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SNETP Forum

High fidelity numerical simulations of strongly coupled processes for repository systems

HERMES

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Introduction: Safe geological disposal of radioactive waste employs a combination of engineered and natural barriers representing a so-called passive multiple barrier concept. Due to the complexity of the repository systems and the extremely long time-periods involved (Figure 1), the assessment of the repository safety relies on model-based descriptions and simulations of possible repository evolution scenarios. Thermo-Hydro-Mechanical-Chemical (THMC) process-based numerical simulations are, thus, the basis for in-depth system understanding and analysis of experimental observations [1].

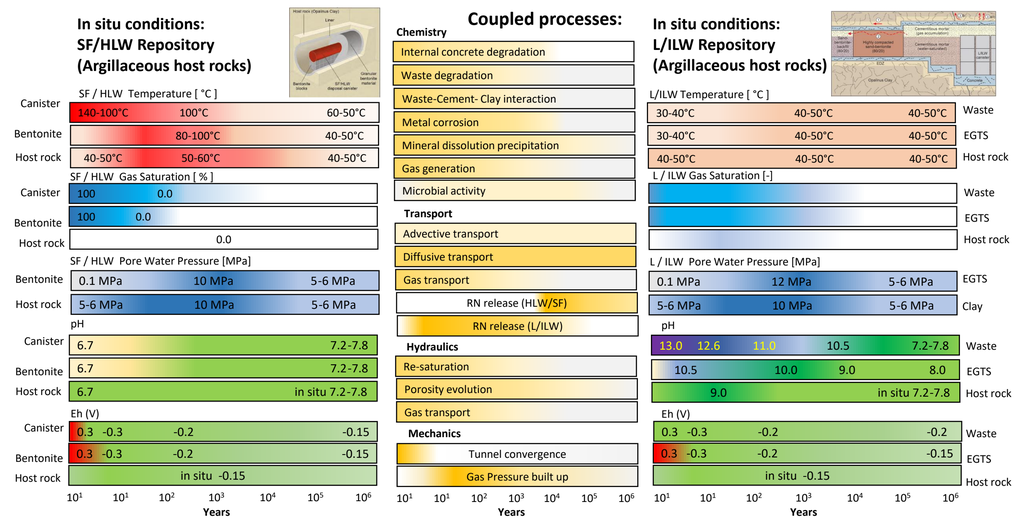

Figure 1: Coupled processes in repository near field and their temporal extent relevant to the repository safety.

Research Aims: Recent developments in the field of data sciences and computational efficiency of surrogate models open new opportunities for developing efficient coupled numerical models (Digital Twins) for real-time numerical analysis of laboratory and field experiments, repository design, components optimization and comprehensive safety analysis [2]. The Work Package-HERMES implemented within the EURAD-II project aims at the development of open-access tools for simulation of strongly coupled THMC Features Events and Processes in repository systems (near-field and host rocks). The developed modelling tools, benchmarks and validation datasets will be made available through Model-Hub to support collaboration between modelling teams, provide an interface with experimenters and make the knowledge from the WP-HERMES available to the broader scientific community. Conceptualization of data and model hub is illustrated in Figure 2.

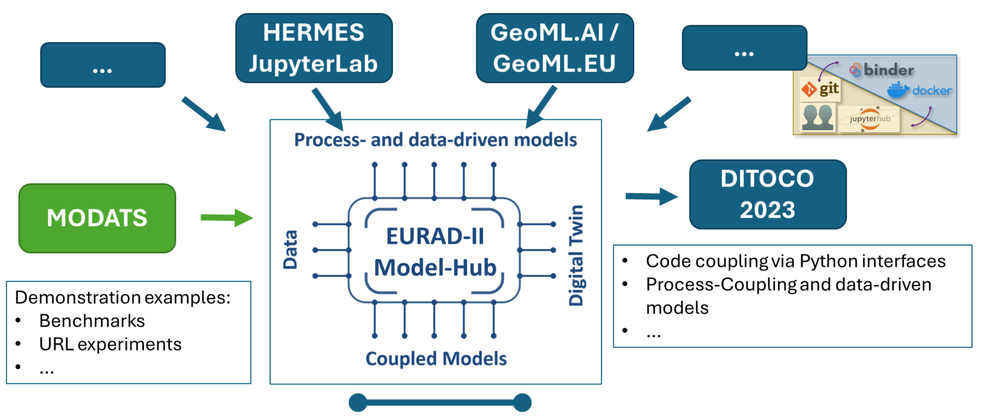

Figure 2: Conceptualization of data and models hub.

Project management:
Project is contributed by 35 research partners from 10 European countries and several contributors from associated states Figure 3. The project comprise 2 administrative and 3 RD&D tasks.

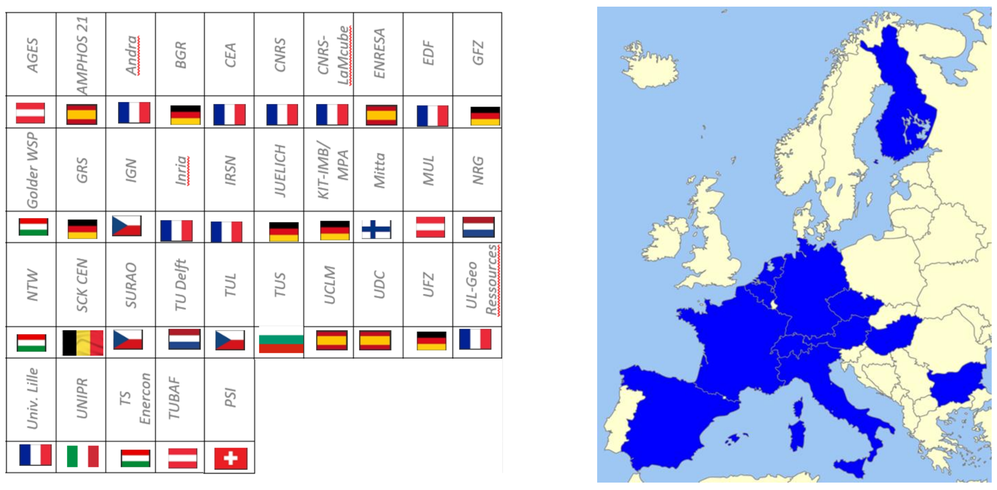

Figure 3: Project partners contribution to HERMES project.

Task 1: Management & coordination of the WP
Task 2: Knowledge Management
- Model and Data hub

Task 3: THMC-Process couplings and computational performance
- Model development and benchmarking of coupled models
- Inverse modelling, sensitivity analysis and upscaling

Task 4: Surrogate models of individual phenomena
- Acceleration of computations for individual processes
- Surrogate models for coupled processes and multi-physics

Task 5: Tailored models for SA/PA and field scale mock-ups
- Real time simulation of field-scale experiments
- High fidelity models for repository near field simulations

Project envisage a close collaboration with WP-DITOCO on the conceptualization of repository digital twins (Figure 4).

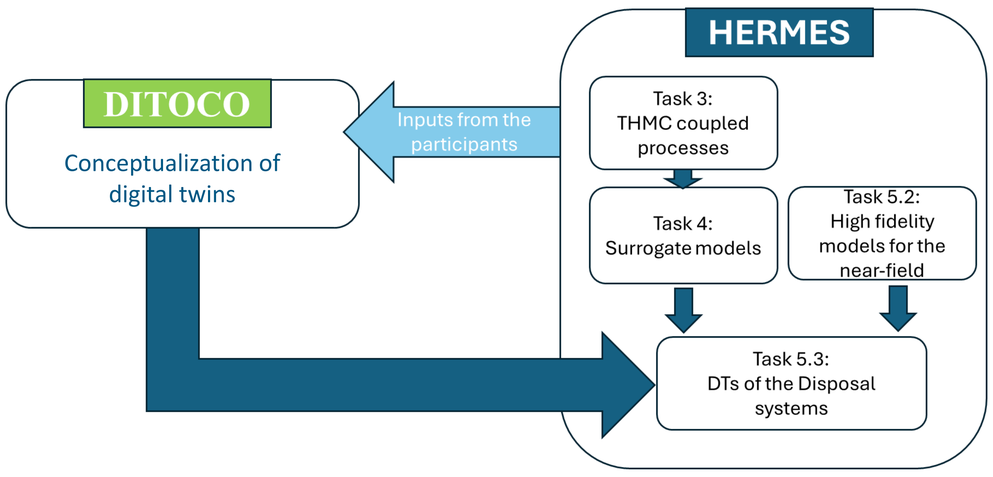

Figure 4: Project organization interaction with other WPs.

References
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[3] Prasianakis N.I., Laloy E., Jacques D., Meeussen J.C.L., Miron G.D., Kulik D.A., Idiart A., Demirer E., Coene E., Cochepin B., Leconte M., Savino M.E., Samper-Pilar J., De Lucia M., Churakov S.V., Kolditz O., Yang C., Samper J., Claret F. (2025) Geochemistry and machine learning: methods and benchmarking. Environmental Earth Sciences, 84:121. doi:10.1007/s12665-024-12066-3

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