

# 3D Simulations of an Injection Test Done Into an Unsaturated Porous and Fractured Limestone

Alain Thoraval<sup>1</sup>, Yves Guglielmi<sup>2</sup>, Frédéric Cappa<sup>3</sup>

<sup>1</sup>INERIS, Nancy, France

<sup>2</sup>CEREGE, Aix-en-Provence, France

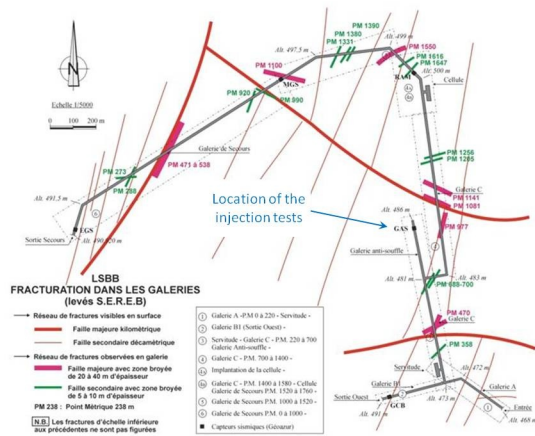
<sup>3</sup>GEOAZUR, Valbonne, France

## Abstract

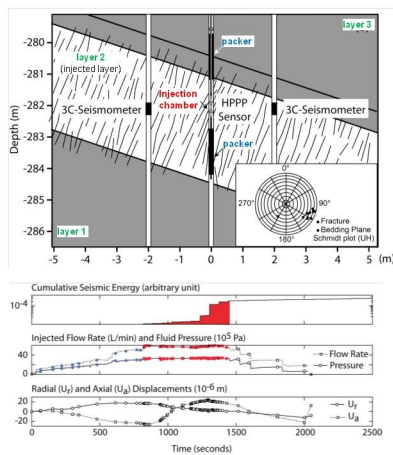
National and local governments show a growing concern about environmental protection on issues such as the stability of rocky slopes or the sealing of underground storage sites (hydrocarbon, radioactive and industrial waste, greenhouse gases). In all cases, hydro-mechanical couplings that occur in fractured media can affect the fluid flow and mechanical deformation processes. Both in situ measurements and model developments are needed to fully understand and predict the risks of instability and the fluid flow pattern into the rock mass. This paper focuses on experiments conducted at the LSBB (Laboratoire Souterrain à Bas Bruit) site close to Rustrel, Vaucluse, France in the field of the French ANR project called "HPPP-CO<sub>2</sub>" (Figure 1). The objectives of our contribution to this program were to develop numerical model to represent the effect of injection test in unsaturated porous and fractured rock mass.

The first step was to develop a COMSOL model including stress-strain constitutive law, two-phase flows, hydro-mechanical coupling. The second step is about the modeling of an in situ injection test done into a vertical borehole at LSBB site (Figure 2). In order to better fit to the real geometry (dip of bedding plane, other fractures crossing the borehole), a 3D model has been developed (Figure 3). The results (Figure 4) allow us to underline the impact of fractures on the hydro-mechanical response of the rock-mass to water injection. Fractures allow a faster dissipation of the water pressures and stress variations induced by the water injection. This leads to pressure decrease and displacement increase into fracture zone. We also estimate the rock mass intrinsic permeability and compressibility of the injected layer. From the simulation done and a comparison to the measurements, we can assume: a rock-mass intrinsic permeability close to 10-14 m<sup>2</sup> and a Young's Modulus close to 5 GPa.

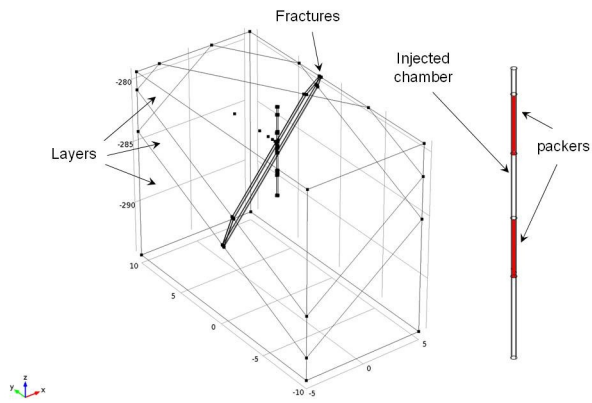
# Figures used in the abstract



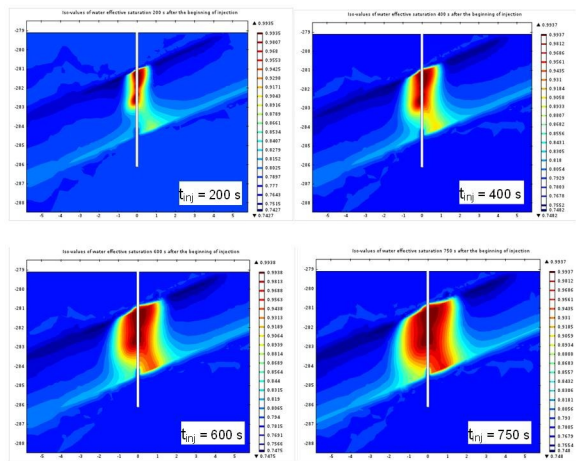
**Figure 1:** Location of the experiments done at the LSBB during the project.



**Figure 2:** Detailed of the experimental zone and of the measurements done during the injection.



**Figure 3:** Model geometry.



**Figure 4:** Iso-values of water effective saturation during water injection.