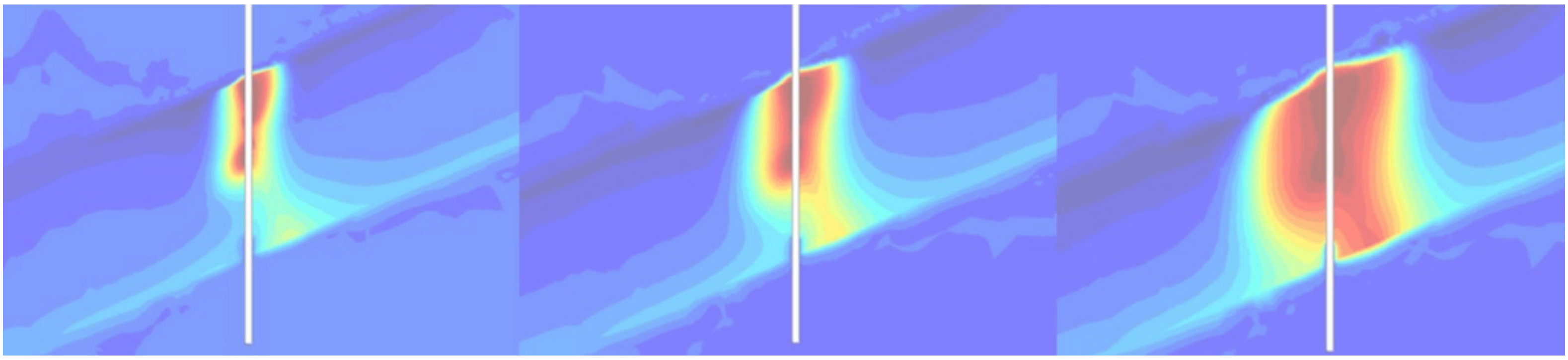
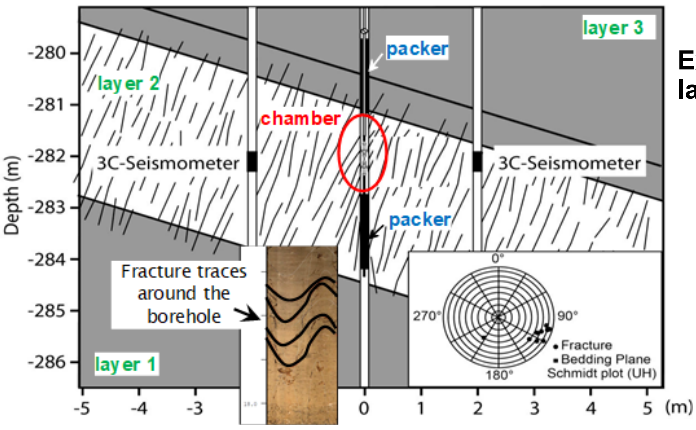


An advanced numerical model to study CO_2 geological storage in unsaturated porous fractured rock masses

CARBON CAPTURE AND STORAGE in deep aquifers is one of the potential levers to mitigate climate change. The efficiency and acceptability of this technology requires long-term risk assessment of CO_2 leakages from the reservoir. Ineris developed an advanced numerical model coupling geomechanical response and two-phases flow to study such an innovative underground operation.

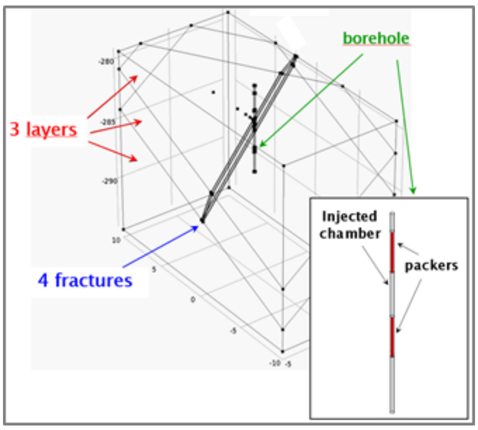
DEVELOPMENT OF AN ADVANCED NUMERICAL MODEL. A specific numerical model has been developed using COMSOL multiphysics© to simulate the hydromechanical behavior of a porous and fractured rock mass in unsaturated condition. A two-phase flow is computed with separate equations for the wetting and non-wetting fluids considering fluid densities, viscosities and compressibilities. Relationships between capillary pressure, wetting and non-wetting relative permeabilities and effective saturation of the wetting fluid are based on the Van Genuchen equations. The hydromechanical coupling relies on Biot theory in which effective stress tensor is linked to strain tensor and fluid content increment to both volumetric strain and pore pressure variation. For a two-phase flow in compressible medium, storage coefficients and source terms (for wetting and non-wetting fluids) are modified in order to include the mechanical impact.

MODEL VALIDATION. A 3D numerical model accounting for the orientation of the bedding planes and fractures was built to simulate the fluid injection and back-calculate the rock mass hydromechanical parameters (intrinsic permeability, compressibility of the injected layer) from the measured data. This experiment enabled to validate the developed numerical approach with the objective to apply it in a second step at the scale of a CO_2 storage reservoir. In the framework of a first research project, an injection test was performed in an underground research laboratory in France. The injection was done in an unsaturated porous medium from a borehole. During the test a set of continuous measurements were conducted including fluid flow rate and pressure, axial and radial displacements along with microseismic activity.



Experimental layout

Model geometry



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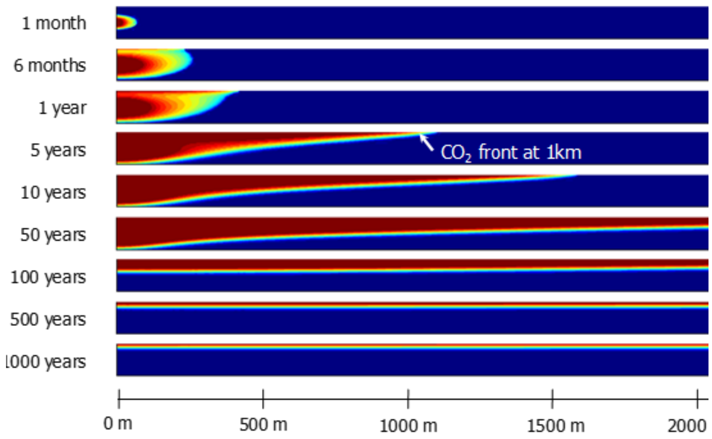
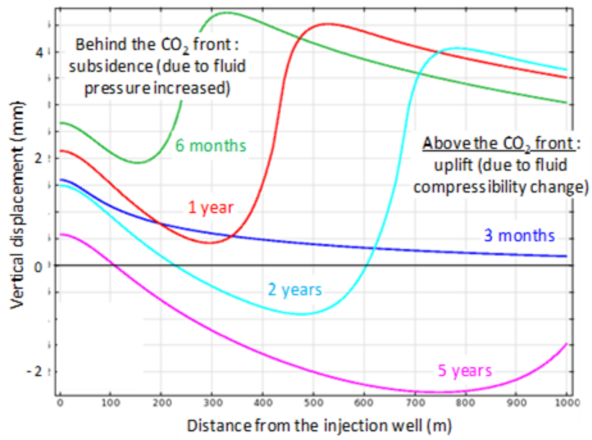
SIMULATION OF A CO_2 INJECTION INTO A DEEP AQUIFER RESERVOIR. In the framework of a second research program devoted to the assessment of risks related to CO_2 storage, a scenario of CO_2 injection in a deep saline aquifer was modelled. The *in silico* scenario consisted in the injection of 1Mt/year supercritical CO_2 during 50 years into a 2.350 m deep 120 m thick sandstone layer initially saturated with water. The CO_2 effective saturation change during and after injection and the vertical displacement induced at the reservoir roof were computed. The combined effects of pressure and compressibility were highlighted respectively ahead and behind the CO_2 front.

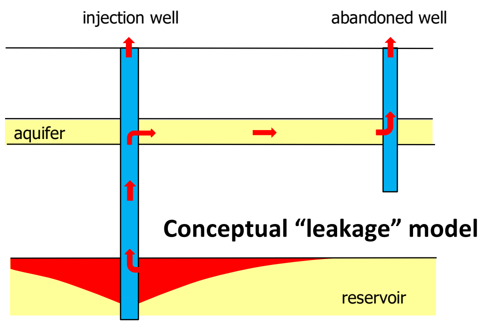


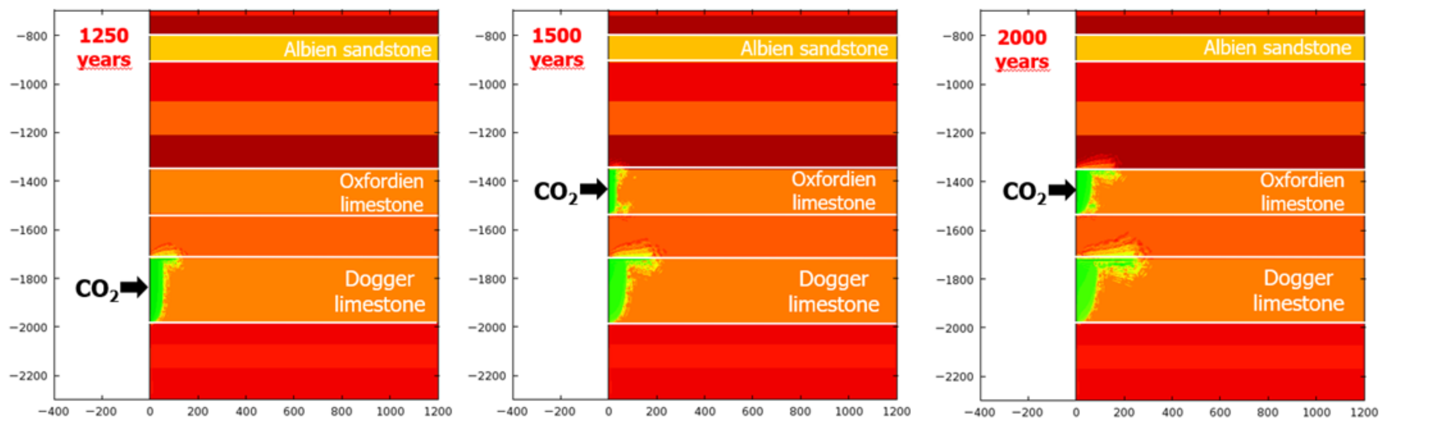
Iso-values of gaseous CO_2 effective saturation during water injection



Vertical displacement at the reservoir roof

Among many scenarios, considering CO_2 leakage along a vertical well through the overlying aquifers and up to the surface is of prominent interest. For this purpose, our model is interfaced with a well model developed by Oxand. Results shows that combinations of vertical and horizontal flows can lead to long term CO_2 migration towards critical aquifers or even to the surface. Migration scheme is quantitatively related to CO_2 overpressure into the reservoir and well degradation assumptions.





Time lapse of computed gaseous CO_2 mass flow into overlying aquifers

LESSONS LEARNED. Numerical modeling is an essential approach to study biphasic fluid flow along with hydromechanical couplings in deep porous fractured rock masses. It is unique when aiming long-term evaluation of the risk of leakage from geological CO_2 storage and assessing quantitatively leakage scenarios. Once validated, such model may include thermal and chemical processes, extending then applications to other types of underground storages with complex processes, covering long term tightness, stability and environmental issues.

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