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Linking the optically monitored channel evolution with tremor like seismic activity during aero-fracturing in a very fine granular medium

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The characterization and comprehension of rock deformation processes due to fluid flow is a challenging problem with numerous applications in many fields. This phenomenon has received an ever-increasing attention in Earth Science, Physics, with many applications in natural hazard understanding, mitigation or forecast (e.g. earthquakes, landslides with hydrological control,volcanic eruptions), or in the industry, as CO_2 sequestration.

Even though the fluids and rocks are relatively easier to understand individually, the coupled behaviour of porous media with a dynamic fluid flow makes the system difficult to comprehend. The dynamic interaction between flow and the porous media, rapid changes in the local porosity due to the compaction and migration of the porous material, fracturing due to the momentum exchange in fast flow, make understanding of such a complex system a challenge.

In this study, analogue models are developed to predict and control the mechanical stability of rock and soil formations during the injection or extraction of fluids. The models are constructed and calibrated based on the experimental data acquired. This experimental data obtained from solid-fluid interaction are monitored using a combination of techniques, both from geophysics and from experimental fluid mechanics.

The experimental setup consists of a rectangular Hele-Shaw cell with three closed boundaries and one semi-permeable boundary which enables the flow of the fluid but not the solid particles. Non expanding polystyrene beads around 80μm size are used as solid particles and air is used as the intruding fluid. During the experiments, the fluid is injected steadily (or injected and suddenly stopped to see the pushback in a setup with four impermeable boundaries) into the system from the point opposite to the semi-permeable boundary so that the fluid penetrates into the solid and makes a way via creating channels, fractures or directly using the pore network to the semi-permeable boundary. The acoustic signals emitted during the mentioned solid-fluid interactions are recorded by various sensors - i.e. Piezoelectric Shock Accelerometer (Freq. range: 1Hz - 26kHz) and Piezoelectrical Sensors (Freq. range: 100kHz – 1MHz) with a sampling rate of 1MHz - on the Hele-Shaw cell. After the experiment, those signals are compared and investigated further in both time and frequency domains. Moreover, by using different techniques localization of the acoustic emissions are done and compared.

Furthermore, during the experiments pictures of the Hele-Shaw cell are taken using a high speed camera. Thus, it is possible to visualize the solid-fluid interaction and to process images to gather information about the mechanical properties of the solid partition. The link between the visual and the mechanical wave signals is investigated.

The spectrum of the signal is observed to be strongly affected by the size and shape of deforming channels created during the process. The power of the recorded signal is related to the integrated deformation rate in the process. Fast avalanches and rearrangements of grains at small scales are related to high frequency (above 10 kHz) acoustic emissions.