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Micro-seismicity and permeability enhancement in sandstone and andesite ruptured by fluid injection under triaxial conditions

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Hydraulic stimulation of a well alters the physical properties (such as permeability) of the surrounding rock and potentially triggers seismicity. This is of special interest for exploitation of geothermal fields for which permeability needs to be enhanced, but induced seismicity should be avoided. Therefore, we performed a study combining records of acoustic emissions (equivalent to micro-seismicity) and local permeability evolution in two permeable rocks: Flechtinger sandstone (Bebertal, Germany) and an andesite from Guadeloupe (French Antillas).

In this study, mechanical instability is triggered in the laboratory by injecting fluid in the pores of the rock (increasing pore pressure) in samples that are under triaxial stresses. During the experiments, acoustic emissions and local permeability changes are recorded with a passive acoustic system and fiber optic measurements, respectively.
Samples are hydrostatically loaded to 20 MPa and then axially loaded to a differential stress of 100 MPa. This stress state is maintained constant for 24h to make sure that no brittle creep takes place and could lead to the macroscopic failure. Then, a pore pressure of 15 MPa is applied at the bottom of the sample and maintained constant.

These experiments were performed in the triaxial cell installed at ENS Paris, which is instrumented with 16 acoustic sensors to record acoustic emissions. During pore pressure increase, acoustic emissions are recorded to understand the coupling between water front migration and induced seismicity. However, local permeability changes could not be recorded with this setup. Thus, the same experiments are performed in a similar triaxial cell at GFZ Potsdam where the samples are instrumented with three optic fibers that are able to record local pore pressure at three equidistant locations along the sample axis. Permeability evolution along the sample axis is calculated with Darcy's law between the points of local pore pressure measurements.

By comparing the results of both experiments, it is shown that injection of water and the resulting increase of pore pressure leads to acoustic emissions denoting crack propagation and local permeability increase.