Radionuclide Transport on the Host-Rock Scale: Coupled Physics and Safety Assessment

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The Site-Selection Procedure in Germany

Aim: Finding the site with the best possible safety for a deep geological repository for high-level nuclear waste in Germany considering clay-, salt-, and crystalline rock

Challenges:

• Three host-rock types with vastly different physical and geochemical attributes

• During the initial phase only existing subsurface data will be used for the site selection process implying that existing uncertainties should be addressed

Approach for the APaRat-project:

• Once candidate sites are identified, coupled thermo-hydro-mechanical-chemical models will play an important role including parametric uncertainty

Motivation of the APaRat-Project

• Assessing the influence of parametric uncertainty on radionuclide transport considering the impact of coupled thermo-hydro-mechanical (THM) processes for all three host rock types

• Far-Field-Perspective: Decisive indicator is the potential radionuclide release from the containment-providing rock zone

• Evaluation of radionuclide release under "what-if"-scenarios like the opening of a fracture close to the engineered repository

• For each host rock type specific evolutions will be identified and modelled, which are relevant for radionuclide release reflecting the time span of one million years

• Dimensionality reduction from 3D to 2D to facilitate multiple model runs

• Parametric uncertainty should be quantified via sensitivity analysis on vertical cross-sections

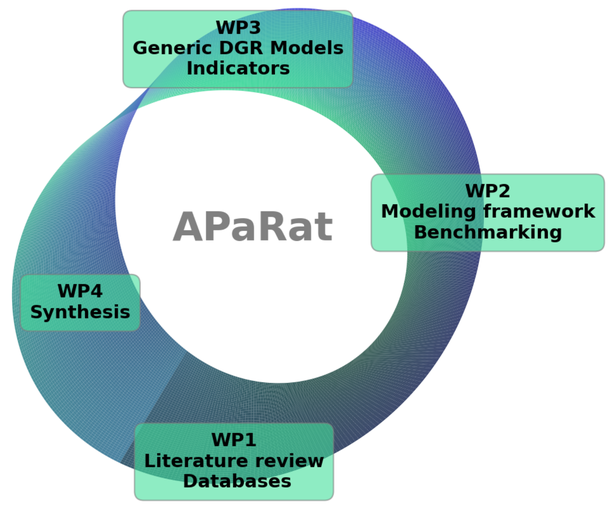

Fig. 1: Work packages of the APaRat-project

Modelling Methodology

THMC-Modelling with OpenGeoSys:

• OpenGeoSys (OGS) is used as simulation platform for solving coupled physical processes

• Monolithically coupled simulations of heat transport (T), variable-density fluid flow (H), and solid mechanics (M) are used for computing the Darcy velocity via the THM-process

• The Darcy velocity from THM is used for coupled flow (H) and solute transport (C) simulations in a unidirectional coupling

• As such, the numerics and model setups for THM and HC can be fine-tuned individually

⟶ We use the P1 Galerkin FEM for THM and a flux-corrected transport FEM after Kuzmin (2009) for solute transport

⟶ Thereby, the effects of coupled physics on solute transport can be evaluated

Python-based workflows:

• Python-based workflows are used for script-based model setup, execution and postprocessing as well as for parameter variations (Lehmann et al. 2024)

•They guarantee reproducibility, operability, and automated evaluations

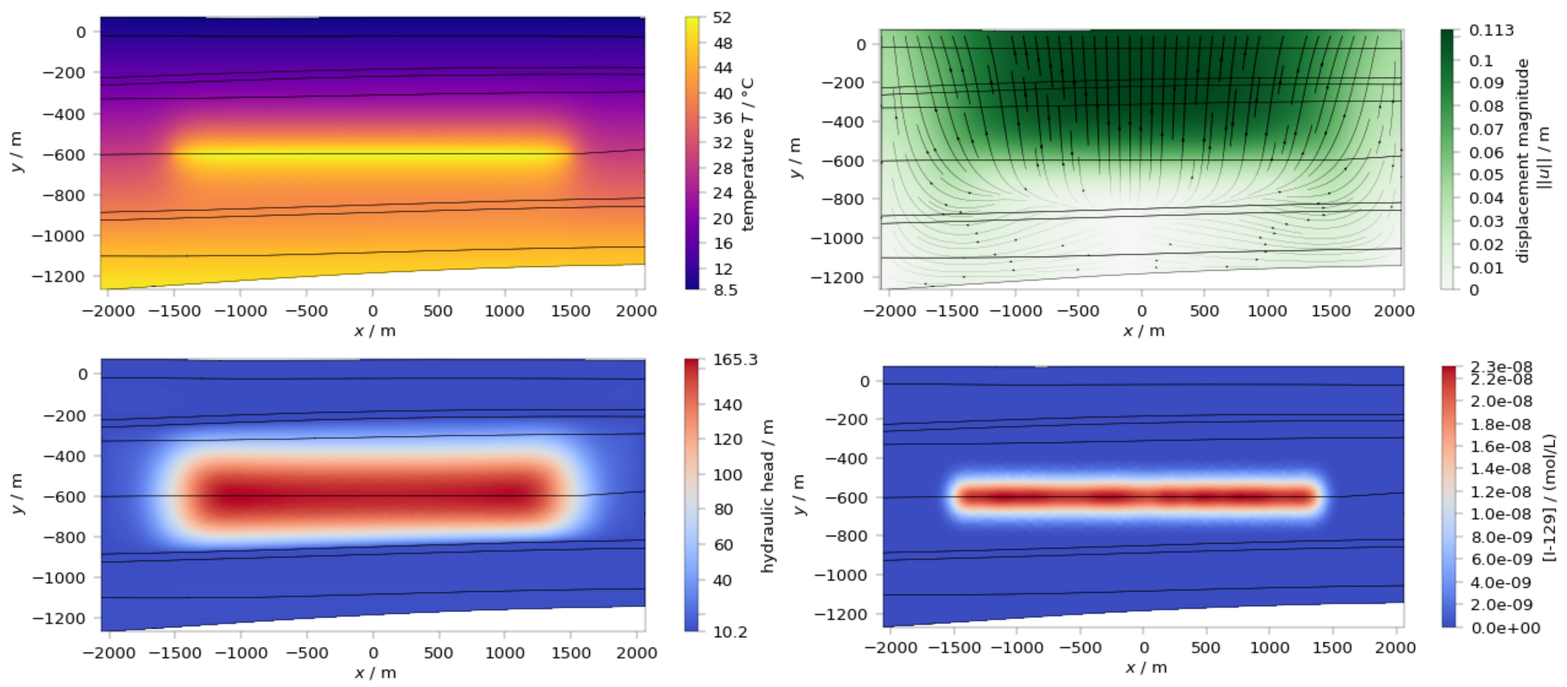

Fig. 2: Example results for ongoing methodological developments reflecting simulated primary unknowns (i.e., temperature, displacement, and liquid-phase pressure converted to hydraulic head) from the THM-model (at t=400 a), where fluid pressure is converted to hydraulic head including a variable water density and solute transport of the iodine inventory (at = 1e6 a) according to the inventory of GRS-A-3985

OpenGeoSys workflows

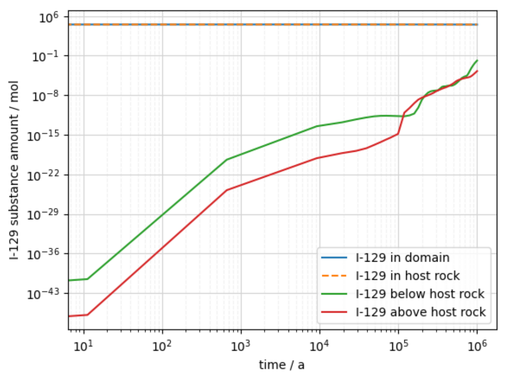

Fig. 3: Exemplary evaluation of I-129 substance amount release from the host rock cumulated over time

Expected Outcomes

• Identification of THM-effects originating from the repository itself acting on the host rock and influencing radionuclide transport

• Quantitative evaluation of the effect of parametric uncertainties on radionuclide transport considering the specifics of the three different host rock types including host-rock-specific potential evolutions over one million years

• Analysis with regard to the requirements defined in EndlSiAnfV § 4 (5) considering radionuclide release from a containment-providing rock zone

• Establishment of a systematic methodology, workflow, and benchmarks to contribute to the scientific basis for the safety assessment of candidate sites within the German site-selection procedure

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