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Numerical stress field analysis for an underground laboratory in anisotropic crystalline rock as basis for hydraulic stimulation tests

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Hydraulic stimulation allows to increase permeability, create fluid paths and raise the flow rate during injection or production in a reservoir. The success of a hydraulic stimulation campaign is coupled to preceding planning and a suitable design. The stress field surrounding the injection well has critical influence on the hydraulic fracture development. Numerical simulation of the in situ stress field is a key task for preparation of a hydraulic stimulation. Knowledge of the geology, geomechanics and hydraulics of the target rock is fundamental to create a feasible model.

Accompanying hydraulic stimulation field tests in the Reiche Zeche underground laboratory in Freiberg, Germany, we conduct a numerical simulation of the in situ stress field. Therefore we create a detailed 3D geological model of the investigation area. A large scale model geometry of 2.5 x 2.5 km horizontal extent and 0.5 km depth incorporating 12 large ore veins, which act as discontinuities, is created based on mine maps and GIS data. Integrated into the large scale model is a local scale model, smaller by a factor of ten. The smaller model contains mining galleries and locally mapped fault structures which the injection borehole would penetrate.
We examine the extent and influence of these local faults on the stress field around the injection borehole and determine the in situ stress at the fracking intervals. For numerical stress field simulation we use an integrated modeling approach and the DEM code 3DEC by ITASCA to consider shear movements in the strongly discontinuous geology. To represent the foliation of the Freiberger Graugneis, an anisotropic elastic constitutive law is applied.Additionally we estimate the tendency of the locally appearing faults to being reactivated by change of in situ stress during stimulation (enhanced slip tendency analysis). Therefore we create a MATLAB routine which can be used for any arbitrarily oriented stress field and discontinuity orientation. The output is visualized and color coded.

The stress field model results fit the measured values of orientation and magnitude of the stress tensor components. Stress measurement data from the field test are used to calibrate the local stress model. The modeled stress field is anisotropic with a ratio of 1.3 : 1 : 0.8 and describes a strike-slip regime. From the local model results we assume that the fault structures mapped at the tunnel walls either do not proceed throughout the rock volume or are healed and have only minor influence on the stress field orientation. From the results of the slip tendency analysis we expect that the local faults are not prone to be reactivated by the hydraulic stimulation.