Heat transport processes in fracture-matrix systems under stress conditions

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Context

Enhanced Geothermal Systems (EGS) in Hot Dry Rock (HDR) offers an alternative to fossil energy and helps reducing CO2 emissions with a clean and renewable energy. Assessing the performance of geothermal reservoirs subject to hydraulic stimulation requires quantifying the changes in permeability due to pore pressure and stress field change, and evaluating the impact of these changes and various exploitation parameters on the geothermal performance. This objective must be reached first at the fracture-matrix scale to be then extended to fracture-network field-scale systems.

Methodology

In stimulated fractured geothermal reservoirs, heat propagation is related to advective and conductive heat transfer processes in the fractures and the surrounding rock matrix, respectively, as well as heat exchange mechanisms between these geological structures. These processes are defined from analytical solutions for simple representations of the fracture-matrix systems (Figure 1).

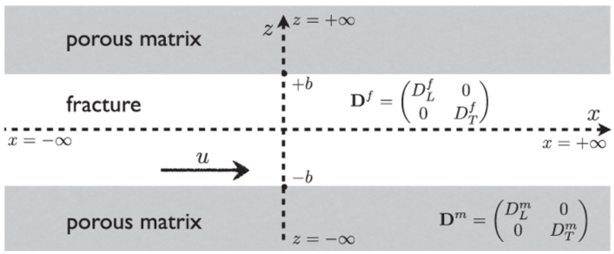

Figure 1 - Simplified representation of fracture-matrix system [Ruiz et al., 2014]

Here, we consider realistic representations of the fractures with heterogeneous self-affine aperture fields (Figure 2). Heat transport will be simulated with particle-based methods [Roubinet et al., 2022] in order to work with a large number of simulations (for uncertainty analysis and Monte Carlo simulations) and to reduce numerical diffusion. Several methods and assumptions will be tested going from pure advection in the fracture to advection-dispersion in the fracture and diffusion in the matrix. A large range of in-situ stress conditions will also be considered.

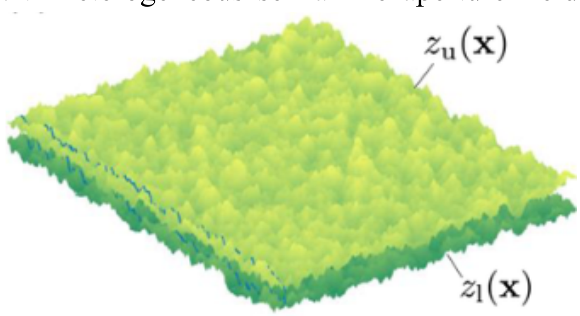

Figure 2 - Heterogeneous aperture field with self-affine behavior [Lenci et al., 2022]

Expected results and perspectives

The heat transport simulations in realistic heterogeneous fracture-matrix systems with particle-based numerical methods and in-situ stress conditions will be used to (i) evaluate the processes representation leading to the best balance between results accuracy and reduced computational cost and (ii) evaluating the impact of stress conditions observed in EGS systems on heat transport at the fracture scale.
The perspectives are (i) upscaling the behavior observed at the fracture-matrix scale, (ii) integrating the fracture-scale representation into fracture-network models, and (iii) performing simulations at the field scale linked to EGS-HDR applications.
This work will be done in collaboration with Yves Méheust (Geosciences Rennes) and Xiaoguang Wang (Chengdu University).

References

Lenci, Alessandro et al. (2022), 10.1029/2022WR032024. Ruiz Martinez, A., D. Roubinet, et al. (2014), 10.1002/2012JB010016; Roubinet, D., et al. (2022), 10.1016/j.advwatres.2022.104183.