

# Safety criteria for CO<sub>2</sub> geological storage in saline aquifers

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# Layout

- > **Purpose of our project**
- > **Risk scenarios**
- > **Simplified risk events models**
- > **Uncertainty management**

# Purpose of the study

## > **Determining safety criteria**

- Requirements to ensure negligible impacts on
  - Human health and safety
  - The environment
  - Other underground resources

## > **Establishing a methodology**

- Flexible
- Simple

# Risk scenarios

## > Development of 2 generic lists

- 11 events
- 9 target types

## > Support to an expert panel workshop

- Site-specific identification

## > Relate risk events to targets

- Deterministic approach
- Evaluate target exposure

# Cap rock failure

## > Cap rock fracturing in the injection zone

- Tensile fracturing
- Shear slip

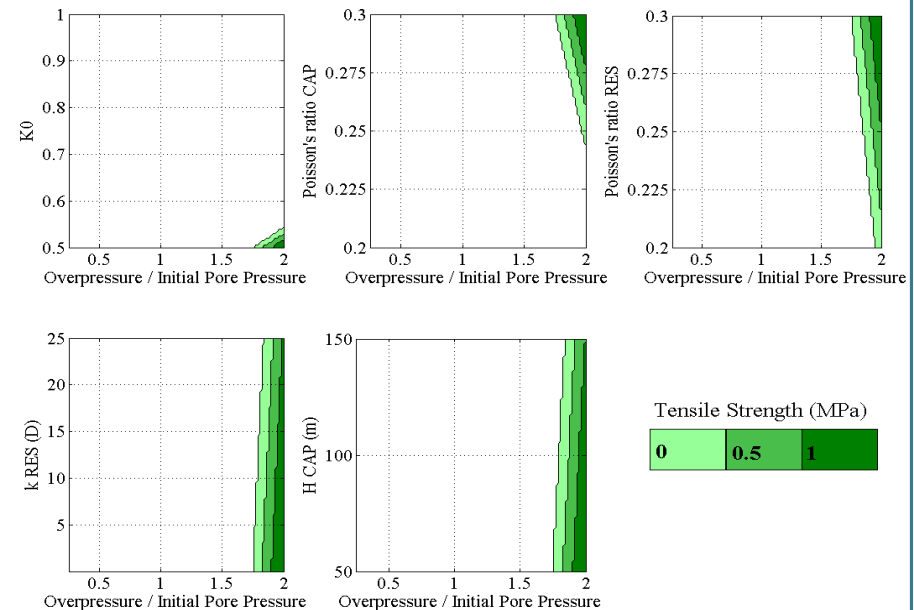
## > Response surface strategy

- Linear regression of the numerical outputs
- Cross validation

## > Abacus

- Sustainable overpressure vs most influential site parameters

*Cf. Rohmer et al.*



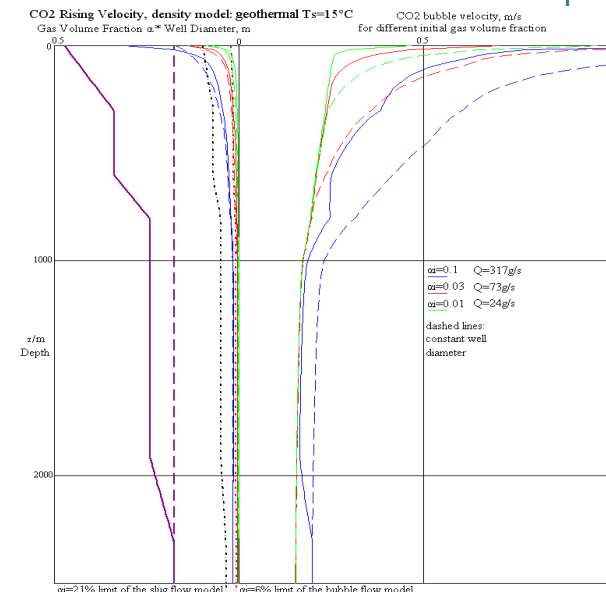
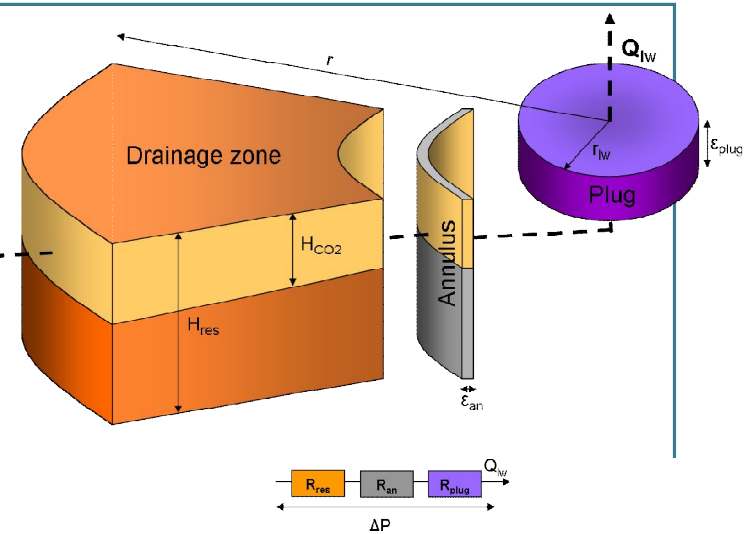
# Well leakage

## > CO<sub>2</sub> flow through the seal

- 1 equivalent seal
- 1-D stationary Darcy monophasic analytical model
- Flow rates through seals are extremely variable
  - $\text{mg}\cdot\text{s}^{-1}$  –  $\text{kg}\cdot\text{s}^{-1}$

## > CO<sub>2</sub> uprise in a water column

- 2-phase flow analytical model
- Steady state
- Rising up of CO<sub>2</sub> extremely fast
  - $0.15 - 3 \text{ m}\cdot\text{s}^{-1}$
- Strong cooling may occur



# Leakage through a porous medium

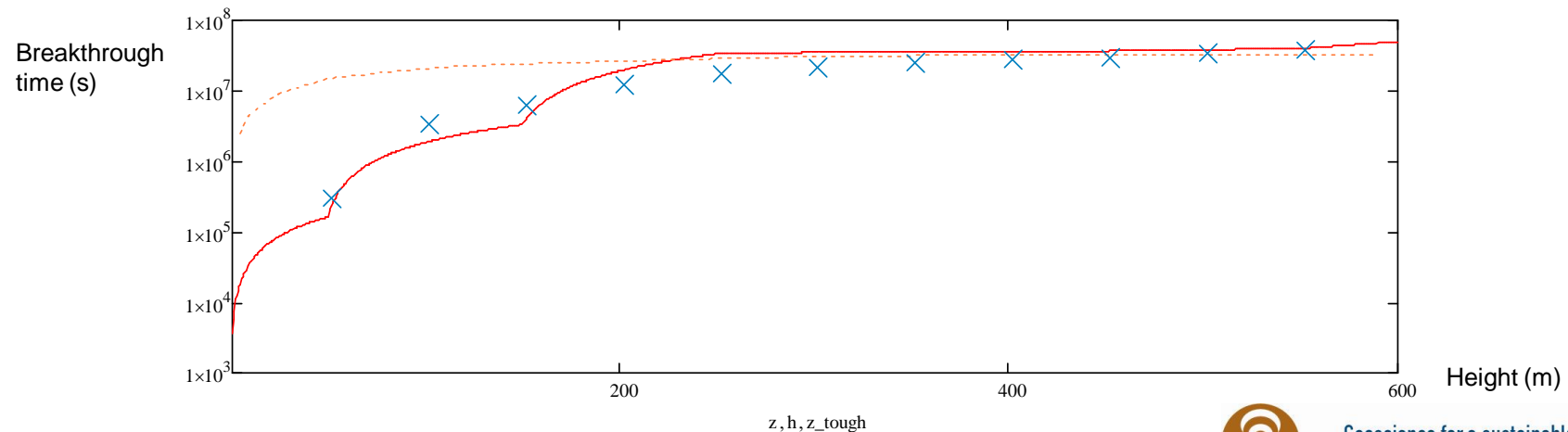
## > 1D biphasic Darcy flow analytical model

- Multilayer column —
- Equivalent homogeneous column ⋯
- Validation by a numerical multilayer model ×

## > Breakthrough time

## > Initial + steady state flow rates

## > Fault, abandoned well, cap rock discontinuity



# Geochemical impact of CO<sub>2</sub> leakage on freshwater aquifers

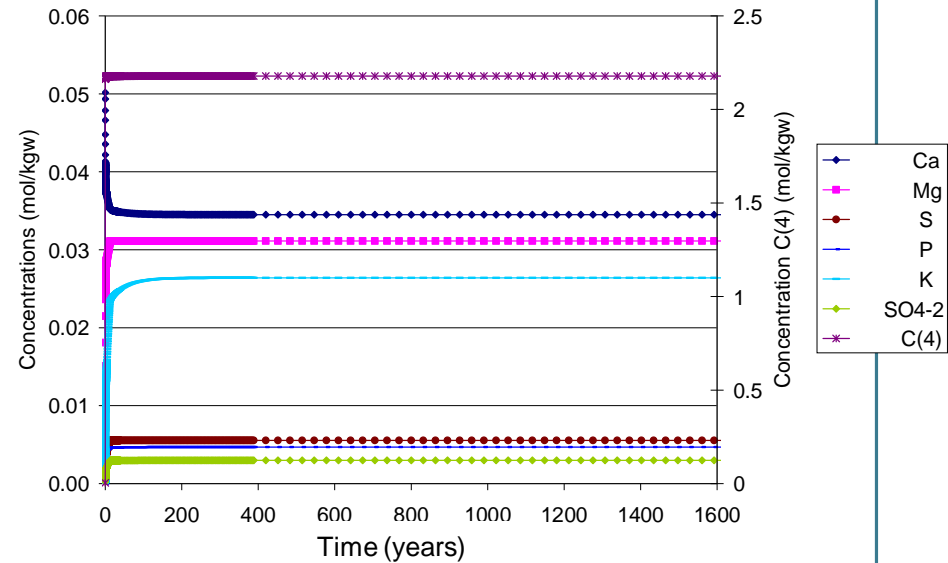
## > Site specific

- Albian aquifer

## > Batch modelling

- Including kinetics
- Water mineralogical model + Gaseous CO<sub>2</sub> (pCO<sub>2</sub> = 6.5 MPa)
- Return to initial conditions (pCO<sub>2</sub> = 1 kPa)
- Effects of impurities

## > Reactive transport modelling underway



Solution species evolution during water exposure to CO<sub>2</sub>

# Accumulation in a secondary trap

## > 2D numerical model

- Regional flow SE → NW
- CO<sub>2</sub> intrusion in the middle of the domain
  - Upper, central or lower mesh

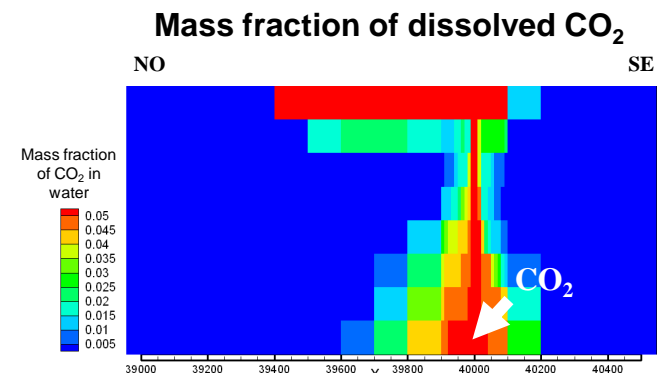
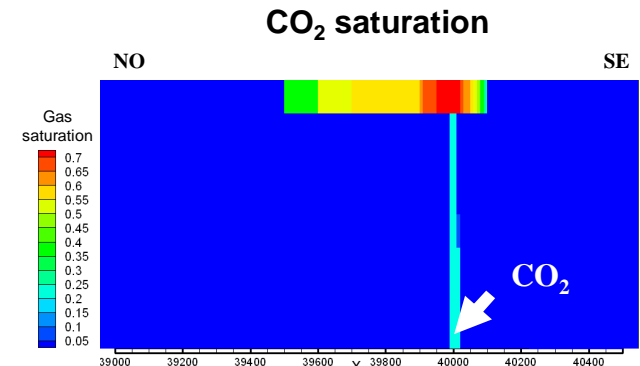
## > Flow rate threshold

- 0.3 g/s/m<sup>2</sup> for gaseous phase

## > Lateral extent

- ~1 km after 5 yrs
- ~20 km after 100 yrs

## > Figures a linear leak



T = 5 yrs

Q = 0.3 g/s/m<sup>2</sup> at the basis of the aquifer

# Uncertainty management

## > **Uncertainties**

- Stochastic
- Epistemic

## > **Correct mathematical representation**

- Avoid introducing subjectivity *a priori*
- Hybrid method
  - Probability theory
  - Fuzzy intervals and possibility theory
  - Geostatistics

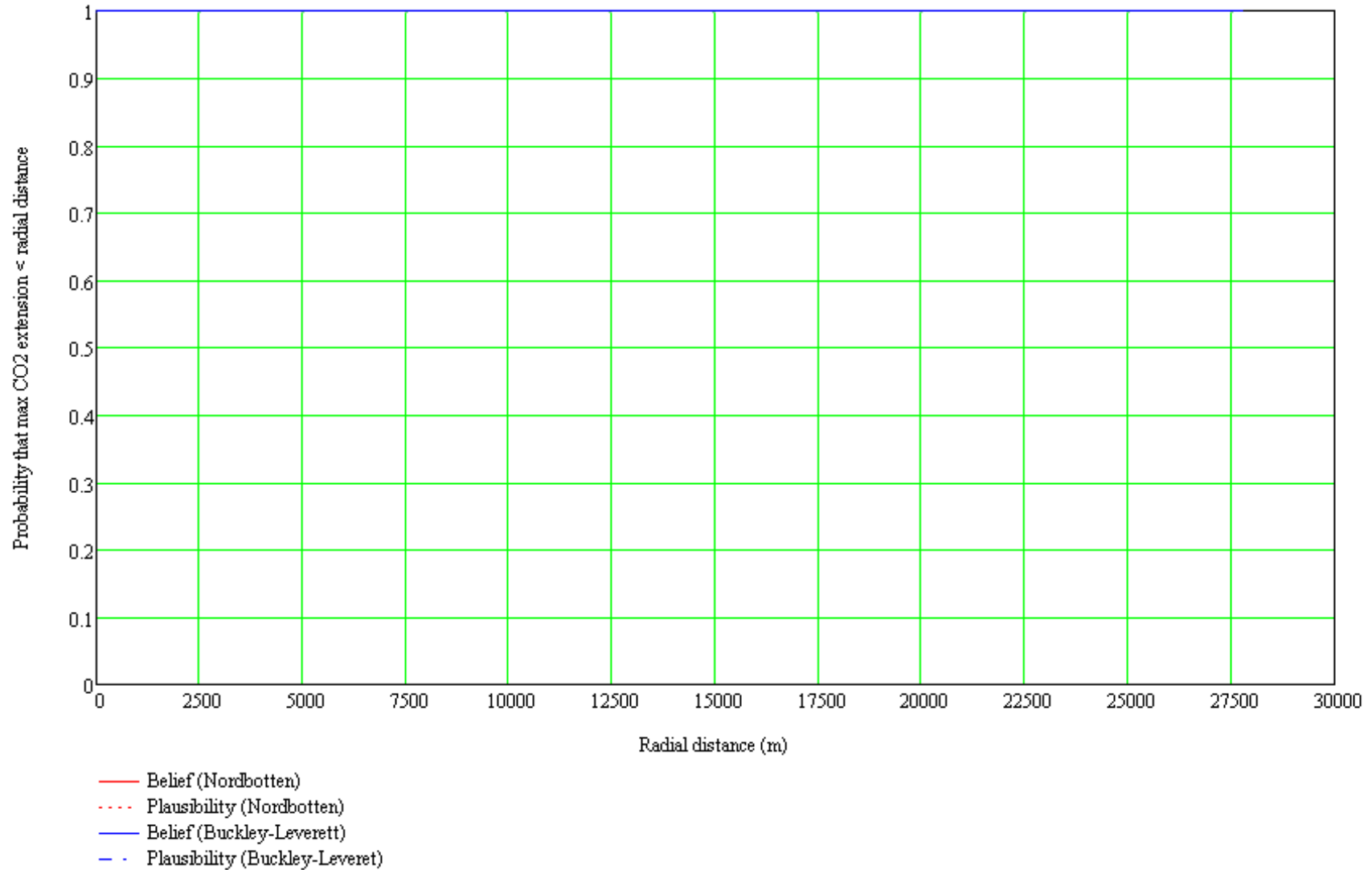
## > **Assess uncertainty propagation**

- Provide an unbiased information
- To support an informed decision

# P(Max. CO<sub>2</sub> extension < radial distance)

$t := \text{FRAME} \cdot \text{yr}$       $t = 0 \cdot \text{yr}$

Injection rate: 1MT CO<sub>2</sub>/yr



# Conclusion and perspectives

## > **Methodology and tools for safety criteria**

- Framework for risk scenarios identification
- Simplified models for the various risk events and impacts on aquifers
- Framework for handling uncertainty

## > **Further work**

- Improve some of the models
- How to take into account surface impacts?
  - Human exposure
- Test the method: determine safety criteria for an example application (Paris Basin)

# Acknowledgements



## > French Research National Agency (ANR)

- CO<sub>2</sub> program: project CRISCO2 n° ANR-06-CO2-003

## > Project team

- BRGM
- Mines ParisTech, Centre de Géosciences
- IRIT, Université Paul Sabatier - Toulouse
- Centre d'Hydrogéologie de l'Université de Neuchâtel
- TOTAL

