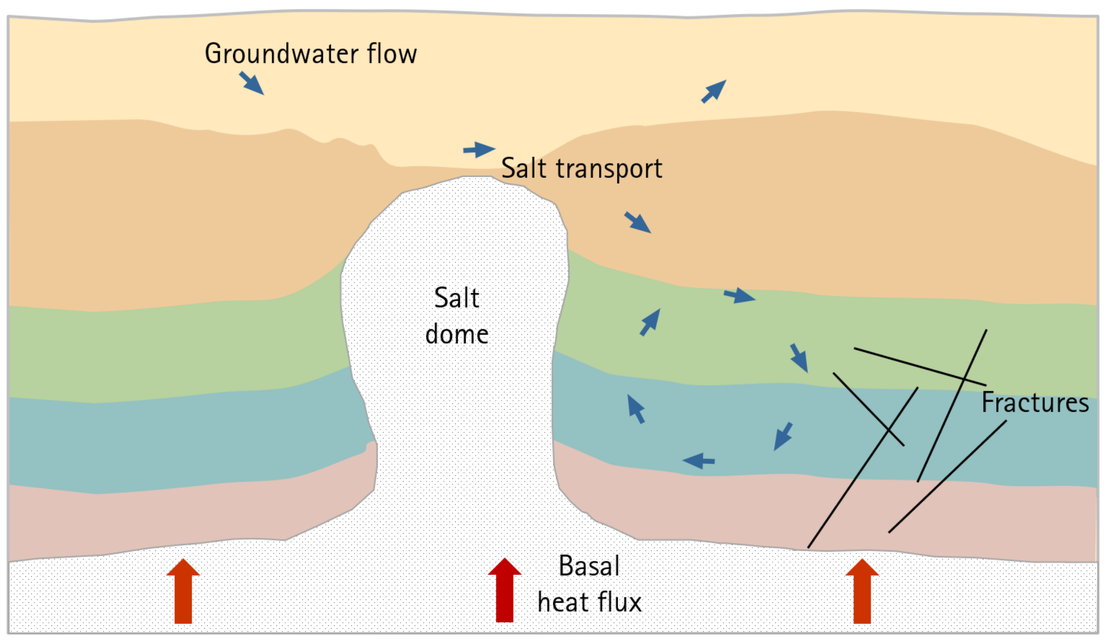
Examiner: Prof. Dr. Thomas Graf
Supervisor: Jonas Suilmann, M. Sc.

Background

Storing highly radioactive waste in deep geological formations is the best option for isolating it from the biosphere in the long term. In Germany and the USA, salt domes are being considered as host rock for these repositories. In the event of an accident, radionuclides could escape from the repository and be transported into the biosphere via the groundwater (see figure). For this reason, groundwater flow above and adjacent to salt domes is of particular relevance for repository safety assessments.
Groundwater flow in the vicinity of salt domes is predominantly driven by thermohaline convection, which results from density differences in the groundwater. These density variations are caused by differences in salinity and temperature and results in density-driven flow. While salinity differences lead to comparatively large changes in fluid density, temperature-induced density variations are relatively small. Temperature, on the other hand, has a much stronger influence on the flow due to the temperature-dependent viscosity of the water.

Task

In this study, a newly developed conceptual model of free thermohaline convection adjacent to salt domes will be systematically investigated using numerical simulations. The individual and combined effects of salinity and temperature in groundwater will be analyzed and compared. In a subsequent step, a global sensitivity analysis will be conducted for all relevant parameters (e.g., hydraulic conductivity, thermal conductivity) and boundary conditions (e.g., surface temperature, geothermal heat flux). Parameters identified as sensitive will then be examined in detail with regard to their influence on system behavior. The primary target variable is the migration of a conservative tracer, serving as a proxy for radionuclide transport from the salt dome. The sensitivity analysis will be based on an extensive literature review of realistic model parameters for the North German Basin, where salt domes considered for repository site selection are located.



Conceptual representation of the relevant processes for groundwater flow near salt domes

Objectives

- Understanding the existing model in FEFLOW for thermohaline convection
- Literature research on realistic model parameters in the North German Basin
- Investigation of convective groundwater flow by:
  a) only salt transport (with and without viscosity differences)
  b) only heat transport (with and without viscosity differences)
  b) combined salt and heat transport, thermohaline (with and without viscosity differences)
- Perform a global sensitivity analysis based on the literature review:
  a) Investigation of all relevant parameters in the realistic value range
  b) Investigation of various boundary conditions in the realistic value range
  c) Further investigation of the sensitive parameters and their resulting effects on the convective groundwater flow
- Evaluation and presentation of the results
- Discussion of the results

Software

- FEFLOW [1]

Useful Modules

If you have attended one of the following courses, this topic might be of particular interest to you:

- Flow and transport processes
- Numerical Methods in Fluid Mechanics

Additional information

The project is intended to be worked on continuously, with regular meetings with the supervisor to discuss interim results and address any questions. The thesis can be written in either English or German. If you are interested, we can arrange a personal meeting where I can explain the project and its objectives in more detail.

Contact

- suilmann@hydromech.uni-hannover.de

References

[1] H.-J. G. Diersch. *FEFLOW: Finite Element Modeling of Flow, Mass and Heat Transport in Porous and Fractured Media*. Springer Berlin Heidelberg, Berlin, Heidelberg, 2013. ISBN 978-3-642-38738-8. doi: 10.1007/978-3-642-38739-5.

[2] Z. Jamshidzadeh, F. T.-C. Tsai, H. Ghasemzadeh, S. A. Mirbagheri, M. T. Barzi, and J. S. Hanor. Dispersive thermohaline convection near salt domes: a case at napoleonville dome, southeast louisiana, usa. *Hydrogeology Journal*, 23(5):983–998, 2015. ISSN 1431-2174. doi: 10.1007/s10040-015-1251-4.

[3] F. Magri, U. Bayer, U. Maiwald, R. Otto, and C. Thomsen. Impact of transition zones, variable fluid viscosity and anthropogenic activities on coupled fluid–transport processes in a shallow salt–dome environment. *Geofluids*, 9(3):182–194, 2009. ISSN 1468-8115. doi: 10.1111/j.1468-8123.2009.00242.x.

[4] F. Magri, U. Bayer, A. Pekdeger, R. Otto, C. Thomsen, and U. Maiwald. Salty groundwater flow in the shallow and deep aquifer systems of the schleswig–holstein area (north german basin). *Tectonophysics*, 470(1-2):183–194, 2009. ISSN 00401951. doi: 10.1016/j.tecto.2008.04.019.