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Estimating the reactivation potential of existing fractures in subsurface granitoids from outcrop analogues and in-situ stress modeling: implications for EGS reservoir stimulation with an example from Meiningen (Thuringia, Central Germany)

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The southwestern part of Thuringia (central Germany) hosts large subsurface extents of Lower Carboniferous granitoids of the Mid-German Crystalline Rise, overlain by an up to several kilometer thick succession of Lower Permian to Mid-Triassic volcanic and sedimentary rocks. The granitic basement represents a conductivity-controlled ('hot dry rock') reservoir of high potential that could be targeted for economic exploitation as an enhanced geothermal system (EGS) in the future. As a preparatory measure, the federal states of Thuringia and Saxony have jointly funded a collaborative research and development project ('Optiriss') aimed at mitigating non-productivity risks during the exploration of such reservoirs.

In order to provide structural constraints on the fracture network design during reservoir stimulation, we have carried out a geometric and kinematic analysis of pre-existing fracture patterns in exposures of the Carboniferous basement and Mesozoic cover rocks within an area of c. 500 km^2 around the towns of Meiningen and Suhl, where granitic basement and sedimentary cover are juxtaposed along the southern border fault of the Thuringian Forest basement high. The frequency distribution of fractures was assessed by combining outcrop-scale fracture measurements in 31 exposures and photogrammetric analysis of fractures using a LIDAR DEM with 5 m horizontal resolution and rectified aerial images at 4 localities. This analysis revealed a prevalence of NW-SE-trending fractures of mainly joints, extension veins, Permian magmatic dikes and subordinately brittle faults in the Carboniferous granitic basement, which probably resulted from Permian tectonics.

In order to assess the reactivation potential of fractures in the reservoir during a stimulation phase, constraints on the current strain regime and in-situ stress magnitudes, including borehole data and earthquake focal mechanisms in a larger area, were needed. These data reveal a presently NW-SE-trending maximum horizontal stress SHmax and a strike-slip regime (Heidbach et al. 2008). In-situ stress magnitudes at a reservoir depth of 4.5 km were calculated assuming hydrostatic pore pressures and frictional equilibrium along pre-existing fractures. Our estimates allow predicting that NW-SE-trending fractures in the reservoir would probably be reactivated as dilational veins during stimulation. In order to ensure that the stimulated rock volume is as large as possible and injected fluids circulate along newly-formed fractures rather than other pre-existing fractures, hydraulic fracturing at reservoir depth should follow a well trajectory parallel to the minimum horizontal stress Shmin, i.e. subhorizontal and NE-SW-oriented.

References:
Heidbach, O., et al., 2008, World Stress Map database release 2008, doi:10.1594/GFZ.WSM.Rel2008.