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Fault criticality of a natural fracture network during injection and production simulations

Nicole Scheidt (1), Gunnar Jansen (2), Stephen Miller (2), Benoit Valley (2), and Jon Mosar (1)

(1) Earth Sciences, Department of Geosciences, University of Fribourg, Fribourg, Switzerland (nicole.scheidt@unifr.ch), (2) Centre of Hydrogeology and Geothermics (CHYN), University of Neuchâtel, Neuchâtel, Switzerland

The understanding of fault criticality in the Alpine foreland basin is of strategic importance for the development of geothermal resources in Switzerland. We combine techniques, such as μCT-scan and microscopy to define porosity and connectivity, and paleostress analysis of the La Sarraz Fault System. This right-lateral strike-slip fault system near the village of Eclépens is located in Cretaceous limestone series at the transition from the Jura Fold-and-Thrust Belt to the Molasse Basin, in western Switzerland.

We present a numerical approach applied to this sub-vertical strike-slip fault system, exposed in the field, in which we vary: (i) the connectivity of the fractures, (ii) the location and pressure regimes of the injection and production wells, (iii) the local stress on the faults, and (iv) the permeability of potential aquifers.

Using Thermaid (Jansen et al. 2017), an open source numerical model for Matlab, we analysed the slip tendency of faults, simulated in four aquifers at depths between 500 and 3'000 meters.

A "homogenous" setup simulates identical fracture permeability, porosity, connectivity with a regional stress field equally acting on all faults. A "heterogeneous" setup consists of the fracture network mapped at the surface where fewer fractures are connected. The faults in the centre of the setup are in failure mode, under the local and the regional stress field; and ten times more permeable than the peripheral faults. The geographical location of injection and production well were varied, as well as, the fluid regime pressures in the wells. We considered three setups: (a) hydrostatic, (b) critical pore pressure and (c) supra-hydrostatic fluid pressure. In total 18 simulations were obtained for each aquifer, producing 72 models.

Most results from 18 simulations homogeneous and heterogeneous fracture network models show critically stressed faults in a perimeter of 500 to 1000 m from the injection well. When placed on optimally oriented faults the production well increased the slip tendency. The production well did not provoke instability on unfavourably oriented faults for hydrostatic and critical pore pressure regimes.

The simulations allowed us to explore the stress conditions induced by fluid pressure variations in injection and production wells on a natural fractured network.