

Both experimental study and numerical modelling of the effect of temperature gradient on CO₂ injection

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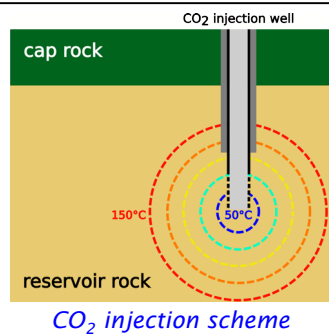
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CONTEXT

CO₂ 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) CO₂ 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.

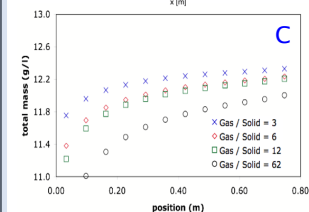
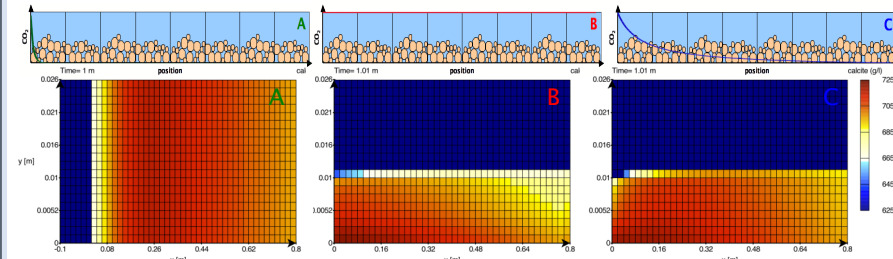


NUMERICAL MODELLING USING HYTEC

Temperature enhances both species transport and reactions kinetics, while CO₂ solubility also greatly decreases.

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

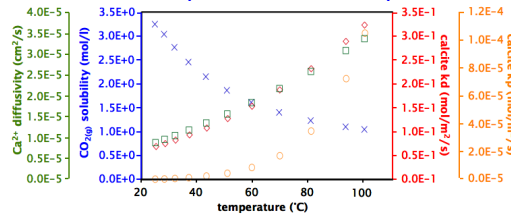
- purely diffusive transport (Oelkers & Helgeson 1988),
- kinetically controlled precipitation/dissolution (Kovac et al. 2006),
- aqueous reactions controlled by thermodynamics (www.ctdp.org).



testing injection scenarios (CO₂ 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...).

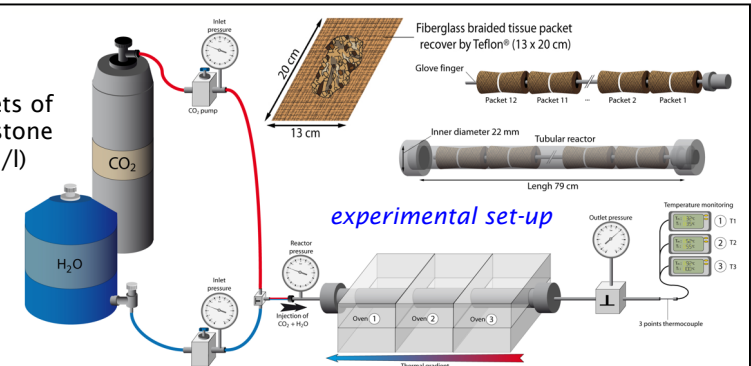
involved phenomena dependences vs temperature



COTAGES EXPERIMENT

PROTOCOL

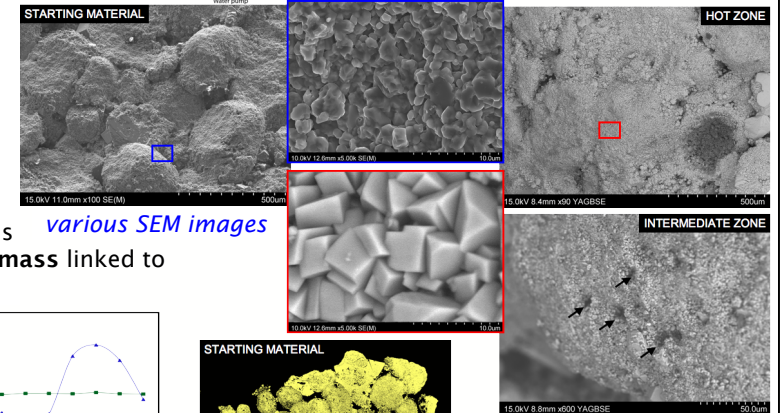
- Loading the reactor with 12 packets of 12.5 g each containing oolitic limestone
- Injecting solution (H₂O + NaCl 4 g/l)
- Heating up zone 3 up to 100°C
- Reaching steady-state (zone 2 ≈ 55°C - zone 1 ≈ 30°C)
- Injecting CO₂ in the cold zone



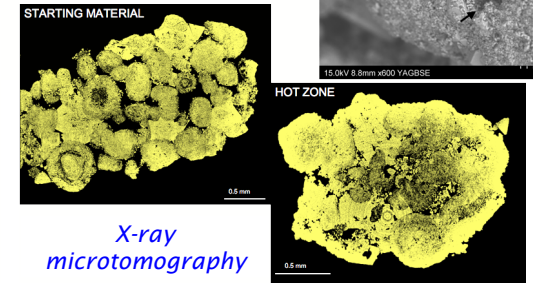
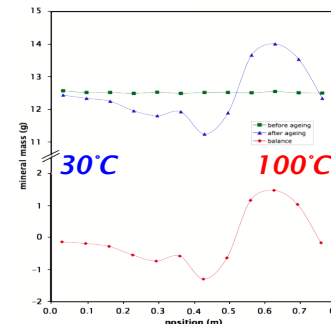
AFTER 30 DAYS OF EXPOSURE

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



mass balance vs temperature



CONCLUSION & PERSPECTIVES

This problem is crucial as **injectivity shall be maintained during the whole CO₂ 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**.