2025 Helmholtz – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:

Numerical modelling of coupled hydro-thermal-chemical interactions in geothermal reservoirs

Helmholtz Centre and/or institute:

Helmholtz Centre for Environmental Research - UFZ

Project leader:

Dr. Haibing Shao, Staff Scientist and Group Leader

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Department: (at the Helmholtz centre or Institute)

Research Group Geothermal System Analysis, Department Environmental Informatics,
Section of Smart Models and Monitoring

Programme Coordinator (Email, telephone and telefax)

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Description of the project (max. 1 page)**:**

The geothermal energy in the deep crystalline subsurface is a largely untapped future resource. The economic planning perspective of a geothermal heat or power plant typically requires 30 years of sustainable operation of the reservoir. The permeability of the fractures in a crystalline reservoir must be maintained over a long period of time. In this context, fundamental research into the underlying chemical and physical processes is needed. In the Helmholtz infrastructure project "GeoLaB", a combination of laboratory and field investigations as well as numerical modelling techniques will be used to make new progress in two scientific fronts. In the first case, chemically based methods will be developed and tested on site to artificially enhance the permeability of fracture systems. On the other hand, numerical modelling approaches will be developed to predict the evolution of fracture permeability changes, especially those due to scaling and fracture geometry evolution, which may affect the preferential flow pathways and determine the long-term performance of the reservoir.

The work of this PostDoc position is aimed at the second front, which is the further development of modelling features tailored to the geothermal fracture system. Currently, numerical models follow a fully mixed approach, assuming that rock minerals and reservoir fluid are mixed in a vessel, with the corresponding (batch) reactions simulated by a geochemical solver such as PhreeqC. In terms of fluid transport, the interface systems are often modelled locally as a porous medium with higher values of porosity and permeability compared to the rock matrix. This PostDoc project plans to adopt the recent developments in materials science, following the phase field approach. This approach allows the mark-up of solid and liquid phases of the model domain, as well as tracking the propagation of fracture geometry within the porous media. Following this approach, the numerical model will be able to predict the fracture evolution based on chemical reactions and mass balance. These microscopic changes in surface geometry can further influence the (macroscopic) fracture permeability, by which the heat transfer and fluid migration may affect the chemical reactions. Successful implementation of this functional relationship will provide engineers a framework to predict the impact of hydrothermal reactions on long-term reservoir performance.

The PostDoc will first work with existing THMC models in the OpenGeoSys software (www.opengeosys.org) to reproduce the results of experiments from collaborating partners. In a second step, the newly developed function of reaction-induced or thermo-hydro-mechanical coupling caused fracture opening will be implemented to analyse the change in fracture and its permeability. The model development will be continuously validated and refined using results from laboratory experiments. The models are then transferred to the reservoir scale and later compared with the results of the field experiments. Ideally, any scale variance of individual processes will be captured, allowing the models to be adapted to the behaviour of the real system.

Description of existing or sought Chinese collaboration partner institute (max. half page)**:**

The research group Geothermal System Analysis has well-established cooperation relationships with the leading research institutions and universities in China. Potential Chinese collaboration partners can be the Institute of Geology and Geophysics, Chinese Academy of Sciences (IGG-CAS), China University of Petroleum Beijing (CUPB), Zhejiang University (ZJU), or Jilin University (JLU).

Required qualification of the postdoc:

- PhD in Applied Mathematics, Geology, Hydrogeology, Geotechnical Engineering and relevant directions;
- Experience with numerical modelling and finite element methods;
- Additional skills in C++, Python programming and High-Performance-Computing will be a plus;
- Established track record in scientific publication;
- English will be the working language; basic German language skill will be a plus.