Probabilistic integrity analyses for a generic high-level radioactive waste repository

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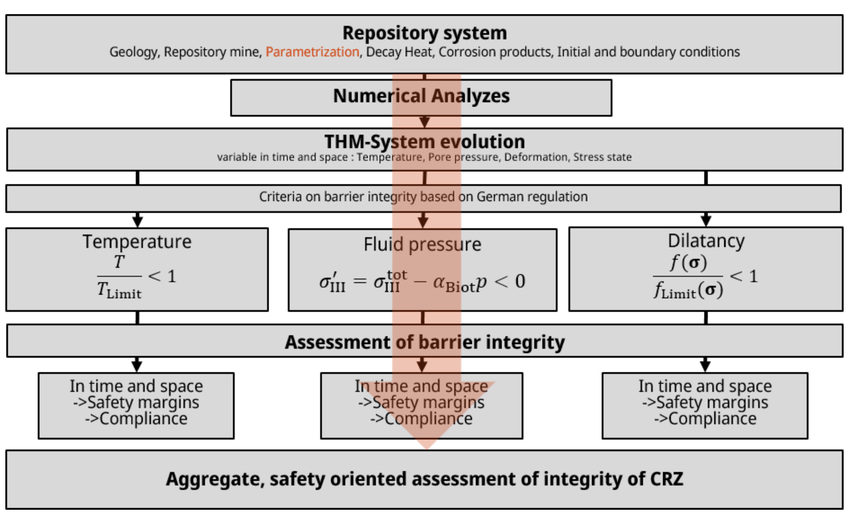
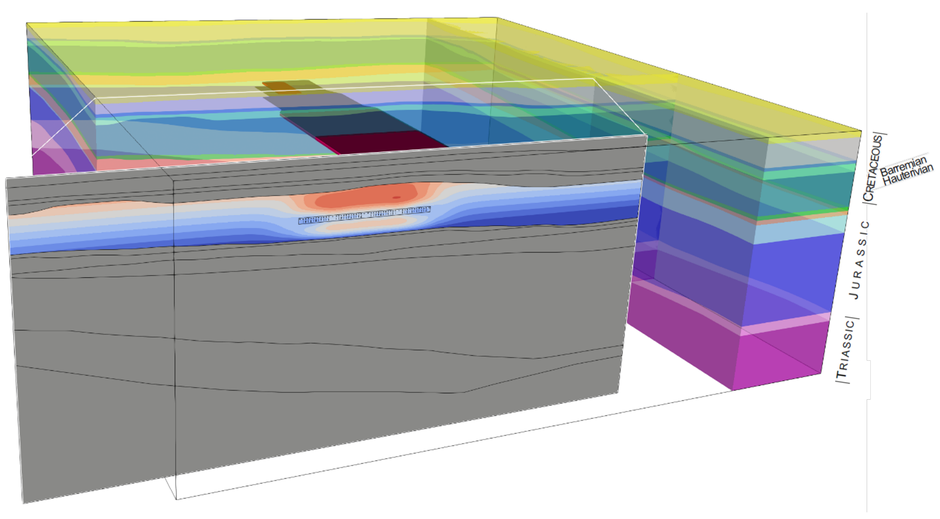
Computational integrity analyses

- Assessment of barrier properties of the host rock under thermo-hydro-mechanical (THM) loading by high-level waste repository.
- THM-coupled simulations using OpenGeoSys [1].
- Quantification of impact of uncertainties in input parameters.



Concept of numerical integrity assessment.

- For repository systems in clay rock, a modeling and assessment methodology has been proposed in the ANSICHT projects [2, 3].
- Demonstration for a generic repository system in Lower Cretaceous clay rock in Northern Germany.
- Focus on tensile failure due to temperature-induced pressure build-up.

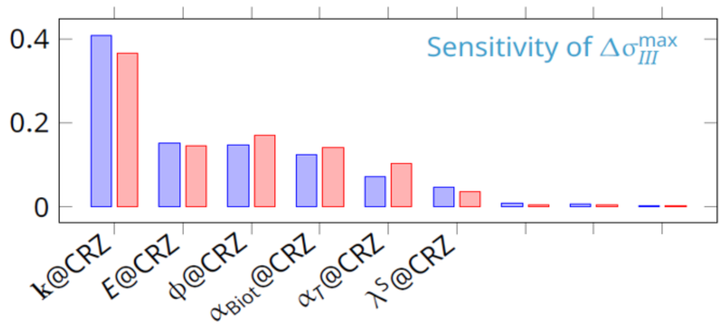


Generic geological model "ANSICHT-NORD" with repository and numerical evaluation results of the fluid pressure criterion in the host rock at a 2D-cross section.

Multi-stage stochastic analysis

Stage 1: Global sensitivity screening

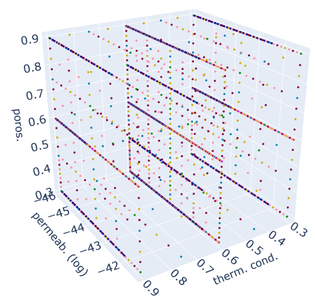
- Screening of all THM model parameters of the 11 geological layers – in total 101 parameters – by impact on failure criterion.
- Uniform distribution on parameter ranges based on a literature review.
- Sobol and Morris screening indicate set of parameters with highest impact.



Sensitivity indicators computed from Morris Screening and Sobol indices.

Stage 2: High-fidelity surrogate model for THM-evolution

- Training of a moderate dimensional sparse grid surrogate for the THM response.
- By adaptive refinements, computationally expensive simulation calls are minimized [4].
- Provides very efficient interpolation of entire finite element time series results [5].



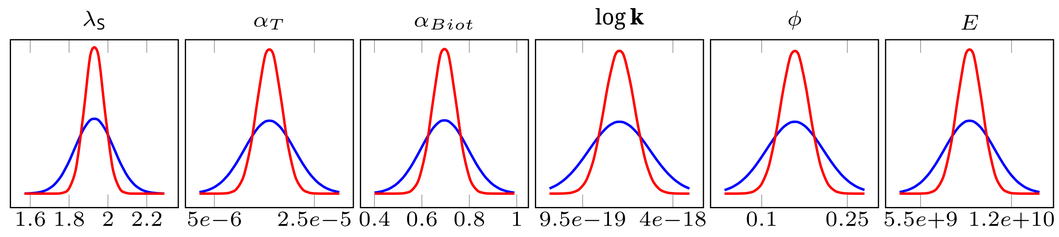
Sampling of a surrogate model.

Project partners

This work developed in the MEQUR project part of the BGE-funded URS research cluster.

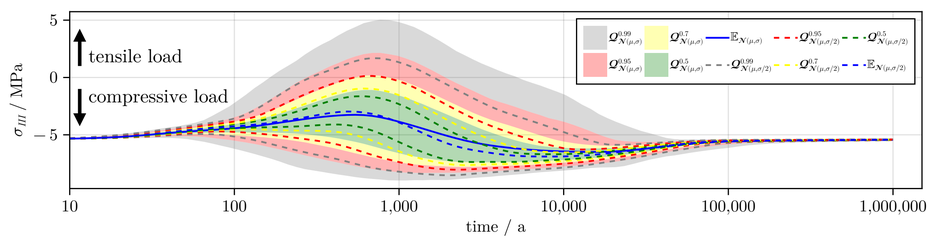
Stochastic evaluation of failure criterion

- Statistical evaluation of THM-quantities and integrity criteria over time and space.
- Monte-Carlo integration of parameter space for condensation of high-dimensional results.
- Different assumptions on input parameter distributions based on literature.



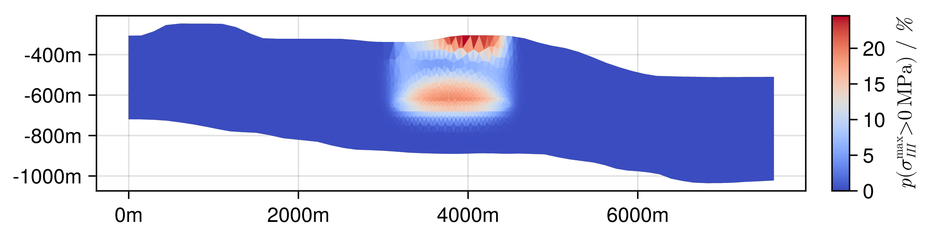
Different assumptions on input parameter distributions

⇒ Quantiles and probabilities of criteria acceptance under given input uncertainty:

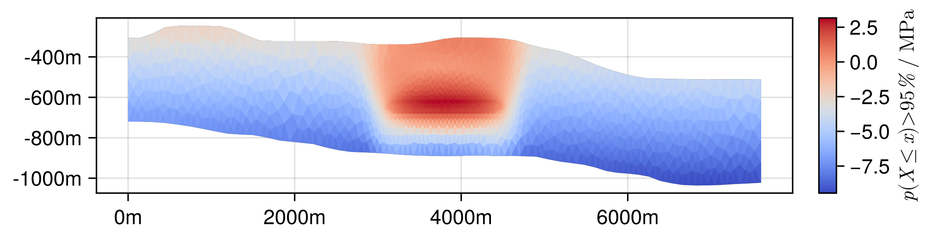


Empirical confidence intervals for evolution of tensile failure criterion at one point 70 m above the repository. Assumption of less parameter uncertainty significantly reduces output uncertainty.

⇒ Spatial evaluation of failure criterion:



Spatial distribution of probility of ocurrence of tensile stress state during assessment period.



Spatial distribution of the 95% percentile for maximal tensile stress.

Conclusions

- Multi stage methodology to assess impact of uncertain parameters.
- Uncertain input parameters impact stress-based failure criteria.
- Influence of initial stress level to be considered in complementary studies.
- Tool set published and available as julia package [6].

References

[1] L. Bilke et al. *OpenGeoSys*. Version 6.4.3. Apr. 2022. DOI: 10.5281/zenodo.7092676. URL: https://doi.org/10.5281/zenodo.7092676.

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