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Towards optimised seismic monitoring of hydraulic stimulations, the STIMTEC and STIMTEC-X experiments at Reiche Zeche Mine, Germany

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The STIMTEC and STIMTEC-X hydraulic stimulation experiments are designed to investigate hydro-mechanical processes controlling the enhancement of hydraulic properties in deep geothermal projects. We combine periodic pumping tests, high-resolution seismic monitoring, structural analysis and mine-back 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 experiments are located at the Reiche Zeche underground laboratory in Freiberg, Saxony/Germany, at a depth of about 130 m below surface in strongly foliated metamorphic gneisses.

The most recent field campaign and initial phase of STIMTEC-X in October 2020 involved eleven local stress measurements in three existing boreholes, previously used for monitoring purposes, with varying orientations and lengths. We hydraulically tested nine previously stimulated intervals and performed eight dilatometer tests in previously stimulated and new intervals to determine deformation characteristics of induced hydrofracs and pre-existing fractures. We monitored these operations in real-time using an adaptive, high-resolution seismic monitoring network comprising six acoustic emission (AE)-type hydrophones, six regular AE sensors and four accelerometers. Hydrophones were never installed before in combination with hydraulic gauges or the double packer probe used for localized injection as during STIMTEC-X. Hydrophones were optimally placed for each measurement configuration anew with at least one deployed in the direct vicinity (~3-4 m) of the injection interval to make best use of the existing infrastructure. This led to an improvement in detection and localisation of induced AE events. A series of active seismic measurements allowed us to establish the polarization, amplitude sensitivity, detection ranges, resonance frequencies and suitability to detect S-waves of the hydrophones. Good signal to noise ratios were recorded for distances up to 17 m. The range of incidence angles, including incidence angles from the opposite direction, in which the sensor is facing, was obtained that can be used for magnitude determination.

A circulation experiment between the injection borehole and two newly drilled boreholes of 23 m and 30 m depth as part of STIMTEC-X is anticipated for March 2021. Here, we present lessons learned from seismic monitoring the STIMTEC and STIMTEC-X hydraulic stimulation campaigns and highlight the advantages of using adaptive and flexible networks. We present an overview of the STIMTEC-X experiment and first results addressing the heterogeneity in stress and deformational behaviour seen throughout the anisotropic reservoir.