Fracture Network Characterisation for Hydrothermal Projects: Application to the AGEPP Project in Lavey-les-Bains, Switzerland

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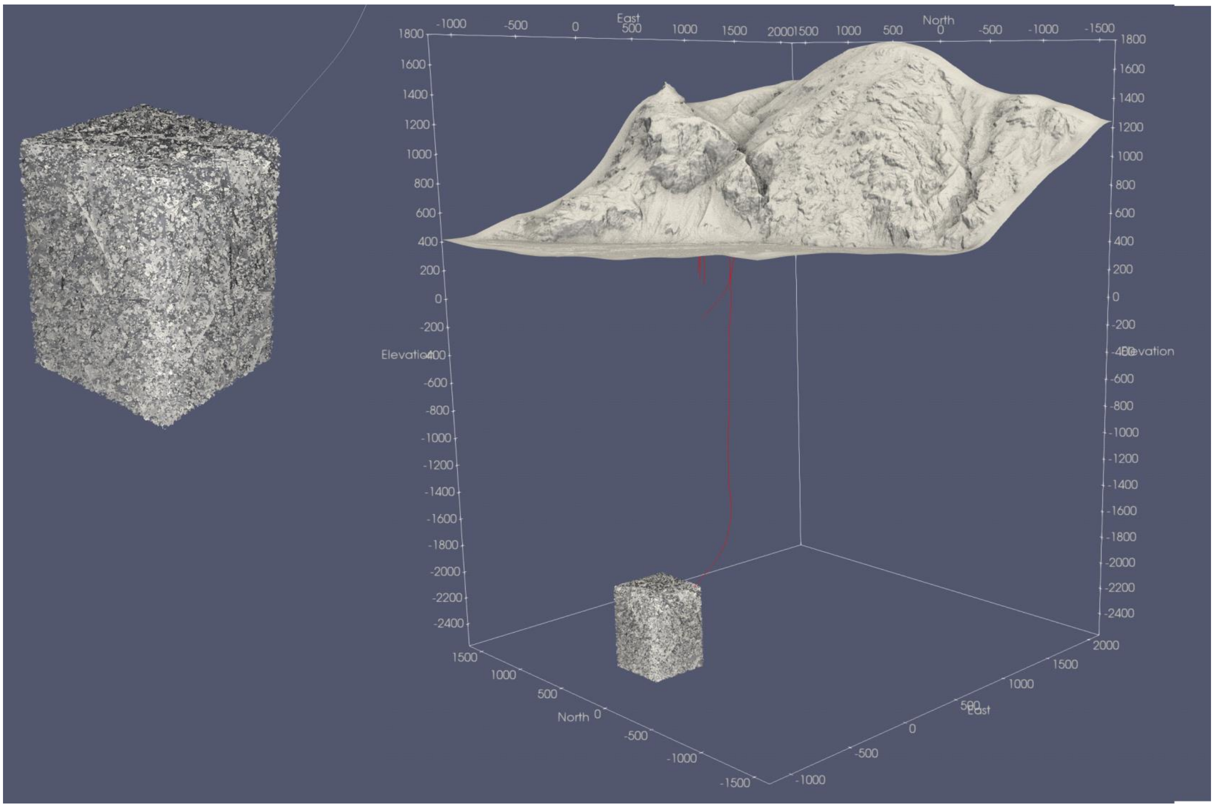
In the Paris Climate Agreement, Switzerland committed to reducing its greenhouse gas emissions by 2030 to 50 % of the emission levels in 1990 (BFE, 2020). To this end, the generation of renewable energies must be expanded quickly and consistently (BFE, 2023). The production of electricity and heat from deep geothermal energy has considerable potential (BFE, 2017). However, one of the biggest obstacles in the development of medium-depth to deep geothermal energy is the subsurface, which is often only poorly known (BFE, 2022).

This work proposes an approach to characterising fracture networks for hydrothermal projects that aim to explore the subsurface with a directional well profile. The approach focuses on finding a wellbore deflection for which the number of intersected productive fractures is maximised, thereby increasing the chances for a required production rate to be met. As part of the characterisation, the fracture network's connectivity is studied, which constitutes a key component for both the hydrogeological and the mechanical behaviour of the fractured rock. In the present case, the characterisation approach is applied to the Aiguilles Rouges Massif in Lavey-les-Bains (VD, Switzerland), which was targeted by the AGEPP hydrothermal project.

A Discrete Fracture Network (DFN) type model was used for the characterisation. DFN model parameters were derived from lineament maps, fracture trace maps and borehole fracture intercepts. To investigate differences that arise during fracture picking as a result of the subjective perception of the interpreter, independent data sets by two interpreters (picking 1 and 2) were analysed. The results of the fracture network characterisation show that the fracture size distribution of the Aiguilles Rouges Massif can be described by a global power-law function with an exponent of 3.54. The spatial distribution of lineaments and fracture traces and the spatial distribution of borehole intercepts only show a slight or no fractal scaling. A comparison between borehole pickings 1 and 2 shows that increases and decreases in fracture frequency along the 2958 m TVD deep borehole coincide well. However, in some cases, the two data sets show substantial differences in the absolute values of fracture frequency. A positive aspect that was identified is that the orientation distributions of the picked fractures are often similar.

Regarding the prediction of wellbore deflections that are favourable in terms of fracture frequency, the task remains challenging when the analysis is based on fracture data from above the kick-off point alone. However, a combined examination based on the criteria of fracture frequency and borehole stability showed that the prediction of favourable wellbore deflections is possible. For the realized wellbore deflection it was shown that it is one of the more favourable deflections for inclinations up to 40°. This is true when the closed fractures are included in the analysis or when only the open fractures are considered. Based on the two pickings, two different wellbore deflections were found to be the most favourable ones with respect to the fracture frequency and borehole stability criteria.

With regard to the connectivity study, it can be said that it is possible, even if not for all studied parameter setups, to generate fracture networks that show a connectivity. The critical threshold was often found in the range of P32 fracture densities that correspond to the P10 values of picked partially open and open fractures. As a result, at most a few connections can be expected to exist in the Aiguilles Rouges fracture network. A change in the maximum diametres of modelled fractures from lmax = 800 m to 100 m has shown that, in most cases, the fracture network changes from possibly connected to unconnected. Knowing that the fracture network in Lavey-les-Bains is connected, and assuming that the DFN model applied in this work is valid, this could be interpreted to suggest that larger discontinuities such as faults play a role in the rising of the geothermal water.



Overview of a 3D DFN developed for the Lavey geothermal project.