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Seismicity and hydromechanical behavior of a fractured porous rock under a high pressure fluid injection.

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Fractured porous rocks exhibit high scientific interest, as well as energy and environmental challenges. A better understanding of the coupling between hydromechanical characteristics and seismo-acoustic signatures of fractured-porous rocks is a key issue in reservoir monitoring, and fault instability studies. The main idea of this work is then to present some preliminary experimental results aiming at improving the understanding of the coupling between seismic waves and flow mass transport in poro-fractured multi-saturated rocks.

To this end, we developed an in-situ mesoscopic-scale experiment in a fractured porous limestone at 250m depth in the LSBB URL, a French underground low noise laboratory located in the karst of the “Grande Montagne”, Rustrel, France. We performed impulsive high-pressure water injections in boreholes drilled across the main fracture network of the porous limestone of characteristic size of the order of 2m inside the experimental gallery. We examined with high-resolution the seismicity, the fluid evolution and the mechanical deformations of the porous matrix produced by the local and fast (few seconds) high-pressure hydraulic injections in boreholes through the fractures. The seismic events and tilts of the gallery’s free wall were monitored at different locations by two 3D broadband accelerometers and two 2D tiltmeters located between 1.5 to 2m from the injection chamber. Changes in fluid pressure and flow rate were simultaneously monitored in the chamber, and dynamic fluid pressure measurements where realized inside the injection chamber with very sensitive and accurate hydrophones.

During the experiment, fluid injections induced rock damage by producing large changes in the effective stress. A damage-induced permeability increase of a factor of 2.2 occurred after a 10 seconds long swarm of complex seismic events caused by a pressure peak injection of $3.5*10^{6}$ Pa and a sudden increase in the injected flow rate from 0 to $5.3*10^{-5}$ m3/s. The various angular directions observed on the tiltmeters, 3D accelerometric components and dynamic measurements of the fluid source, indicate that the origin of the deformation remains complex and evolves over the time of fluid pressure diffusion in the fractures. At the beginning, signals appear dominated by the source geometry, the rock mass boundary and the stress conditions. After the damage and during the pressure decay, tangential slipping of the fracture behavior dominates stress relaxation in the medium.

Finally, tilt monitoring coupled with seismo-acoustic measurements on both fluid and rock matrices present a promising method to quantitatively estimate the relationships between the changes in fractured rocks permeability and seismicity induced by a fluid pressurization.