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Numerical modeling of the induced seismicity during the deep geothermal project in St. Gallen, Switzerland

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The deep geothermal project in St. Gallen in 2013 was the second major geothermal project in Switzerland after the Enhanced Geothermal System (EGS) project in Basel in 2006. The hydrothermal project in St. Gallen targeted a reservoir in fractured carbonate rock at a depth of about 4 km, not expected to require permeability enhancement and associated hydro-shearing of the rock. Hence, the risk for induced seismicity was estimated to be rather small. In order to test the hydraulic response of the reservoir, an injection test and two acid stimulations with total injection volumes of <500 m3 were performed, inducing only minor seismicity. Two days later, sudden gas release from an unidentified source forced the operators to inject drilling mud (∼700 m3) into the wellbore to push the gas back into the subsurface. Subsequently, multiple earthquakes were induced, the largest with a magnitude of ML = 3.5, distinctly felt throughout the population centers near the well. Despite the induced seismicity, the city council of St. Gallen continued to support the geothermal project. However, after a production test in October 2013, it was found that the reservoir was not as permeable as required to maintain flow rates sufficient for power production. Permeability enhancement through hydraulic stimulation was not considered an option anymore since the risk for further induced seismicity was expected to be too large.

In this study, we present a conceptual model and simulation results capable of explaining the main features of the induced seismic sequence in St. Gallen. We base our study on observations from wellbore logs, geological information from a 3-D seismic survey, and accurate event relocations of the induced seismicity sequence in St. Gallen. We implement the conceptual model as a numerical model using TOUGH2-Seed, which couples the multi-phase and multi-component fluid flow simulator TOUGH2 with a geo-mechanical stochastic seed model. First, we calibrate the model against the measured well pressure of the initial injection test. The simulation of the injection test confirms that the low injection rates can indeed be sufficient to induce seismicity, even several hundred meters distant to the injection well, as it was observed in St. Gallen. Secondly, we simulate the gas kick and the subsequent injection during the well control measures. In doing so we aim for a more accurate understanding of the influence of two-phase fluid flow on the induced seismicity in St. Gallen and in general, and contribute to an improved understanding of induced events in deep geothermal energy plays.