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Fluid induced microseismicity: from pore pressure diffusion to hydraulic

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Experiments with borehole fluid injections are typical for exploration and development of hydrocarbon or geothermal reservoirs. The fact that fluid injection causes seismicity has been well-established for several decades. Current on going research is aimed at quantifying and control of this process. The fluid induced seismicity covers a wide range of processes between two following asymptotic situations.

In liquid-saturated rocks with low to moderate permeability the phenomenon of microseismicity triggering by borehole fluid injections is often related to the process of the Frenkel-Biot slow wave propagation. In the low-frequency range (hours or days of fluid injection duration) this process reduces to the pore pressure diffusion. Fluid induced seismicity typically shows then several diffusion indicating features, which are directly related to the rate of spatial grow, to the geometry of clouds of micro earthquake hypocentres and to their spatial density. In some cases spontaneously triggered natural seismicity, like earthquake swarms, also shows such diffusion-typical signatures.

Another extreme is the hydraulic fracturing of rocks. Microseismicity occurring during hydraulic fracturing violates the Kaiser effect. Propagation of a hydraulic fracture is accompanied by the creation of a new fracture volume, fracturing fluid loss and infiltration into reservoir rocks as well as diffusion of the injection pressure into the pore space of surrounding rocks and inside the hydraulic fracture. Some of these processes can be seen from features of spatio-temporal distributions of the induced microseismicity. Especially, the initial stage of fracture volume opening as well as the back front of the induced seismicity starting to propagate after termination of the fluid injection can be well identified. We have observed these signatures in many data sets of hydraulic fracturing in tight gas reservoirs. Evaluation of spatio-temporal dynamics of induced microseismicity can contribute to estimate important physical characteristics of hydraulic fractures, e.g., penetration rate of the hydraulic fracture, its permeability as well as the permeability of the reservoir rock.

Understanding of fluid-induced seismicity by hydraulic fracturing in boreholes can help us to understand natural fracture processes related to dehydration and degassing phenomena by subduction and faulting.