Geophysical Research Abstracts
Vol. 17, EGU2015-11461, 2015
EGU General Assembly 2015

Tracking and understanding the acoustic signature of fluido-fractures: a dual optical/micro-seismic study

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The characterization and comprehension of irreversible 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, control the mechanical stability of rock and soil formations during the injection or extraction of fluids, landslides with hydrological control, volcanic eruptions), or in the industry, as CO_2 sequestration.
In this study, analogue models are developed (similar to the previous work of Johnsen[1] but in rectangular shape) to study the instabilities developing during motion of fluid in dense porous materials: fracturing, fingering, channelling… We study these complex fluid/solid mechanical systems using two imaging techniques: fast optical imaging and high frequency resolution of acoustic emissions. Additionally, we develop physical models rendering for the fluid mechanics (similar to the work of Niebling[2] but with injection of fluid) in the channels and the propagation of microseismic waves around the fracture. We then confront a numerical resolution of this physical system with the observed experimental system.
The experimental setup consists in 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. During the experiments, the fluid is injected into the system with a constant injection pressure from the point opposite to the semi-permeable boundary. The fluid penetrates into the solid using the pore network. At the large enough injection pressures, the fluid also makes its way via creating channels, fractures to the semi-permeable boundary. During the experiments acoustic signals are recorded using different sensors then, those signals are compared and investigated further in both time and frequency domains. 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 peaks and the variation of the peaks over time on frequency domain are investigated. Those peaks are developing initially then decaying with establishing channelling network and relaxation period. These peaks are strongly influenced by the size and branching of the channels, compaction of the media, vibration of air in the pores and the fundamental frequency of the plate.

[1] Ø. Johnsen, R. Toussaint, K. J. Måløy, and E. G. Flekkøy, “Pattern formation during air injection into granular materials confined in a circular hele-shaw cell,” Physical Review E - Statistical,Nonlinear, and Soft Matter Physics, vol. 74, no. 1, 2006.
[2] M. J. Niebling, E. G. Flekkøy, K. J. Måløy, and R. Toussaint, “Mixing of a granular layer falling through a fluid,” Physical Review E - Statistical, Nonlinear, and Soft Matter Physics, vol. 82, no. 1, 2010.