3D reactive transport (RT) modeling of CO_2 injection in a limestone core: wormhole formation

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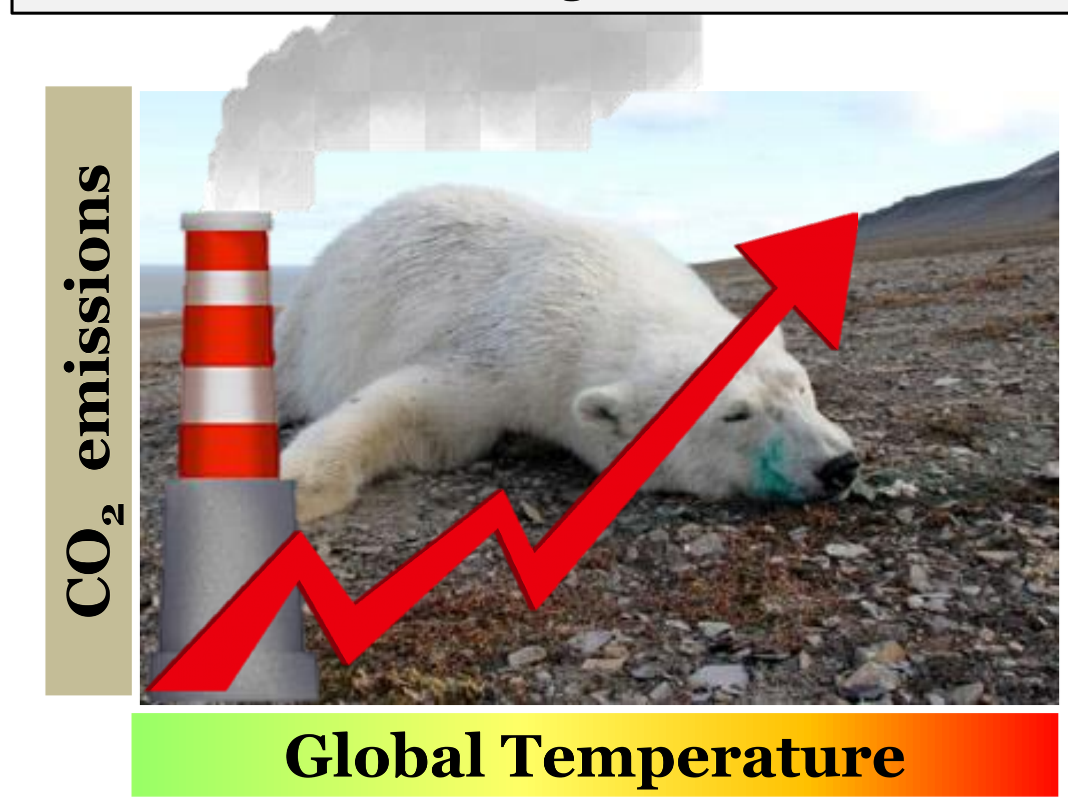
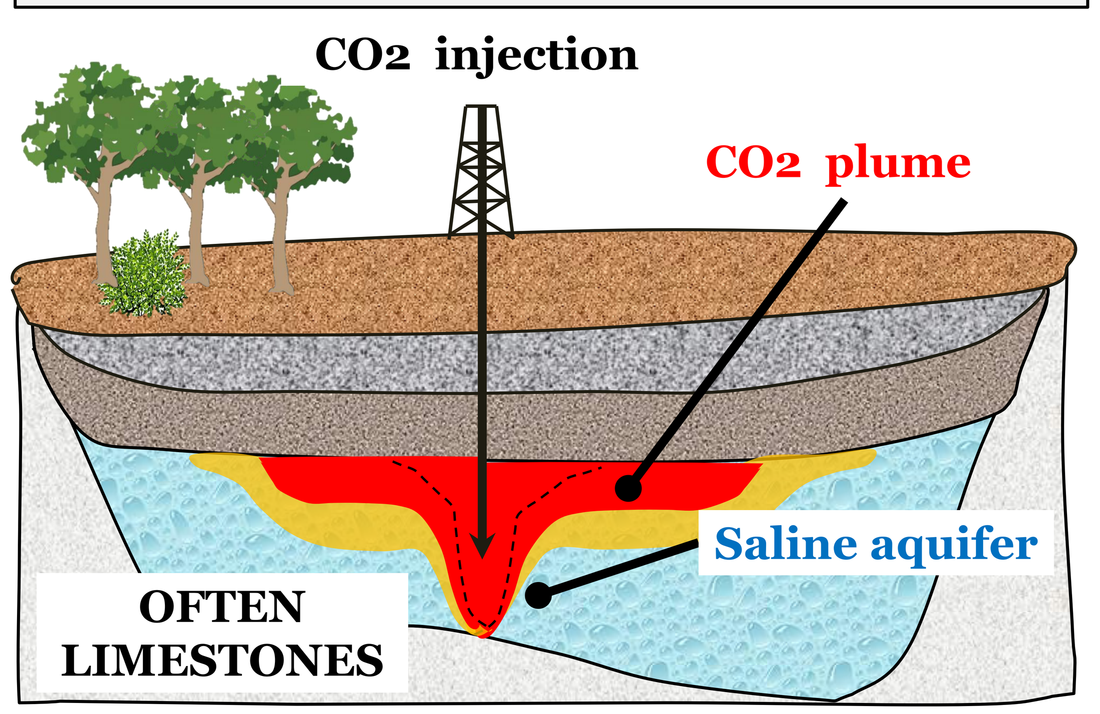
Introduction

Global warming is a fact! It needs urgent action!



CO2 storage is a part of solution!



Limestones response to acidic CO2:
- ***Localized dissolution***
- ***Hard to predict permeability changes***

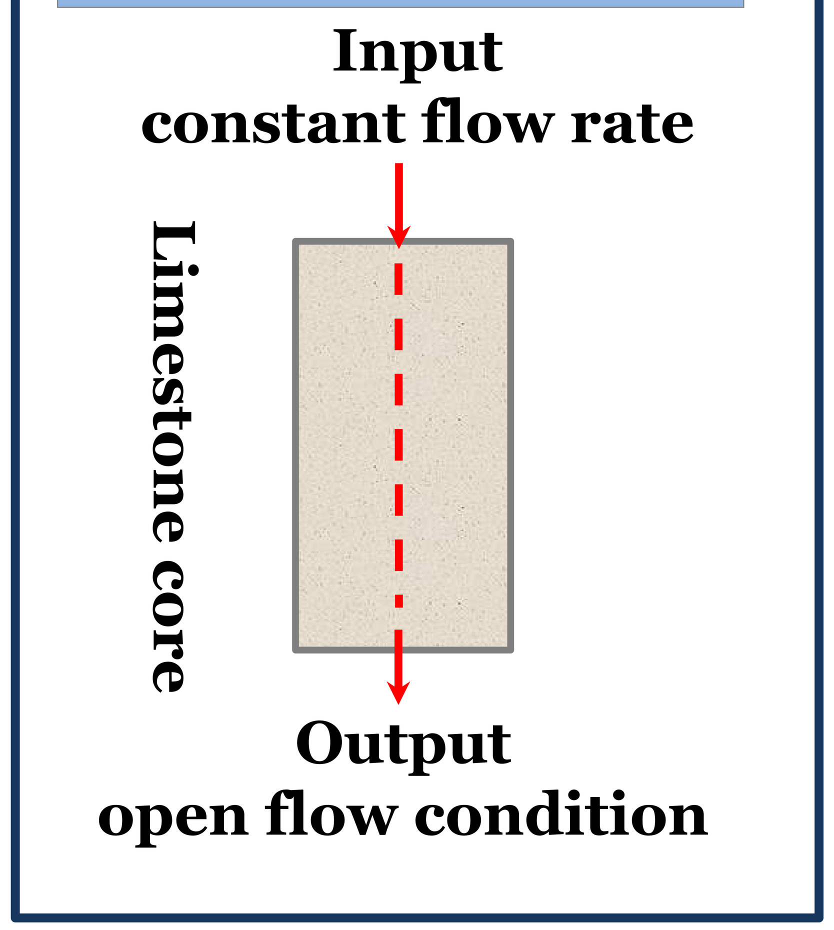
Percolation experiment

Percolation experiment with ***CO2-rich water*** is performed with ***Pont Du Gard limestone.*** Geochemical processes are interpreted by RT modeling at millimeter scale.

Conditions
Sample length = 4.4 cm
Sample diameter = 2.5 cm
Flow rate = 0.15 mL/min
Temperature = 60 °C
P_{CO_2} = 100 bar
[CO2]= 1.02 mol/kgw
Duration = 4 weeks

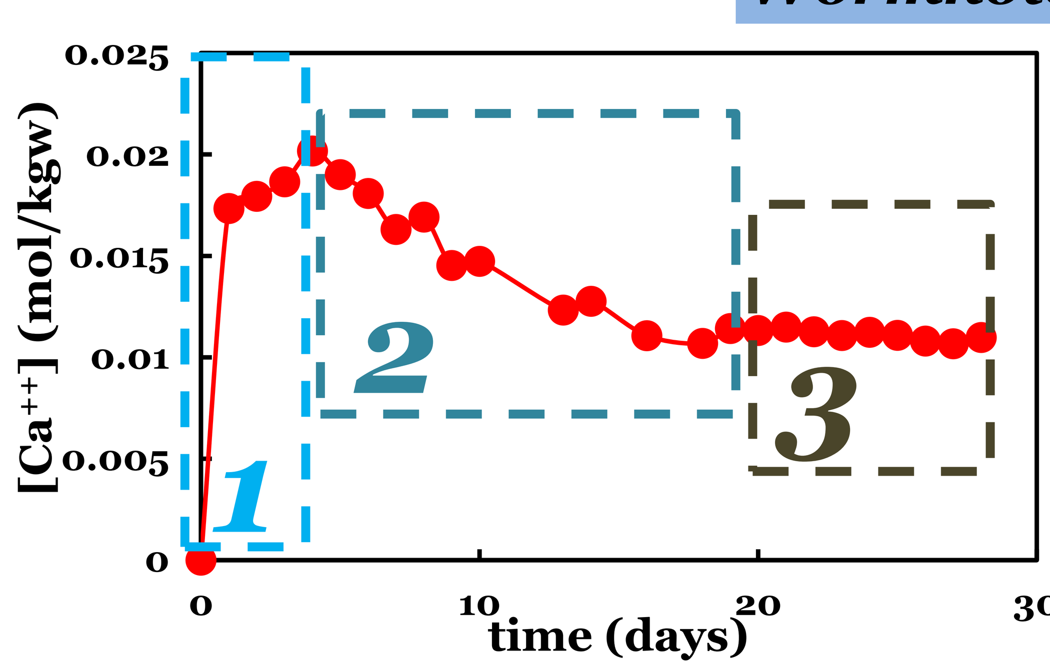
Baseline evaluations
Effluent chemistry analysis
XCMT analysis
Porosity measurement
Permeability measurement

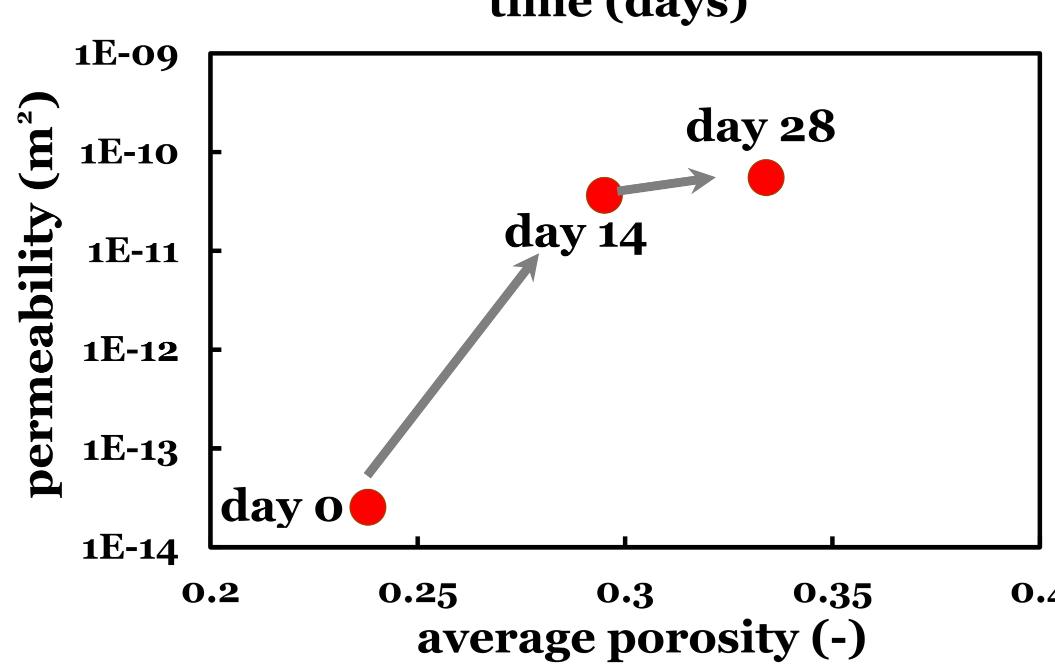
Schematic of injection experiment



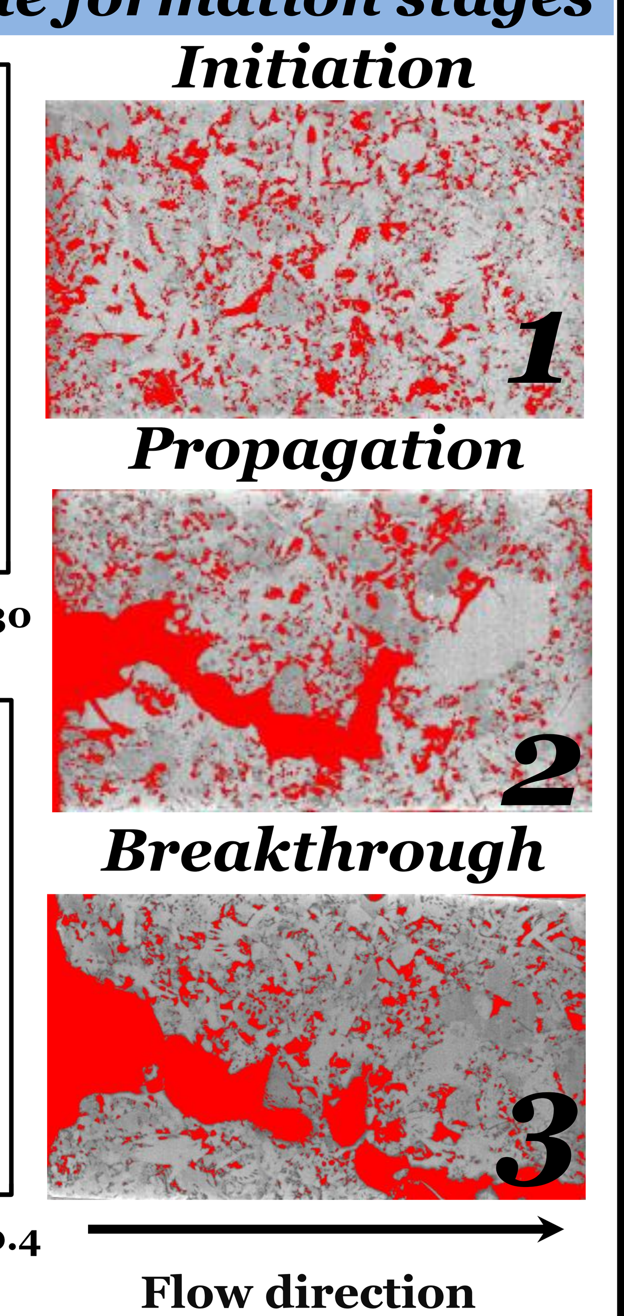
Experimental Results

- ***Dissolution leads to formation of wormhole***
- ***10 % increase in porosity***
- ***2000-fold increase in permeability***

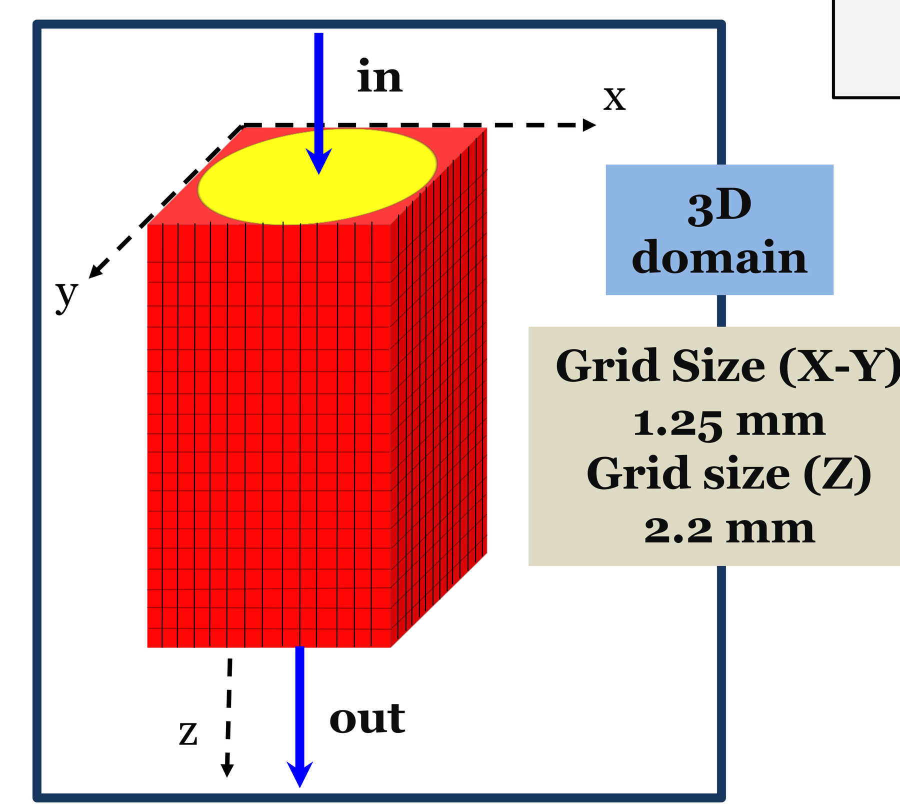




Wormhole formation stages



Numerical simulation



3D RT simulation (CrunchFlow code)

Initial and boundary conditions (2 replicates)
No-flow lateral boundaries
Constant outlet pressure
Constant inlet flux

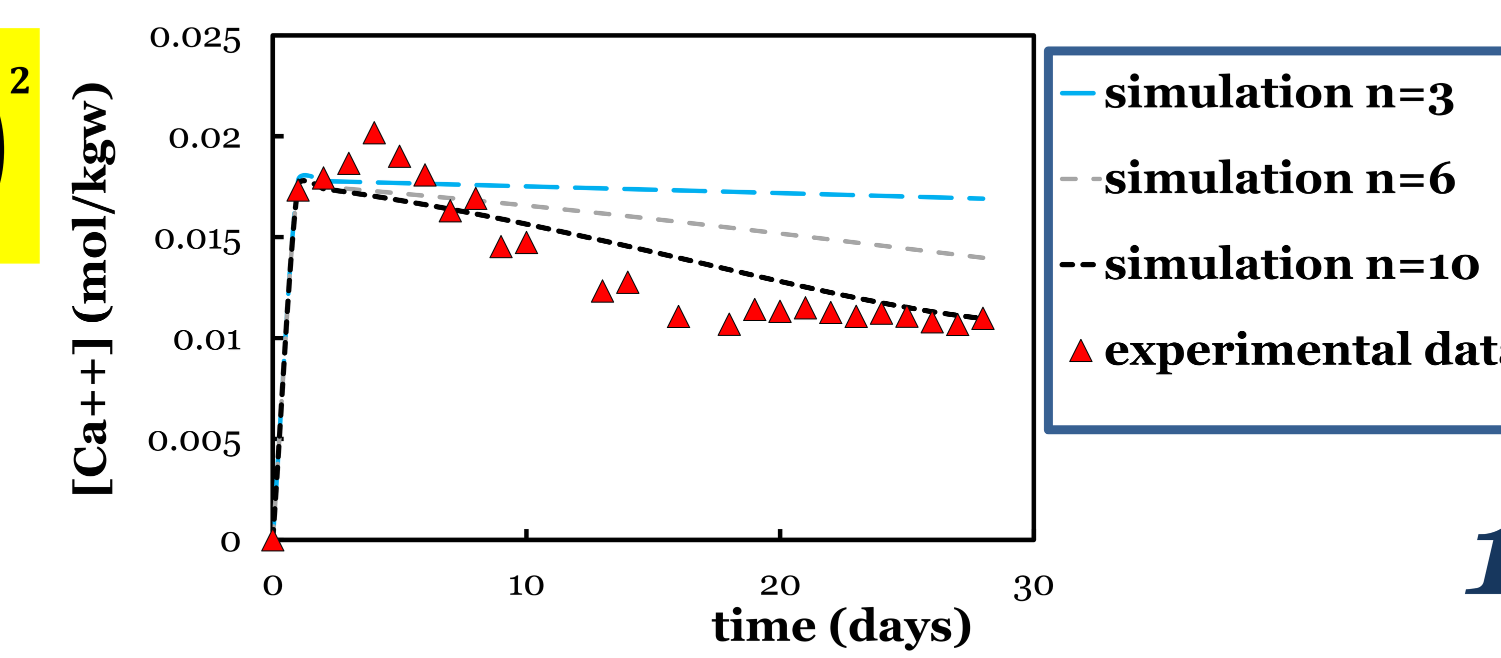
Initial heterogeneity is considered
3D porosity and permeability maps are constructed using CT images and the MATLAB code.

3D simulation results

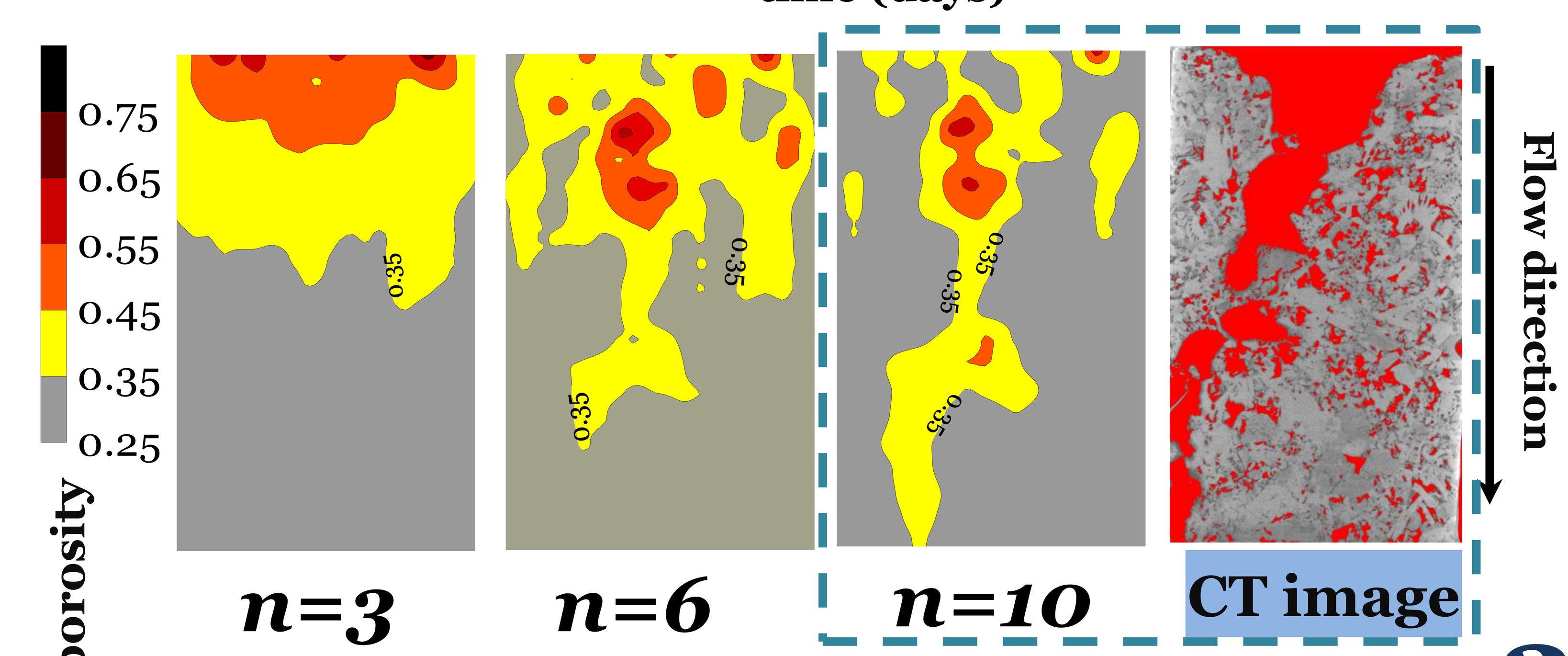
- In the RT model, ***the porosity-permeability relationship requires updating*** for an effective interpretation of the evolution of pore space in ***heterogeneous limestones***.

$$\frac{k}{k_0} = \left(\frac{\phi}{\phi_0}\right)^n \times \left(\frac{1-\phi_0}{1-\phi}\right)^2$$

Needs modification



Effect of different values on results



Key findings

- *The infiltration of* ***CO2-saturated waters*** into ***carbonate rocks*** leads to the formation of ***highly conductive wormholes***!
- *In* the power-law porosity-permeability relationship, ***high values for the n coefficient (e.g., 10 in our case) are needed*** to simulate the wormhole structures and to better reproduce the experimental data!