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Jérôme Corvisier, Vincent Lagneau, Emmanuel Jobard, Jérôme Sterpenich,  
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# Both experimental study and numerical modelling of the effect of temperature gradient on CO<sub>2</sub> injection

Jérôme Corvisier<sup>1</sup>, Emmanuel Jobard<sup>2</sup>, Aurélien Randi<sup>2</sup>, Vincent Lagneau<sup>1</sup>, Jérôme Sterpenich<sup>2</sup>, Jacques Pironon<sup>2</sup>

<sup>1</sup> MINES ParisTech, Centre de Géosciences - 35, rue Saint-Honoré Fontainebleau F-77305 FRANCE

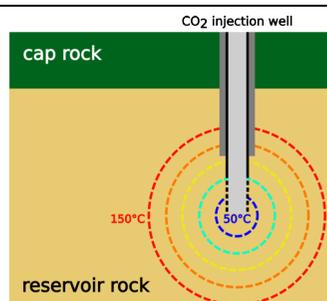
<sup>2</sup> Nancy-Université, Laboratoire G2R - BP 70239 54506 Vandoeuvre-lès-Nancy FRANCE

[jerome.corvisier@mines-paristech.fr](mailto:jerome.corvisier@mines-paristech.fr) - [emmanuel.jobard@g2r.uhp-nancy.fr](mailto:emmanuel.jobard@g2r.uhp-nancy.fr)

## CONTEXT

CO<sub>2</sub> injection and underground storage obviously requires dealing with **temperature differences** between the **injection well** and the **reservoir**. For example, in Rouse-Lacq (french capture and storage project led by TOTAL) CO<sub>2</sub> is injected at 50°C in a gas depleted reservoir whose temperature is 150°C.

To assess this issue, an experimental set-up, COTAGES, has been designed and numerical simulations with the reaction/transport code HYTEC has also been performed to reproduce the observed behavior.



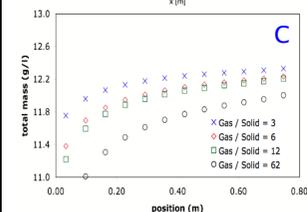
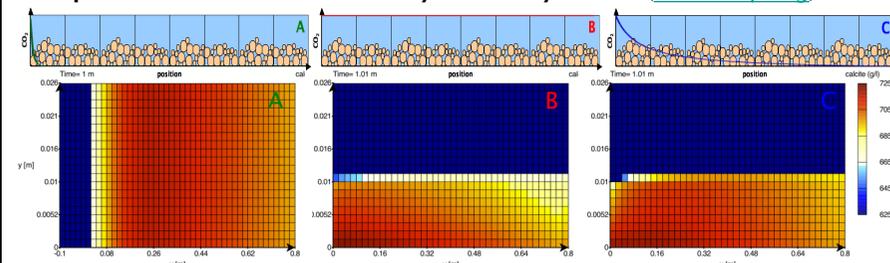
CO<sub>2</sub> injection scheme

## NUMERICAL MODELLING USING HYTEC

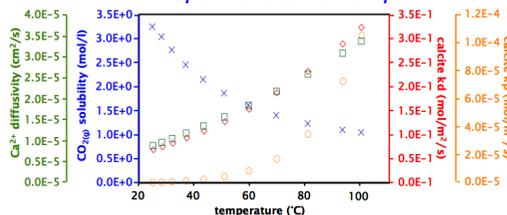
Temperature enhances both species transport and reactions kinetics, while CO<sub>2</sub> solubility also greatly decreases.

2D numerical simulations have been run with the following assumptions:

- purely diffusive transport (Oelkers & Helgeson 1988),
- kinetically controlled precipitation/dissolution (Kovac et al. 2006),
- aqueous reactions controlled by thermodynamics ([www.ctdp.org](http://www.ctdp.org)).



involved phenomena dependences vs temperature



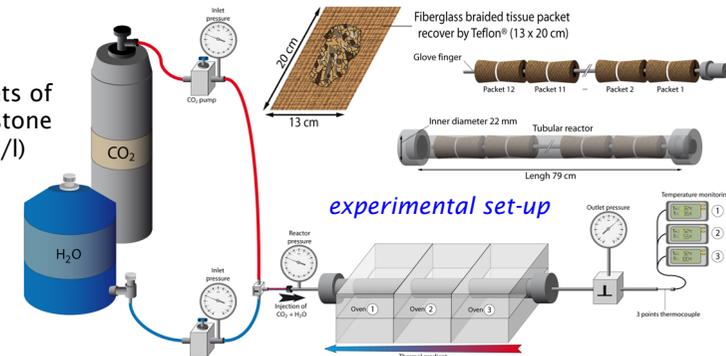
testing injection scenarios (CO<sub>2</sub> initial location and quantity)

- dissolution/transport competition is qualitatively reproduced.
- precipitation kinetics seems underestimated.
- efforts has still to be done on transport (porosity effect, advection...).

## COTAGES EXPERIMENT

### PROTOCOL

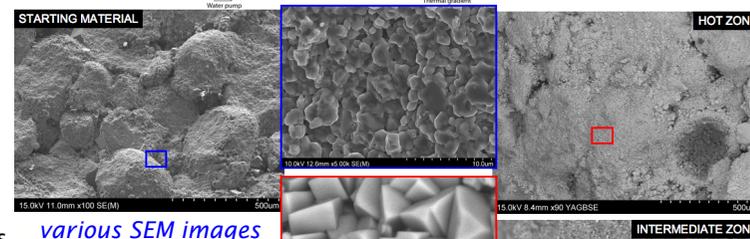
- Loading the reactor with 12 packets of 12.5 g each containing oolitic limestone
- Injecting solution (H<sub>2</sub>O + NaCl 4 g/l)
- Heating up zone 3 up to 100°C
- Reaching steady-state (zone 2 ≈ 55°C - zone 1 ≈ 30°C)
- Injecting CO<sub>2</sub> in the cold zone



### AFTER 30 DAYS OF EXPOSURE

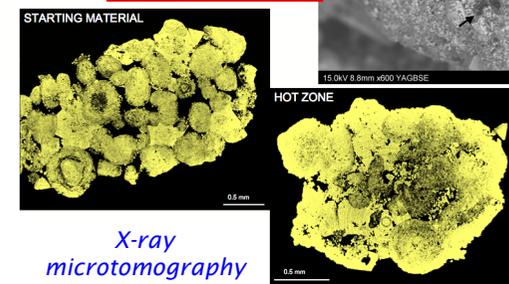
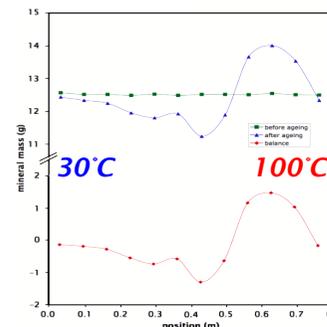
Mass transfer between the intermediate zone (2) and the hot zone (3)

- HOT ZONE (3) : carbonates precipitation on the surface of grains and formation of aggregates
- INTERMEDIATE ZONE (2) : dissolution around grains and etch pits on the surface of oolites
- COLD ZONE (1) : weak loss of mass linked to moderate dissolution



various SEM images

mass balance vs temperature



X-ray microtomography

## CONCLUSION & PERSPECTIVES

This problem is crucial as **injectivity shall be maintained** during the whole CO<sub>2</sub> injection and the combined approaches appear promising in this purpose. The developed **experimental set-up** will now be used to **test various assemblages** (cement, reservoir rocks, cap rocks, water composition, gas composition...). Greater analyses will help **improve our numerical model** and its ability to **reproduce quantitatively experimental results** and possibly **allow upscaled predictions**.