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Understanding porous rocks (Louis Néel Medal Lecture)

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Understanding the physics and mechanics of porous rocks is a stimulating challenge. Such rocks constitute an intermediate state between the external (fluid) and the internal (solid) layers of our planet. The first five kilometres of the earth are an ambiguous medium that is solid, but has the capability of retaining fluids. For that reason, porous rocks play a key role as they are the places for hydrocarbons resources and for underground storage. Moreover, fault mechanics too is involving porous rocks. Major progresses have been observed through experimental and theoretical research in recent years. Even shales, that are certainly the most complex sedimentary rocks, have been well documented. The goal is to understand the macroscopic behaviour, relying on the micro scale that is governing the mechanics and physics of such rocks. In that respect, the approach follows the lessons given by Louis Néel sixty years ago when he explained the large variety of macroscopic magnetic properties of rocks from a few basic microscopic interaction processes.

Since Terzaghi (Vienna, 1923), one knows that there are two conflicting pressures in that story (solid pressure and pore pressure). The resulting "effective pressure" has proven to be a key concept in many fields of geophysics. Porous rocks can compact. The process, strangely enough, may involve some dilatancy. Compaction is expected to produce subsidence. If localised, compaction can also result in permeability barriers (compaction bands).

Cracks account for a very small fraction of porosity. The consequences of cracking are nevertheless major at it affects strongly elastic wave velocities. This implies a possible passive and active monitoring, that is of interest to 4D seismics: microseismic activity and elastic wave velocities provide a way to monitor the reservoir and /or the overlying layer. Again experiments are providing results on acoustic emissions (pico-earthquakes that are heard at the laboratory scale) triggering and elastic wave velocity variations in controlled conditions. Progress relies on our ability to understand these results. Combining the measurement of acoustic emission monitoring, elastic wave velocity measurements with mechanical deformation seems to be a fruitful method in that case.

High porosity rocks are, for most of them, the end product of a long and complex history. Their past provides explanations for their composition and microstructure. Their future is considered for storage, but requires experimental and theoretical efforts to unravel their physical behaviour. The same is true for the small porosity rocks that are part of fault systems. Understanding the mechanics of faults requires the same efforts.