Abstract in English

The behaviour of subsurface-reservoir porous rocks is a central topic in resource engineering industry and has relevant applications for hydrocarbon and water production or CO_2 sequestration. One of the key open issues is the effect of deformations on the hydraulic properties of the host rock, specifically in saturated environments. Deformation in geomaterials is rarely homogeneous because of the complex boundary conditions they undergo as well as for their intrinsic tendency to localise. This non uniformity of the deformation yields a non uniform permeability field, meaning that the traditional macroscopic analysis methods are outside their domain of validity. These methods are in fact based on measurements taken at the boundaries of a tested sample, under the assumption of internal homogeneity. At this stage, our understanding is in need of direct measurements of the local fluid permeability and its relationship with localised deformation.

This doctoral dissertation focuses on the acquisition of such local data about the hydromechanical properties of porous geomaterials in full-field, adopting neutron and x-ray tomography, as well as on the development of novel analysis methods. While x-ray imaging has been increasingly used in geo-sciences in the last few decades, the direct detection of fluid has been very limited because of the low air/water contrast within geomaterials. Unlike x-rays, neutrons are very sensitive to the hydrogen in the water because of their interaction with matter (neutrons interact with the atoms' nuclei rather than with the external electron shell as x-rays do). This greater sensitivity to hydrogen provides a high contrast compared to the rock matrix, in neutron tomography images that facilitates the detection of hydrogen-rich fluids. Furthermore, neutrons are isotope-sensitive, meaning that water (H_20) and heavy water (D_20), while chemically and hydraulically almost identical, can be easily distinguished in neutron imaging.

The use of neutron imaging to investigate the hydromechanical properties of rocks is a substantially under-explored experimental area, mostly limited to 2D studies of dry, intact or pre-deformed samples, with little control of the boundary conditions. In this work we developed a new servocontrolled triaxial cell to perform multi-fluid flow experiments in saturated porous media, while performing *in-situ* loading and acquiring 4-dimensional neutron data.

Another peculiarity of the project is the use of high-performance neutron imaging facilities (CONRAD-2, in Helmholtz Zentrum Berlin, and NeXT-Grenoble, in Institut Laue-

Langevin), taking advantage of the world's highest flux and cutting edge technology to acquire data at an optimal frequency for the study of this processes. The results of multiple experimental campaigns covering a series of initial and boundary conditions of increasing complexity are presented in this work.

To quantify the local hydro-mechanical coupling, we applied a number of standard postprocessing procedures (reconstruction, denoising, Digital Volume Correlation) but also developed an array of bespoke methods, for example to track the water front and calculate the 3D speed maps.

The experimental campaigns performed show that the speed of the water front driven by imbibition in a dry sample is increased within a compactant shear band, while the pressure driven flow speed is decreased in saturated samples. The 3D nature of the data and analyses has revealed essential in the characterization of the complex mechanical behaviour of the samples and the resultant flow speed.

The experimental results obtained contribute to the understanding of flow in porous materials, ensure the suitability of the analysis and set an experimental method for further *in-situ* hydromechanical campaigns.