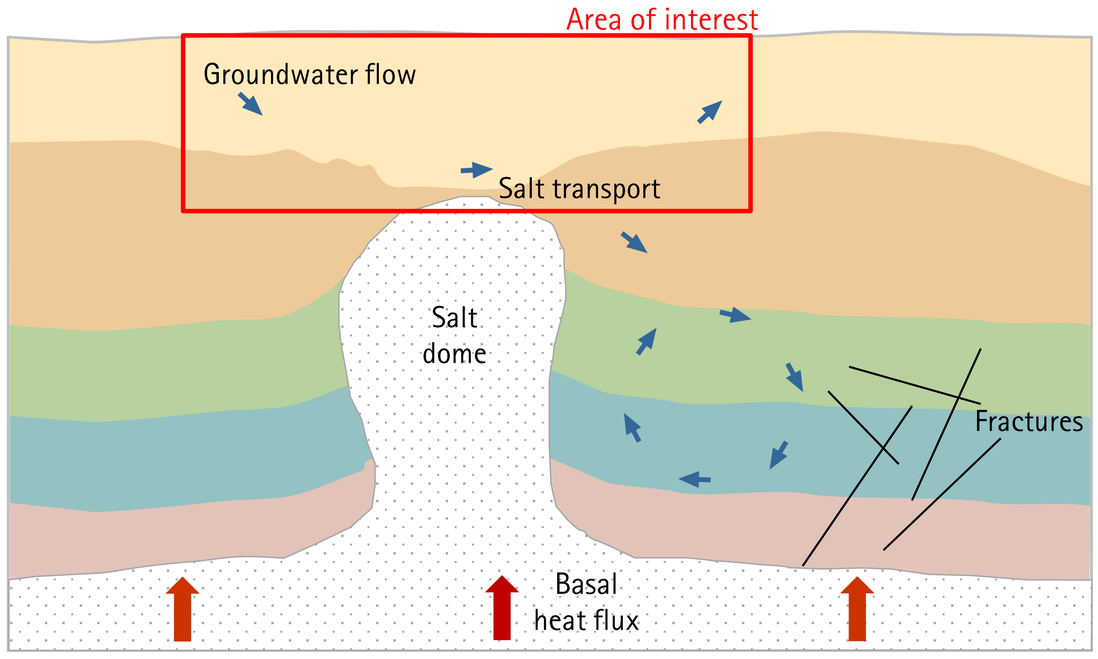
Institute of Fluid Mechanics
and Environmental Physics
in Civil Engineering

IP/MA/BA - Numerical investigation of 3D coupled groundwater flow and transport above a salt dome

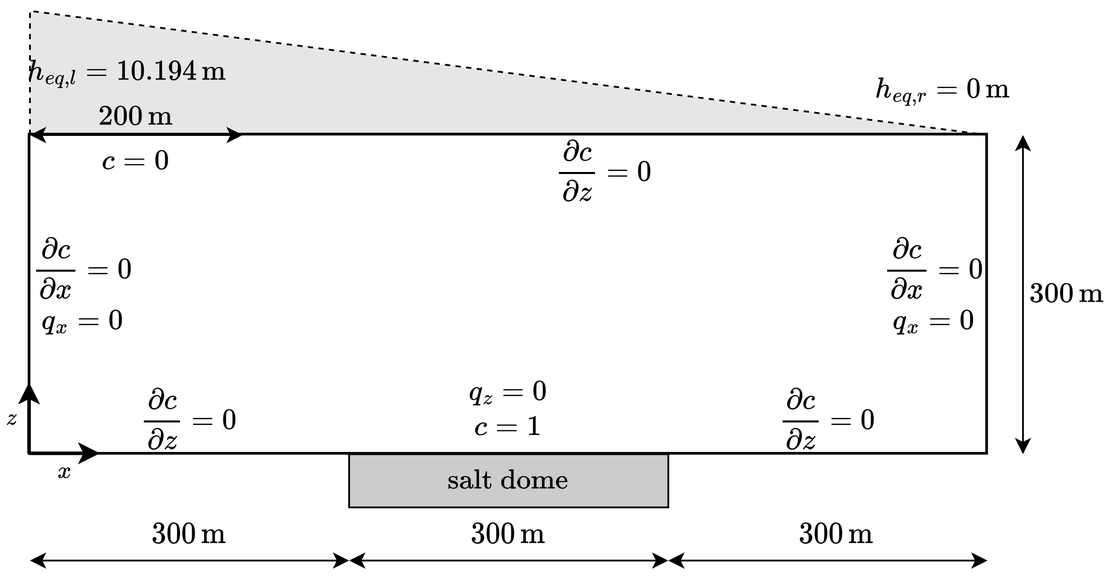
Examiner: Prof. Dr. Thomas Graf
Supervisor: M. Sc. Jonas Suilmann

Motivation

Storing high-level nuclear 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 considered as host rocks for these repositories [5]. In case of accidental hazardous events, radionuclides may escape the repository and be transported into the biosphere via groundwater (see upper figure). Therefore, the groundwater movement above those salt dome structures is of particular interest for the safety assessment of repositories. The groundwater flow above a salt dome is affected by the dissolution of the salt into the groundwater, which changes the density of the water and therefore influences its flow. This phenomenon, known as density-dependent flow, has been studied using a simplified 2D conceptual model of groundwater flow coupled with salt transport above a salt dome [4]. This led to the development of the "Salt dome problem" (see conceptional model in the lower figure) [2] [6]. In this work, the 2D salt dome problem shall be extended to a 3D problem to obtain a more realistic representation of the density-dependent flow above salt domes. The problem shall be simulated using the Finite-Element code Saltflow [3].



Conceptional representation of relevant processes in groundwater flow around salt domes



Conceptional model of the salt dome problem (adapted from [2] and [1])

Main Goals

- Literature research on density-dependent flow above salt domes
- Representation of numerically solved governing equations
- Conception of a 3D salt dome problem including:
  a) length of model in 3^{rd} dimension
  b) appropriate boundary conditions
  b) 3D spatial discretization of model domain
- Conceptualizing and simulation of
  a) different model scenarios of flow boundary conditions
  b) different transport parameter scenarios
- Evaluation and presentation of results
- Discussion of results

Software

- Saltflow [1]

Benefecial courses

If you have taken some of these courses, this topic might be a good fit for you

- Flow and Transport Processes
- Numerical Methods in Fluid Mechanics

Additional Information

This work is intended as an Interdisciplinary Project, but the extent could also be adapted for a Bachelor's thesis or a Master's thesis. For the most part, the project should be worked on continuously, with regular meetings with the supervisor where preliminary results can be discussed and questions can be asked. The thesis can be written in English or German.

Kontakt

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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] A. W. Herbert, C. P. Jackson, and D. A. Lever. Coupled groundwater flow and solute transport with fluid density strongly dependent upon concentration. *Water Resources Research*, 24(10):1781–1795, 1988. ISSN 00431397. doi: 10.1029/WR024i010p01781.

[3] J. W. Molson and E. O. Frind. Saltflow user guide - version 5.0: Density-dependent flow and mass or age transport model in three dimensions. *Université Laval & University of Waterloo*, 2023.

[4] OECD. The international hydrocoin project: Groundwater hydrology modelling strategies for performance assessment of nuclear waste disposal. level 1: Code verification.

[5] M. I. Ojovan and H. J. Steinmetz. Approaches to disposal of nuclear waste. *Energies*, 15(20):7804, 2022. doi: 10.3390/en15207804.

[6] A. Younes, P. Ackerer, and R. Mose. Modeling variable density flow and solute transport in porous medium: 2. re-evaluation of the salt dome flow problem. *Transport in Porous Media*, 35(3):375–394, 1999. ISSN 0169-3913. doi: 10.1023/A:1006504326005.