Numerical investigation of thermohaline convection in fractured-porous media near salt domes: the fractured salt chimney problem

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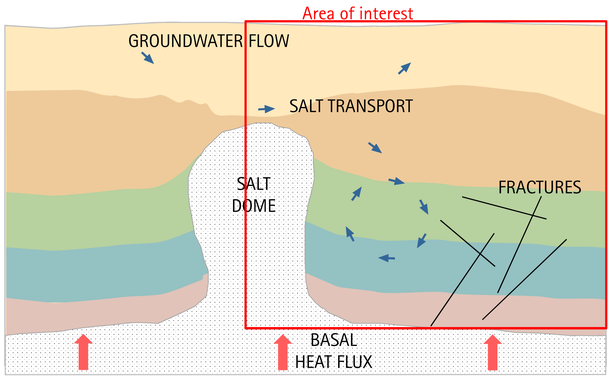
Abstract

Motivation



- Salt domes considered for **deep geological repositories** of high-level nuclear waste
- Potential transport of accidentally leaking radionuclides via groundwater
- Temperature and salinity effects lead to **thermohaline convection** in groundwater

Research Objective

Numerically investigate and understand effects of **fracture distribution** and **fracture density** on thermohaline convection and radionuclide transport near a salt dome.

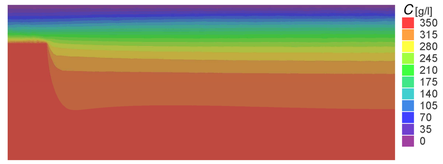
Results

Unfractured Base Case

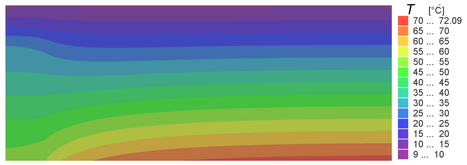
t = 1 M years

Steady state:

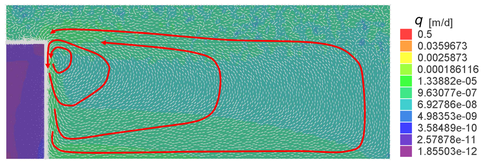
Salt concentration



Temperature

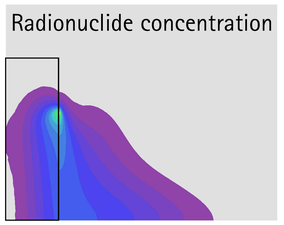


Darcy flux

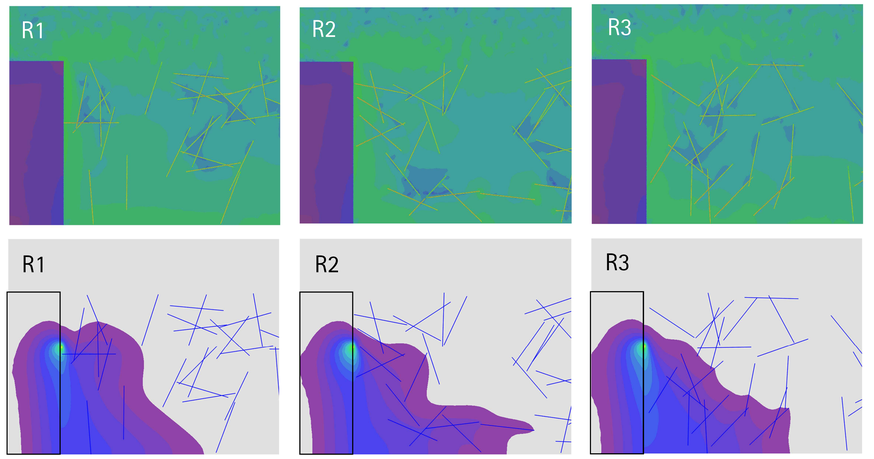


Darcy flux

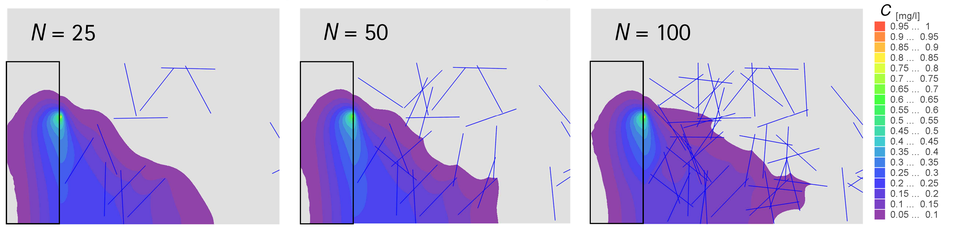
Radionuclide concentration



Effect of fracture distribution (N = 50, L = 500 m), t = 1 M years



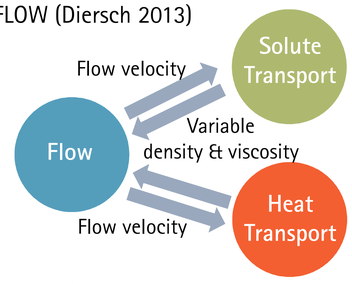
Effect of fracture density (L = 500 m), t = 1 M years



Methodology

Numerical model

- FEM code FEFLOW (Diersch 2013)



- Strongly coupled variable density & viscosity flow simulations
- Parallel plate fractures in single continuum using cubic law for hydraulic conductivity
- Radionuclide Transport (conservative & without decay)

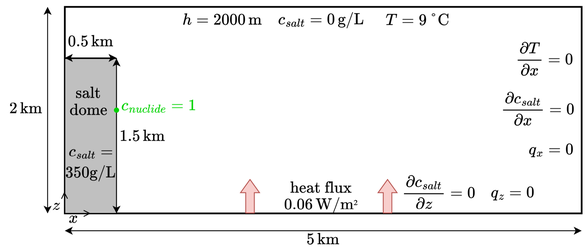
Model parameter

Fracture aperture	500 µm
Fracture length	500 m
Permeability	1e-15 m^2
Permeability salt	1e-22 m^2
Freshwater density	999.7 kg/m^3
Max. brine density	1210 kg/m^3
Thermal conductivity solid	2.3 W/m/°C
Thermal conductivity salt	6 W/m/°C

Fluid density: linear dependence on C, nonlinear on T

Fluid viscosity: nonlinear dependence on C and T

Model domain



Fractures

- Fracture position & angle are randomly generated
- Fracture density scenarios: Networks are iteratively built, starting with N = 25 and adding random fractures to reach N = 50 and N = 100
- Mesh is refined near fractures

Summary & Conclusion

- Thermohaline convection is disturbed by fracture networks and velocities in fractures are increased
- Fractures orthogonal to flow inhibit transport of radionuclide plume, while fractures in flow direction act as preferential flow paths and increase transport distance from source
- Transport distance from source is highly dependent on fracture distribution
- Higher fracture density favors propagation of the radionuclide plume

Results highlight the **importance of fracture networks on thermohaline convection and plume transport** near salt domes.

Outlook: Further investigation of fracture distribution, density, length, aperture, and orientation. Investigation of heat-generating radioactive waste effect.

This project is part of the research cluster "Uncertainties and Robustness with regard to the safety of a repository for high-level radioactive waste (URS)" funded by the Bundesgesellschaft für Endlagerung (BGE).
For more information, scan:

References: Diersch H-JG (2013) FEFLOW: Finite Element Modeling of Flow, Mass and Heat Transport in Porous and Fractured Media. Springer Berlin Heidelberg, Berlin, Heidelberg