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Temporal pore pressure induced stress changes during injection and depletion

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Induced seismicity is observed during injection of fluids in oil, gas or geothermal wells as a rather immediate response close to the injection wells due to the often high-rate pressurization. It was recognized even earlier in connection with more moderate rate injection of fluid waste on a longer time frame but higher induced event magnitudes. Today, injection-related induced seismicity significantly increased the number of events with M>3 in the Mid U.S. However, induced seismicity is also observed during production of fluids and gas, even years after the onset of production. E.g. in the Groningen gas field production was required to be reduced due to the increase in felt and damaging seismicity after more than 50 years of exploitation of that field. Thus, injection and production induced seismicity can cause severe impact in terms of hazard but also on economic measures. In order to understand the different onset times of induced seismicity we built a generic model to quantify the role of poro-elasticity processes with special emphasis on the factors time, regional crustal stress conditions and fault parameters for three case studies (injection into a low permeable crystalline rock, hydrothermal circulation and production of fluids). With this approach we consider the spatial and temporal variation of reservoir stress paths, the “early” injection-related induced events during stimulation and the “late” production induced ones. Furthermore, in dependence of the undisturbed in situ stress field conditions the stress tensor can change significantly due to injection and long-term production with changes of the tectonic stress regime in which previously not critically stressed faults could turn to be optimally oriented for fault reactivation.