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Multiphase fluid flow and geomechanical analysis of the induced seismicity at the geothermal project in St. Gallen (Switzerland)

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The deep geothermal project in St. Gallen conducted in July 2013 aimed at gaining energy for district heating and producing electricity for the city of St. Gallen. After an injectivity test and two acid jobs that induced only minor seismicity, a gas kick forced the operators to inject water and heavy fluid (∼700 cubic meters), which induced multiple seismic events including a ML 3.5 earthquake that was distinctly felt throughout the population centers near the well. In contrast to many other sites, in St. Gallen the reactivated fault plane is located hundreds of meters away from the borehole, while no seismicity is observed in the direct vicinity of the injection well. Furthermore, the seismicity may be affected by the potential multi-phase fluid interactions during the gas kick and the well control measures. Although the geothermal project was suspended because of the low porosity and permeability of the reservoir and a too high gas content as would be required to maintain flow rates adequate for hydrothermal utilization, it represents an interesting case to analyze possible mechanisms that lead to induced seismicity and to study the potential influence of the gas.

Here, we present the results of a detailed hydro-mechanical analysis of the seismicity in St. Gallen. We combine information from a 3-D seismic survey, borehole logs, pressure and injection data as well as the earthquake catalog to propose a conceptual model. We then test this concept by means of a numerical model using the multiphase fluid simulator TOUGH2 coupled with different geomechanical codes. In a first step, we simulate the injectivity test to evaluate potential mechanisms that lead to the seismicity on the distant fault. The results show that the fault reactivation may either be explained by a fracture zone acting as a hydraulic conduit between the borehole and the fault or by a model without a hydraulic connection, where stress changes on the fault are purely governed by poroelasticity. In a second step, we use the fracture zone model to simulate the gas kick and the subsequent injection assuming an overpressurized gas pocket in the vicinity of the reactivated fault. Using this model, we are able to reproduce the timing and strength of the gas kick at the borehole and to simulate the main sequence along the reactivated fault. Our results may contribute to a more accurate understanding of the multiphase fluid-rock interaction at reservoir depth and the potential influence of a gas phase on induced seismicity.