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How structural geology can contribute to geothermal exploration: a case study from Germany

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For geothermal reservoirs to be of economic use, a necessary condition is that there is a high flow rate of hot water through the rock. In most geothermal reservoirs, particularly in man-made reservoirs, fluid transport is through rock fractures, that is, the host-rock permeability is fracture-controlled („fractured reservoirs“). The permeability of a geothermal reservoir can be increased through stimulation, either by shearing and opening of existing rock fractures or by creating new hydraulic fractures in the reservoir rock, resulting in Enhanced Geothermal Systems (EGS). Here we show how structural geology can contribute to maximise the likelihood of success in geothermal projects, particularly as regards EGS projects. As an example, we present results of a case study on the prognosis of fracture systems and permeability in granite close to Erfurt, Thuringia (Eastern Germany).

In fractured reservoirs only interconnected fracture systems reach the percolation threshold necessary for fluid transport. Therefore, information on the geometry of existing fracture systems is necessary so as to be able to estimate the potential permeability of man-made geothermal reservoirs. To obtain this information, we analyse outcrop analogues, that is, outcrops of the same rock types as those supposed to host the man-made reservoir at geothermal depths. The outcrop studies were performed in the Thuringian Forest and represent the rocks expected at depth in the Thuringian Syncline. Important fracture parameters include attitude, aperture, and interconnectivity to fracture systems.

Our field results indicate that there are subhorizontal primary igneous joints as well as several sets of subvertical fractures. The orientations of the subvertical fracture sets, however, vary considerably between the outcrops. Also, fracture frequencies range from less than one fracture per metre up to more than four fractures per metre within minor fault zones or near igneous dykes. For all outcrops, the interconnectivity of the fracture systems is high, indicating a relatively high fracture-related permeability of the granite.

We use these field data for analytical and numerical models of potential fluid transport through statistically simulated fracture systems in granite. These models allow estimates of potential fluid flow rates through virtual potential bore holes. Finally we show how numerical models help to understand the local stress fields as well as the connectivity of existing and newly created fracture systems and therefore the fluid transport in the geothermal reservoir.

Structural geological field studies in outcrop analogues of the same rock types as the potential geothermal reservoir rocks help to understand the fluid transport in future man-made geothermal reservoirs and thus contribute to maximise the likelihood of success in deep geothermal projects.