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Hydro-Mechanical Modeling of the Year 2000 Hydraulic Stimulation of GPK2 Well, Soultz-sous-Forêts, France

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Hydraulic stimulation of pre-existing fractures and faults plays a significant role in improving hydraulic conductivity of the fracture network around injection and production wells in geothermal reservoirs. It is therefore important to characterize the hydro-mechanical behavior of the faults against fluid injection. The Soultz-sous-Forêts site (France) has been an EGS pilot site where several major hydraulic stimulations have been performed and are well documented (https://cdgp.u-strasbg.fr/ and https://tcs.ah-epos.eu/).

Here we use the 3DEC numerical modeling tool (Itasca) to analyze the year 2000 stimulation of GPK2 well where large scale seismic anomalies have been evidenced during the different stages of the stimulation using 4D-P-wave tomography (Calo et al, 2011). The specificity of the approach is to combine two modeling at different scales. First, a small-scale model (100x100x100 m^3) is built to analyze the effective mechanical response of a stochastic discrete fracture network (DFN) following the statistical features of the observed fracture network (Massart et al, 2010). Second, a large-scale numerical model of the Soultz-sous-Forêts reservoir (5000x5000x5000 m^3) containing the largest faults of the reservoir defined by Sausse et al., 2010, is developed including regional stresses. The objective is to constrain the large-scale mechanical properties of the surrounding matrix around the fault from the small-scale model, in particular, its hydro-mechanical behavior in terms of non-linear elastic response related to the stochastic DFN. As a first step only the largest fault (GPK3-FZ4770) is considered. The first stage of the stimulation is modelled as a constant flow rate of 30 ls^{-1} of water injected into the fault at the depth of approximately 4.7 km. We explored the effect of the normal and shear stiffness of the fault on the dynamical response of pore pressure along the fracture and the onset of slip. It is found that the increase of the aperture of the fault during the injection shows a slow migration (~2 cm/s) owing to poro-elastic effects. Also generated fluid pressure throughout the fault shows a long period oscillating behavior (~5 hr) sensitive to the magnitude of the fracture normal stiffness.