DGMK/ÖGEW-Frühjahrstagung, Fachbereich Aufsuchung und Gewinnung
Celle, 5./6. April 2017

Induced Seismicity: Stress makes the difference

B. Müller*, F. Schilling*, Th. Röckel**, Oliver Heidbach***
*KIT Karlsruhe, **Piewak & Partner, Bayreuth, *** Deutsches GeoForschungsZentrum Potsdam

Abstract

To develop geothermal or hydrocarbon production in low permeable rocks high rate injection of fluids are used. The accompanying seismicity occurs almost immediately in response to fluid injection in rather close vicinity to the injection well. The magnitude of the induced evens in general is increasing with the amount of fluid injected. Higher event magnitudes occur in connection with more moderate injection rates but massive volumes of fluid (e.g. waste water) on a longer time frame: today, injection-related induced seismicity significantly increased the number of events with M>3 in the Mid U.S. In order to understand the different onset times and magnitudes of induced events and to quantify the role of poro-elastic processes we built a generic model with special emphasis on the factors time, regional crustal in situ stress conditions and fault parameters. We use this generic model for three case studies, namely injection into a low permeable crystalline rock (such as in EGS systems), a combination of injection and production wells (as *e.g.* in hydrothermal circulation) in permeable rocks and long-term injection into porous rock (waste water injection).

We use an analytical approach, which is based on poro-elastic relations to deduce stress changes caused by changes of pore pressure due to injection into or production from a reservoir. Pore pressure changes induce changes in the stress pattern as a function of distance to injection/production, permeability and elastic rock parameters. These stress changes modify the proximity of the state of stress with regard to failure. With this approach we consider the spatial and temporal variation of critical stress states and show that depending on the undisturbed in situ stress field conditions the stress tensor can change significantly (including changes of the tectonic stress regime) and previously not critically stressed faults could turn to be optimally oriented for fault reactivation.

In the EGS case study pore pressure stress coupling processes can help to understand the increase in seismic event magnitudes even in the shut-in phase. For the circulation of fluids in porous systems as in hydrothermal circulation geothermal projects, the relative orientation of the injection and production wells with respect to the tectonic stress orientation plays an essential role for the occurrence and magnitudes of induced seismic events. This leads to the conclusion that not only active reservoir pressure management, but also optimal well positioning can reduce the probability and expected magnitude of induced seismicity.