EGU23-14784

EGU General Assembly 2023

Numerical modelling of high-temperature aquifer thermal energy storage (HT-ATES) in the Upper Jurassic reservoir of the German Molasse Basin

Technical University of Munich

Kalliopi Tzoufka[1], Daniela Pfrang[1], Daniel Bohnsack[2,3], and Kai Zosseder[1]

[1]Technical University of Munich, Department of Civil and Environmental Engineering, Geothermal Energy Group, [2]Technical University of Munich, Department of Civil and Environmental Engineering, Professorship of Geothermal Technologies, [3]SWM Stadtwerke München

1. Intoduction

HT-ATES concepts are currently considered for geothermal heat storage in the Upper Jurassic Reservoir (Malm) of the German Molasse Basin. This North Alpine Foreland Basin comprises a site of extensive implementation of geothermal projects. Nevertheless, the suitability of the Upper Jurassic aquifer for storage of high-temperature fluids has not been yet considerably investigated. Here, we present our initial approach to assess the suitability of this reservoir for the development of HT-ATES systems.

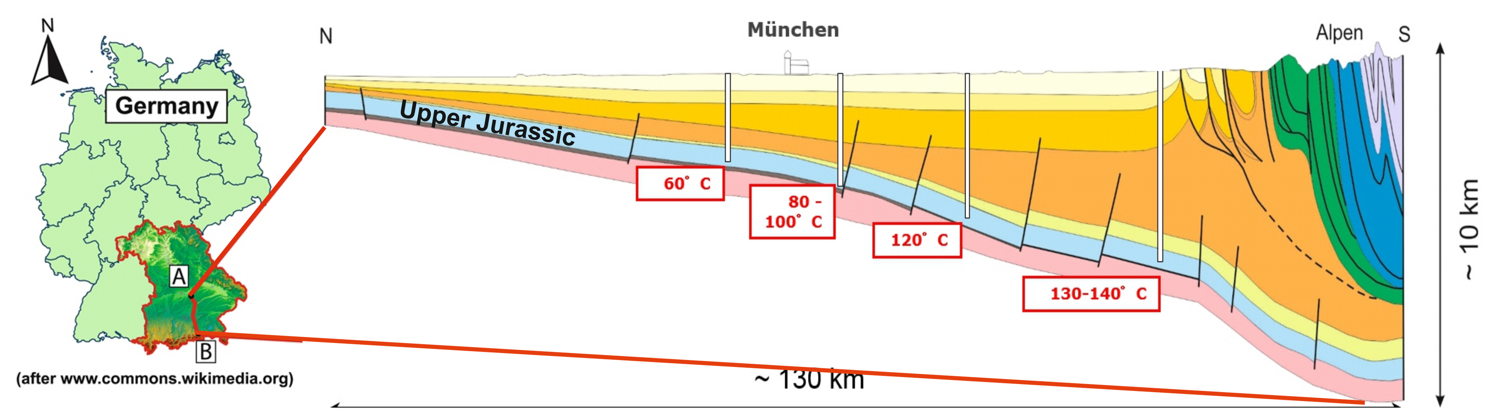


Fig. 1. Location map and vertical cross-section illustrating the southward dipping of the Upper Jurassic reservoir towards the North Alpine Range, and respective encountered reservoir temperatures [1].

Objective

Numerical coupled hydrothermal simulations are performed to capture thermal and hydraulic effects of heat storage

Evaluate the potential for HT-ATES application in the German Molasse Basin

2. Reservoir characterisation

- Sequences of limestones and dolomites compose the Carbonate rocks of the Lower Cretaceous and Upper Jurassic reservoir
- Karstification and fracturing induce high structural and geological heterogeneity
- Reservoir thickness of ca. 500 m
- Favorable reservoir conditions for geothermal engineering applications

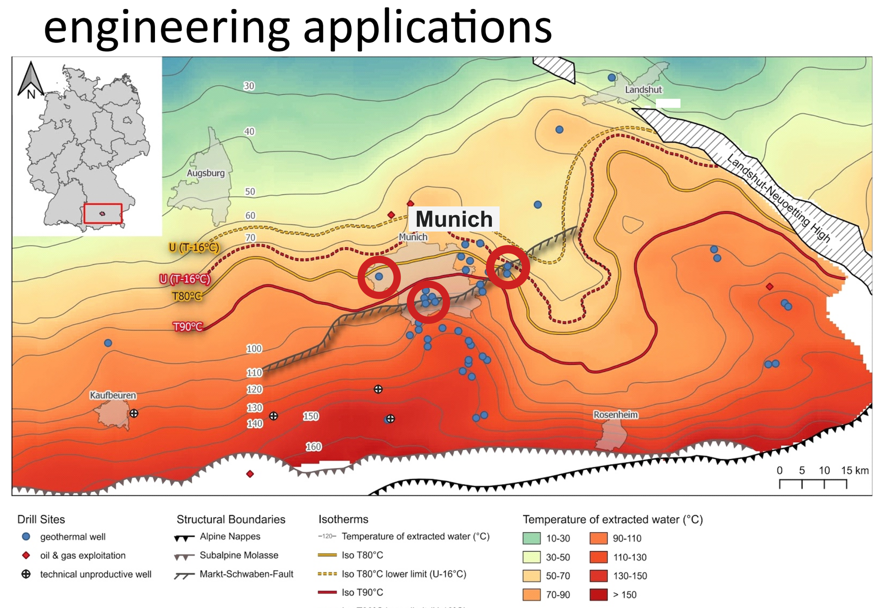


Fig. 2. Temperature field in the greater area of Munich. Red circles highlight the three operating geothermal reservoirs in focus of the present numerical analysis [2].

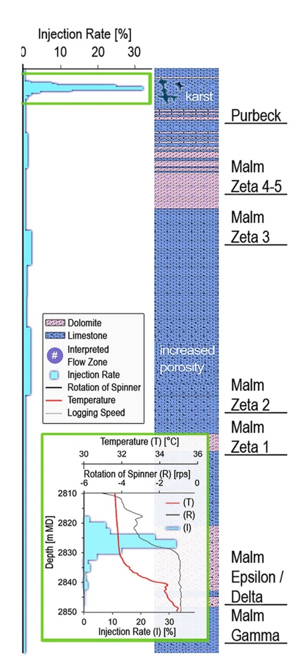


Fig. 3. Interpreted inflow zones from flow-meter data in a production well of the Schäftlarnstraße geothermal site. Zoom into top karstified inflow zone is shown in the green framed box [3].

In the area of Munich

Reservoir depth at ca. 1000-3000 m TVD

Reservoir temperature of 70- 120 °C

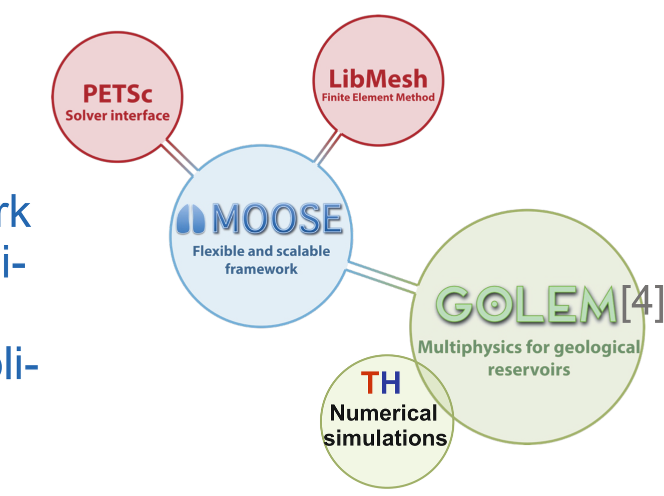
3. Numerical approach

- Emphasis on reservoir segments governed by karst-dominated fluid flow
- Three operating geothermal systems at depths of ca. 2000-3000 m TVD comprise the basis of the numerical simulations
- Reservoir is subdivided into three homogeneous modelled units
- Two impermeable units hydraulically disconnect the reservoir from overlying and underlying strata
- High-temperature heat storage through two vertical wells intersecting the entire reservoir

Numerical Simulator

Open-source **MOOSE** framework (**M**ultiphysics **O**bject-**O**riented **Si**mulation **E**nvironment) and complementary **Golem** application

https://mooseframework.inl.gov/
https://github.com/ajacquey/golem



4. Numerical model

- Physical parameters derived by weighted averages for each model unit [1]
- Local mesh refinement of the matrix surrounding the wellbores
- Seasonal operation with semi-annual load cycles over 10 years
- T_{cold} = 95 °C, T_{warm} = 120 °C, q = 100 l/s

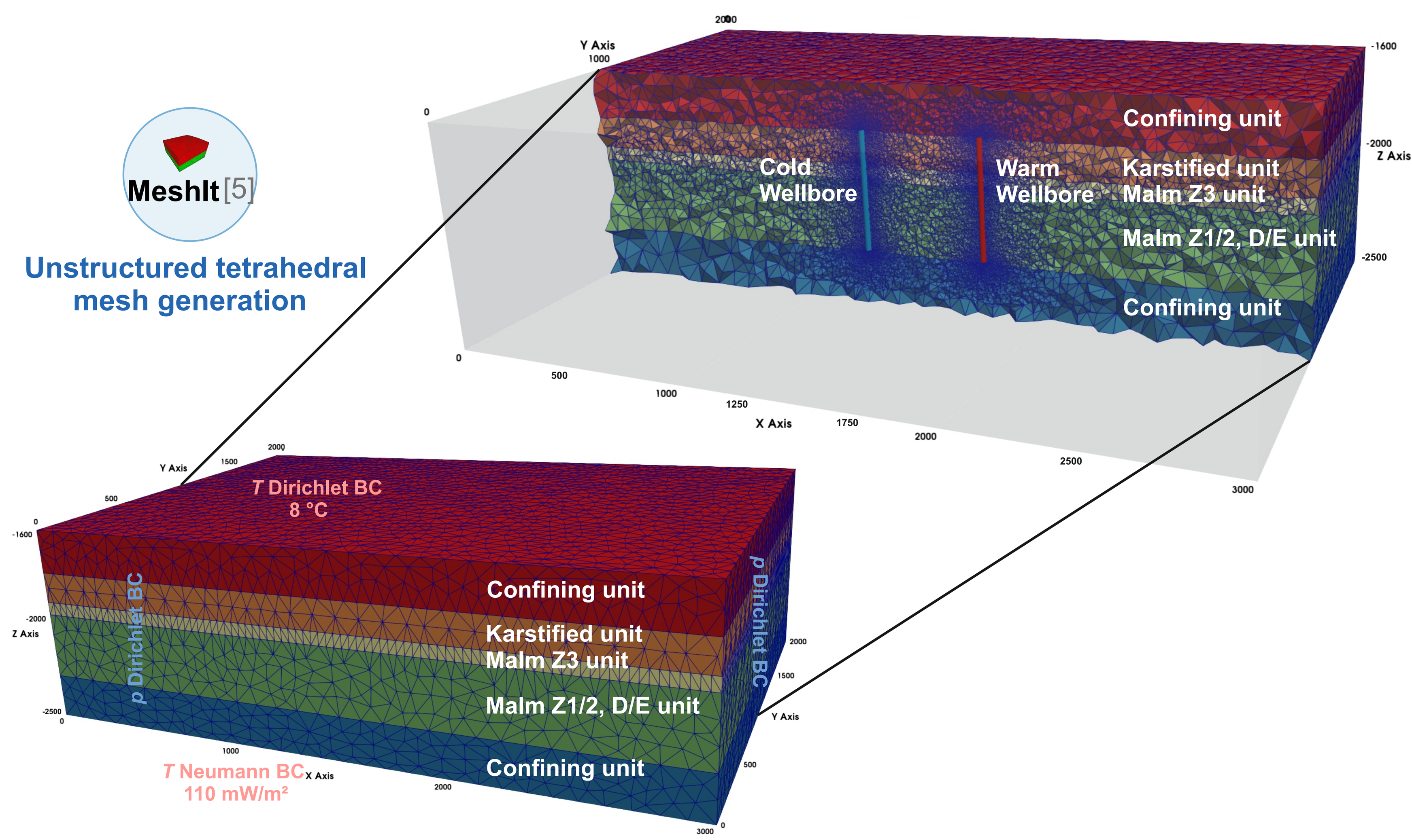


Fig. 4. 3D model domain, respective modelled units and generated unstructured tetrahedral mesh. Hydraulic and thermal Boundary Conditions are also shown. Cross-section illustrates the location of the well doublet and the assigned local mesh refinement of the matrix surrounding the wells.

5. Numerical results

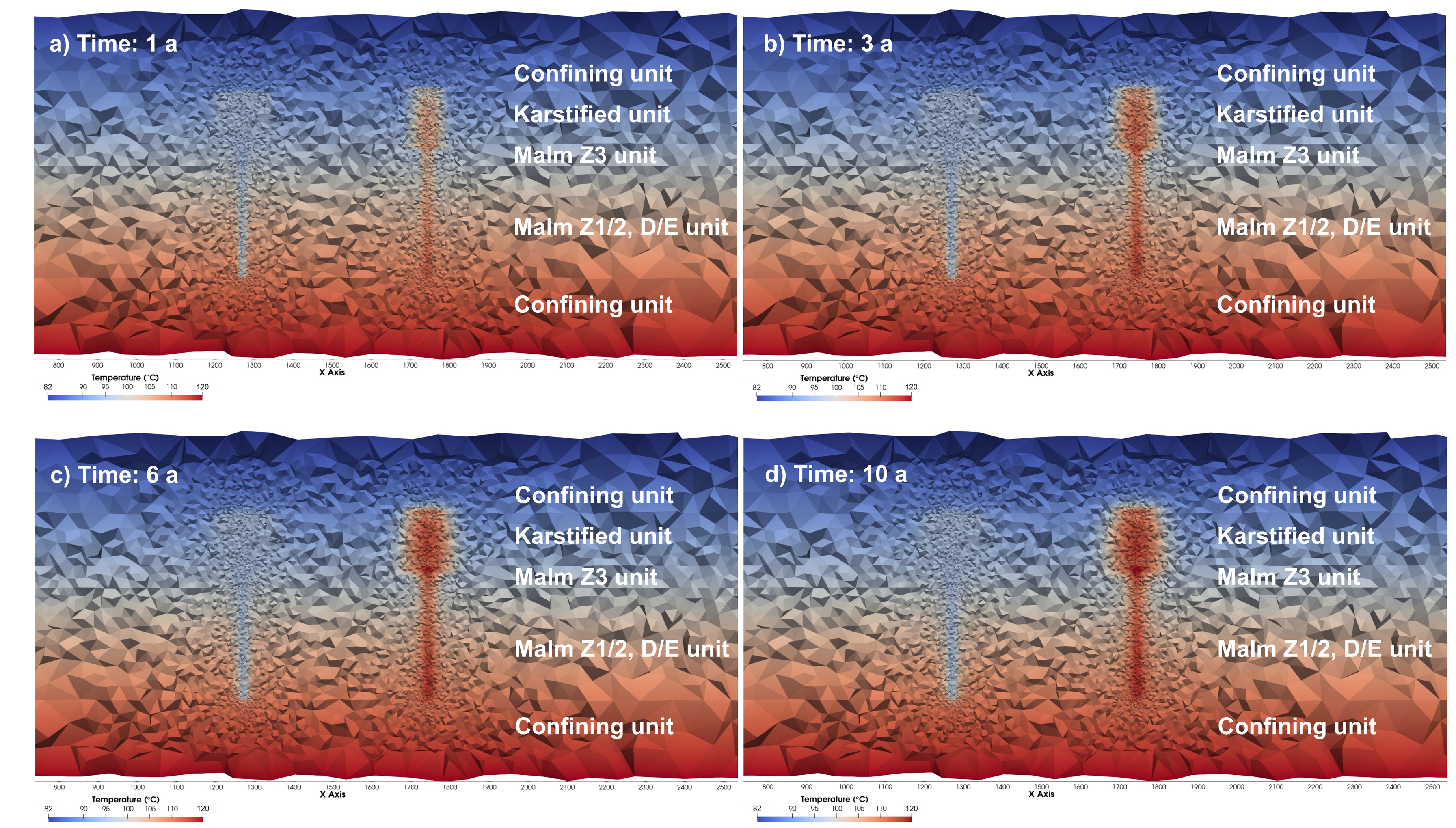


Fig. 5. Model cross-section illustrating the simulated temperature field at the end of the production phase from the warm wellbore after **a)** 1 year, **b)** 3 years, **c)** 6 years, and **d)** 10 years of operation.

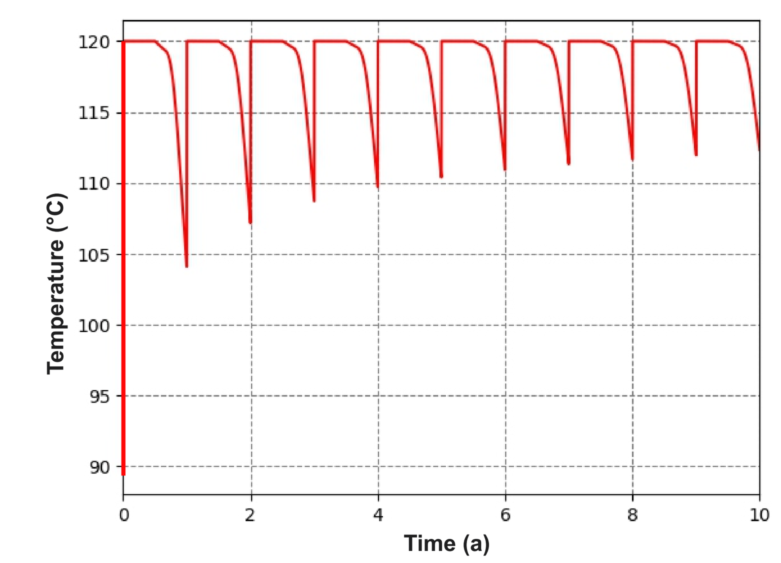


Fig. 6. Simulated temperature development in the warm wellbore.

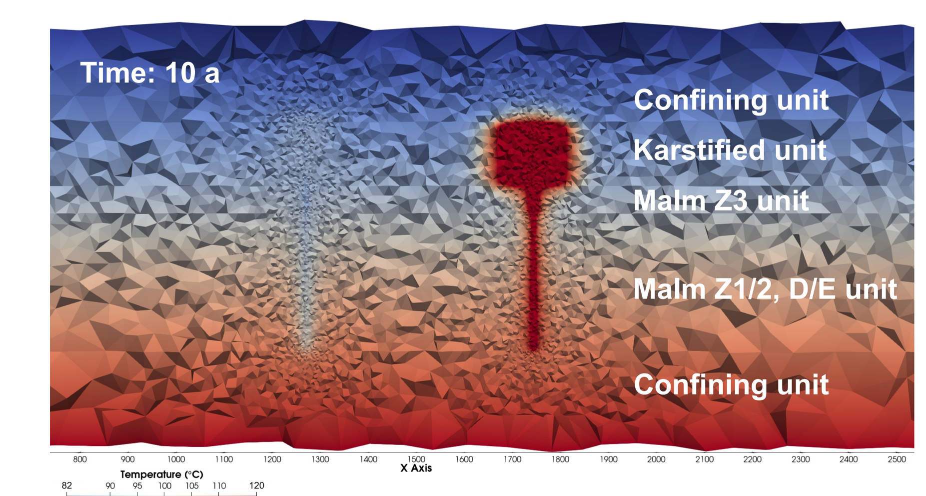


Fig. 7. Model cross-section depicting the simulated temperature distribution at the end of the injection phase in the warm wellbore after 10 years of operation.

6. Conclusions

- Thermal perturbation advances mainly in the karstified zone (Fig. 5)
- Progressive temperature increase in the warm wellbore per operation cycle (Fig. 6)
- No thermal interference between the doublet system
- Negligible conductive heat losses in the overlying and underlying strata

References

1. Bohnsack, D., Potten, M., Pfrang, D., Wolpert, P., Zosseder, K. Porosity–permeability relationship derived from Upper Jurassic carbonate rock cores to assess the regional hydraulic matrix properties of the Malm reservoir in the South German Molasse Basin, Geothermal Energy 8, 12, 2020.
2. Zosseder K, Pfrang D, Schölderle F, Bohnsack D, Konrad F. Characterisation of the Upper Jurassic geothermal reservoir in the South German Molasse Basin as basis for a potential assessment to foster the geothermal installation development–Results from the joint research project Geothermal Alliance Bavaria. Geomechanics and Tunnelling 15(1):17-24, 2022.
3. Schölderle F, Lipus M, Pfrang D, Reinsch T, Haberer S, Einsiedl F, Zosseder K. Monitoring cold water injections for reservoir characterization using a permanent fiber optic installation in a geothermal production well in the Southern German Molasse Basin. Geothermal Energy. 2021 Dec;9:1-36.
4. Cacace, M. and Jacquey, A. B.: Flexible parallel implicit modelling of coupled thermal–hydraulic–mechanical processes in fractured rocks, Solid Earth 8, 921–941, 2017.
5. Cacace, M., Blöcher, G. MeshIt - a software for three dimensional volumetric meshing of complex faulted reservoirs. Environ Earth Sci 74, 5191–5209, 2015.

Acknowledgements

The SpeicherCity project is supported by the German Federal Ministry of Education and Research - BMBF (grant 03G0911). We further thank the GFZ project partners for support related to the GOLEM numerical simulator.

Speicher CITY

Federal Ministry of Education and Research

Chair of Hydrogeology
Department of Civil and Environmental Engineering
Technical University of Munich

Contact: kalliopi.tzoufka@tum.de