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# Induced seismicity in crystalline basement: Understanding the reasons

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In recent years, cases of induced seismicity have been reported for geothermal wells in aseismic regions.
The use of geothermal energy naturally influences the reservoir as heat and water are withdrawn. However, most geothermal plants reinject the water so that pressure levels within the reservoir remain more or less stable. Despite this and despite low injection pressures, some of these reinjecting plants experience induced seismicity.
One example is the well Unterhaching Gt2, close to Munich, Germany. Here, the reservoir is an approximately 500 m thick karstified limestone layer of the Upper Jurassic, in which extraction and reinjection take place. Flow rates of more than 100 l/s have been established with reinjection pressures below 10 bar. Nevertheless, induced seismicity occurs. Most of the events are below 1.0 but some reach up to 2.4 on the Richter scale. Due to their location, they can without any doubt be attributed to the reinjection process. However, the origin of the quakes is not within the reservoir but located in the crystalline basement. As the reinjection well cuts through a steeply inclined fault, a hydraulic connection between reservoir, borehole and basement is given if a hydraulically open fault is assumed.
So far, it was impossible to find a correlation between the occurrence of induced seismicity and operating parameters of the geothermal plant like flow rate, injection pressure, or temperature.
Therefore, thermo-hydraulic-mechanical numerical models of the subsurface have been developed to understand the interaction between different parameters and to possibly identify critical thresholds for the initiation of induced seismicity.
Due to the large scale of the model, several kilometers in each direction, an equivalent porosity approach has been chosen for the hydraulic modeling of the karstic limestone layer. Flow within in the fault is also described by Darcy's law as the fault is not assumed to be a surface but a volume. This assumption is based on the analysis of seismic data of this region, which indicate a zone of damaged rock several tens of meters in diameter. Because of this approach to model the hydraulics, the pore pressure within the fault will most likely be the determining factor for the onset of induced seismicity. Therefore, it is of high interest to analyse the influence of the operating parameters of the geothermal plant on this parameter.