Probabilistic analysis of fault stability at the Bavarian Molasse basin

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ABSTRACT

The geothermal development in the south German Molasse Basin is successful for district heating as well as power generation. This requires optimized reservoir management, not only for hydraulic and thermal issues but also to reduce the hazard of induced seismicity.

We analyze all available borehole data to better characterize the regional stress field. Technical pressure test data (cementations pressure, formation integrity tests, leak-off tests) exists for the Tertiary overburden but not for the upper Jurassic reservoir. The analysis highlights a stress drop from a S_h-gradient of 16-18 MPa/km at the Tertiary to a S_h-gradient of 15 MPa/km at the upper Jurassic. Stress limitation concept of the hydrostatic Tertiary at a typical S_h-gradient of 18 MPa/km indicates a S_H-gradient of 1.09 S_v (μ=0.3) to 1.22 S_v (μ=0.4) near to the transition from normal to strike-slip faulting regime. Under-hydrostatic conditions and a typical S_h-gradient of 15 MPa/km at the upper Jurassic, limits the S_H-range to 1.2 S_v (μ= 0.6) and 1.43 S_v (μ= 0.8).

In order to provide further knowledge of the tendency of a fault structure to slip and the interplay with micro-seismic observation we use a Coulomb-Failure Model. A Monte-Carlo-Simulation define a critical probability for reactivation to address the geological uncertainty for a fault pattern and under the contemporary tectonic stress. This method is applied to the fault dataset in the greater Munich area and the project locations (Unterhaching, Poing and Sauerlach / Dürrnhaar) where micro-seismicity has been observed in recent years. We compare the observation of micro-seismic events to the critical probability of the nearby fault structures. It highlights a potentially critically stressed fault plane at the Unterhaching site. Fault structures at the Poing site are not critically stressed in the regional stress field. But the time delay of the onset of the seismicity in comparison to the begin of geothermal circulation indicates a slow triggering process within the reservoir. We interpret this situation by a stress heterogeneity caused by circulation (thermo-elastic or poro-elastic) leading to a localized stress rotation. A clockwise rotation of S_H by 20° results in a critically stressed fault segment of very limited length, which might be responsible for the perceived seismicity of Magnitude 2.1. At the Sauerlach and Dürrnhaar site this study indicates a low reactivation potential of the nearby fault structures and minor reactivation potential for local operation induced stress rearrangement. Our study shows that with a high quality data management (Fault zone, Stress field) an optimized development strategy can be defined which minimize the triggering of micro seismicity.