Triggering Mechanisms of Post-Injection Induced Seismicity Using The Enhanced Geothermal System of Basel (Switzerland)

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Induced seismicity is a limiting factor in the widespread deployment of Enhanced Geothermal Systems (EGS). Induced seismicity occurs not only during injection, but also after the stop of injection, with the largest magnitude earthquakes usually occurring after the stop of injection at different scales of time (hours to months). The post-injection large magnitude seismicity is counterintuitive and is still not well understood. Multiple mechanisms have been identified as triggering induced seismicity in EGS systems. Pore pressure increase due to fluid injection is the most commonly accepted triggering mechanism to explain induced seismicity. Yet, coupled poromechanical effects and static stress transfer are also important mechanisms in the process of fault reactivation. We study the combination of these different mechanisms by simulating coupled hydromechanical processes of the Deep Heat Mining Project at Basel, Switzerland (2006), a well-known case of short-term post-injection large-magnitude seismicity. We apply the material characteristics and stress conditions of the site to a simplified 2-dimensional fault network that is based on the monitored seismic events. In our model, pore pressure has a dominant effect on the triggering of the seismicity in the vicinity of the injection well, but its effect decreases away from the well as static stress transfer and poroelastic stressing gain importance. Poroelastic stress can have a stabilizing effect when its direction is opposite to the fault slipping orientation; but an abrupt shut-in, and consequently a quick poroelastic relaxation, reactivates the fault soon after the shut-in. Later post-injection induced seismicity is partially due to the post-injection diffusion of the pore pressure, but is mainly induced by constant static stress redistribution from reactivations of the different faults of the domain. Understanding the processes inducing seismicity, and especially the post-injection large-magnitude seismicity, should enable developing better strategies of shut-in to mitigate the risks of post-injection large-magnitude seismic events.