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Understanding the evolution of channeling and fracturing in porous medium due to fluid flow.

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Fluid induced brittle deformation of porous medium is a phenomenon commonly present in everyday life. From an espresso machine to volcanoes, from food industry to construction, it is possible to see traces of this phenomenon. In this work, analogue models are developed in a linear geometry, with confinement and at low porosity to study the instabilities that occur during fast motion of fluid in dense porous materials: fracturing, fingering, and channeling. We study these complex fluid/solid mechanical systems - in a rectangular Hele-Shaw cell with three closed boundaries and one semi-permeable boundary - using two monitoring techniques: optical imaging using a high speed camera (1000 fps), high frequency resolution accelerometers and piezoelectrical sensors. Additionally, we develop physical models rendering for the fluid mechanics in the channels and the propagation of microseismic waves around the fracture. We then compare a numerical resolution of this physical system with the observed experimental system.

In the analysis phase, we compute the power spectrum of the acoustic signal in time windows of 5 ms, recorded by shock accelerometers Brüel & Kjaer 4374 (Frq. Range 1 Hz – 26 kHz) with 1 MHz sampling rate. The evolution of the power spectrum is compared with the optical recordings. These peaks on the spectrum are strongly influenced by the size and branching of the channels, compaction of the medium, vibration of air in the pores and the fundamental frequency of the plate. Furthermore, the number of these stick-slip events, similar to the data obtained in hydraulic fracturing operations, follows a Modified Omori Law decay with an exponent p value around 0.5. An analytical model of overpressure diffusion predicting $p = 0.5$ and two other free parameters of the Omori Law (prefactor and origin time) is developed. The spatial density of the seismic events, and the time of end of formation of the channels can also be predicted using this developed model.

Different sources of the recorded signal (vibrations due to air, changes in the effective stress due to fluid-solid interactions) are separately analyzed using a far field approximation of Lamb waves. In the analysis phase, power spectrum of different timewindows (5 ms) obtained from the recorded signal are computed. We found that, in the synthetic dataset, the peaks in the low frequency range ($f < 20$ kHz) diminishes while the medium fractures as suggested in experimental work. Furthermore, to localize these events, we propose a new localization method applicable for thin plates which is based on energy amplitude attenuation and inversed source amplitude comparison. This inversion is tested on synthetic data using a direct model of Lamb wave propagation and on experimental dataset.

Moreover, the characteristic properties of the different type of earthquakes (namely Type-A and Type-B) are compared with different type of events (defined based on their power spectral signatures) recorded in the Hele-Shaw cell during experiments. Using optical and acoustic datasets and numerical simulations, the mechanics leading Type-A and Type-B earthquakes are explained and the results are shown to be compatible with the real earthquakes.