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STIMTEC – a mine-back experiment in the Reiche Zeche underground laboratory

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The STIMTEC underground experiment was designed to investigate stimulation processes involved in hydrofrac and hydroshear activation aiming at a permeability enhancement in deep geothermal projects. We combined periodic pumping tests, high resolution seismic monitoring, structural analysis and drilling into stimulated volumes in an effort to improve near-real-time monitoring, phenomenological models of the hydrofrac/hydroshear process, and prognosis strategies. The ongoing experiment is located at the Reiche Zeche underground laboratory below Freiberg in Saxony/Germany at a depth of about 130 m below surface in metamorphic gneisses. A structural analysis of the test volume enclosed by tunnels preceded the experimental program. The massive gneiss was found to be strongly foliated and three steeply dipping shear zones were identified that cut across the test volume between the access tunnels. Subsequently, a combined seismic network consisted of 12 broad-band acoustic emission sensors (sensitivity 1-100 kHz) and three 1-component Wilcoxon accelerometers (sensitivity 50 Hz-25 kHz). These sensors were installed in boreholes drilled into the test volume, surrounding the stimulation site, and providing optimum spatial coverage. A stimulation borehole with 63 m length was drilled with 15° northward inclination. Analysis of the core material, and borehole logs were used to identify potential intervals for hydraulic tests and stimulation. With a maximum horizontal stress direction striking 10°W from N, as typical for Germany, stimulation-induced fractures were expected to form NNW-SSE striking tensile hydrofractures and NNE-SSW striking hydroshears. We performed a series of laboratory tests on core samples to estimate fracture toughness and elastic properties of the gneiss. A strong elastic wave anisotropy was found with fast and slow propagation parallel and perpendicular to the foliation, respectively. The laboratory measurements were found to be in good agreement with an extensive series of active ultrasound measurements performed in the mine to establish a velocity model of the test volume. In addition to a strong effect of metamorphic foliation on the elastic properties, the field measurements revealed significant local velocity variations possibly related to damage/fault zones. After an extended campaign characterizing the hydraulics of the test volume, a series of ten stimulation tests were performed in the injection borehole. Each stimulation stage consisted of a frac stage, several refracs, and a subsequent hydraulic testing period. A total of > 5000 high frequency events were induced. Currently, analyses of the induced microseismicity and the hydraulic measurements are performed. In Spring 2019, a series of boreholes will be drilled into the stimulated volume as identified by the spatial distribution of detected seismicity. These boreholes will be fully cored to retrieve samples for structural analysis and testing. A series of hydraulic tests using the mine-back boreholes will conclude the experiment.