Effect of CO_2-rich water injection on the hydromechancial properties of Pont Du Gard limestone

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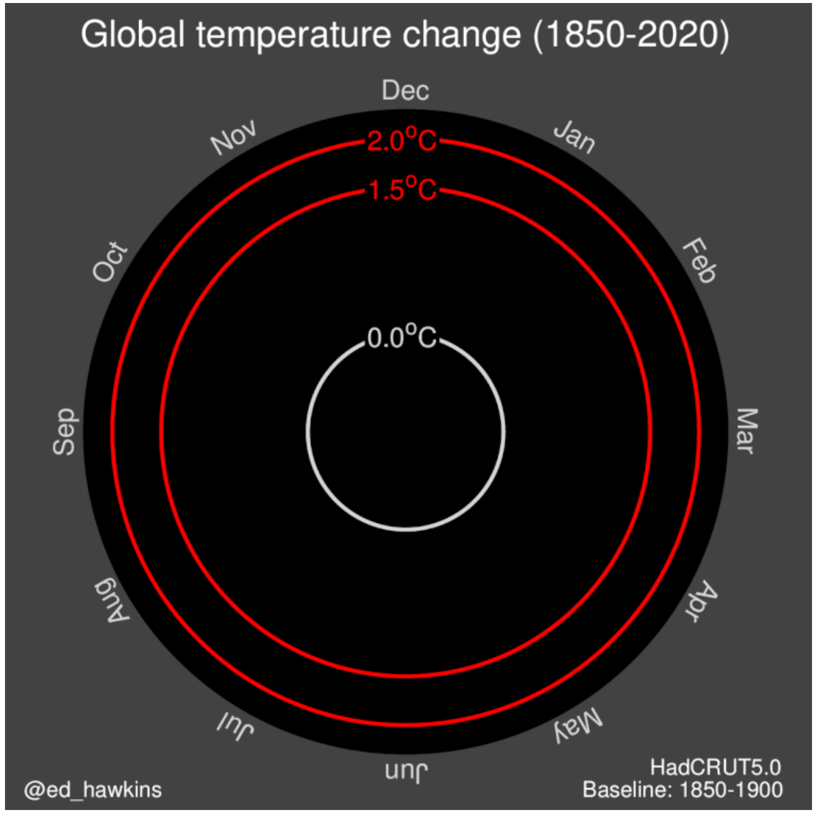
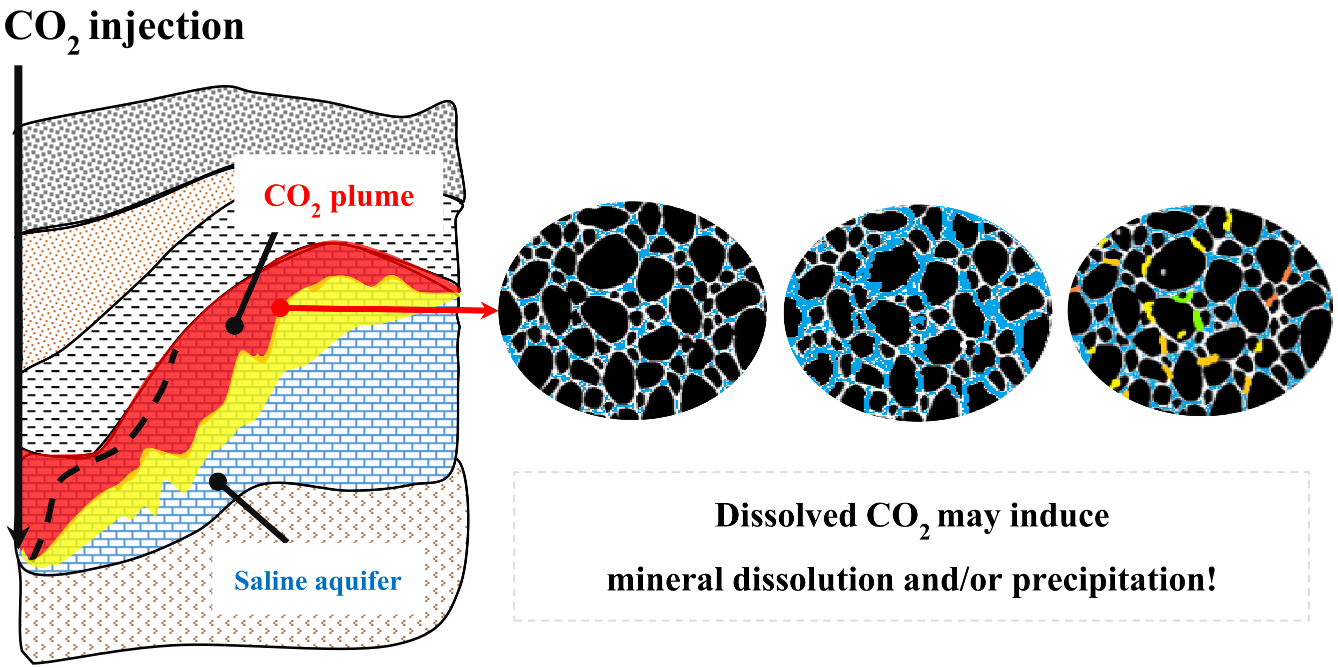
It is essential to curb atmospheric CO_2 emissions to avoid catastrophic global warming and associated climate change!

Geologic Carbon Storage (GCS) is a critical but less-well understood piece of the climate puzzle!



2020 was the hottest year on record since 1850!

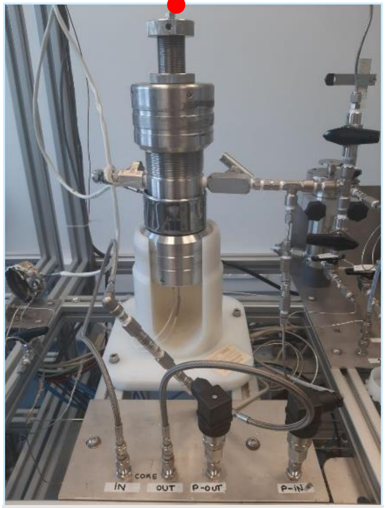


Dissolved CO_2 may induce mineral dissolution and/or precipitation!

CO_2-induced reactions cause irremediable alterations in rock properties!

Assessing rock alterations brought on by CO_2 injection at different temporal and spatial scales is a priority!

Lab experiments at core-scale are employed to assess short term alterations in rock!



Flow-through setup

Experimental conditions:

CO_2-saturated water injection

time = 2-4 weeks

T = 60 ˚C

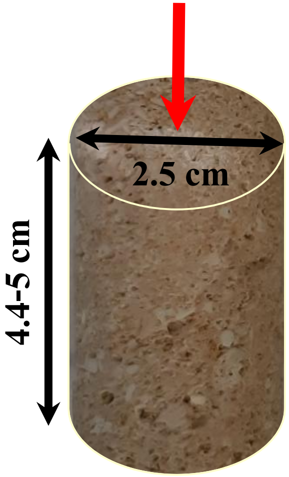
PCO_2 = 100 bars

Q = 0.15 mL/min

pH = 3.14

Percolation experiments are conducted on two heterogeneous limestone cores

Pre- and post-reaction evaluations to assess the evolution of hydromechancial properties of the cores.

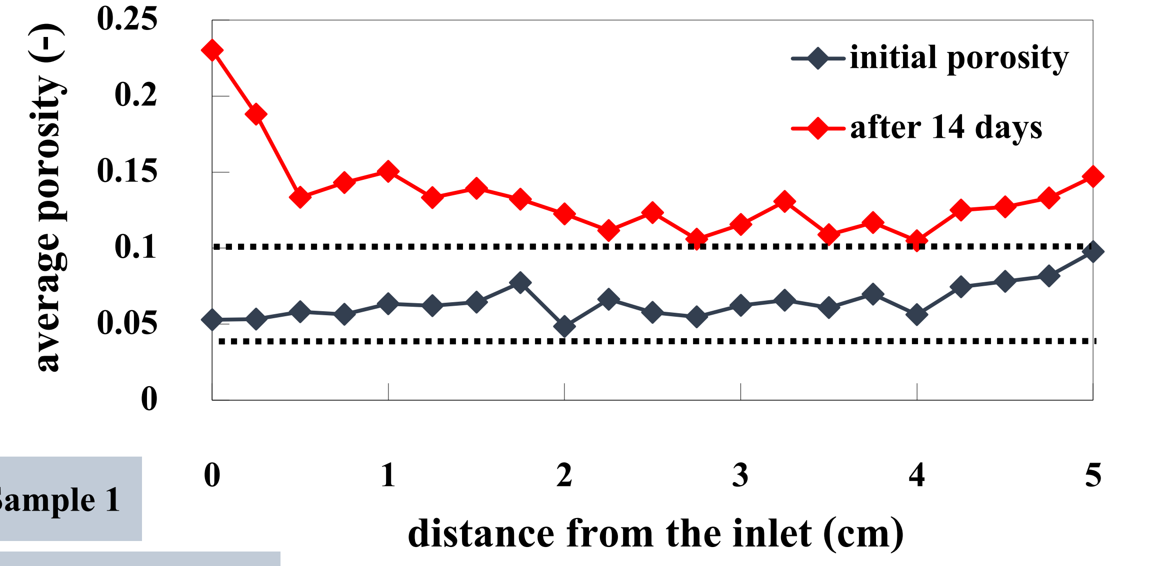


- ✓ Porosity and permeability measurements
- ✓ X-ray Micro Computed Tomography
- ✓ ICP-OES/ aqueous chemistry analysis
- ✓ Ultrasonic velocity measurement

Pont Du Gard limestone ~ 100% calcite

Calcite dissolution leads to substantial increase in the porosity of the specimens!

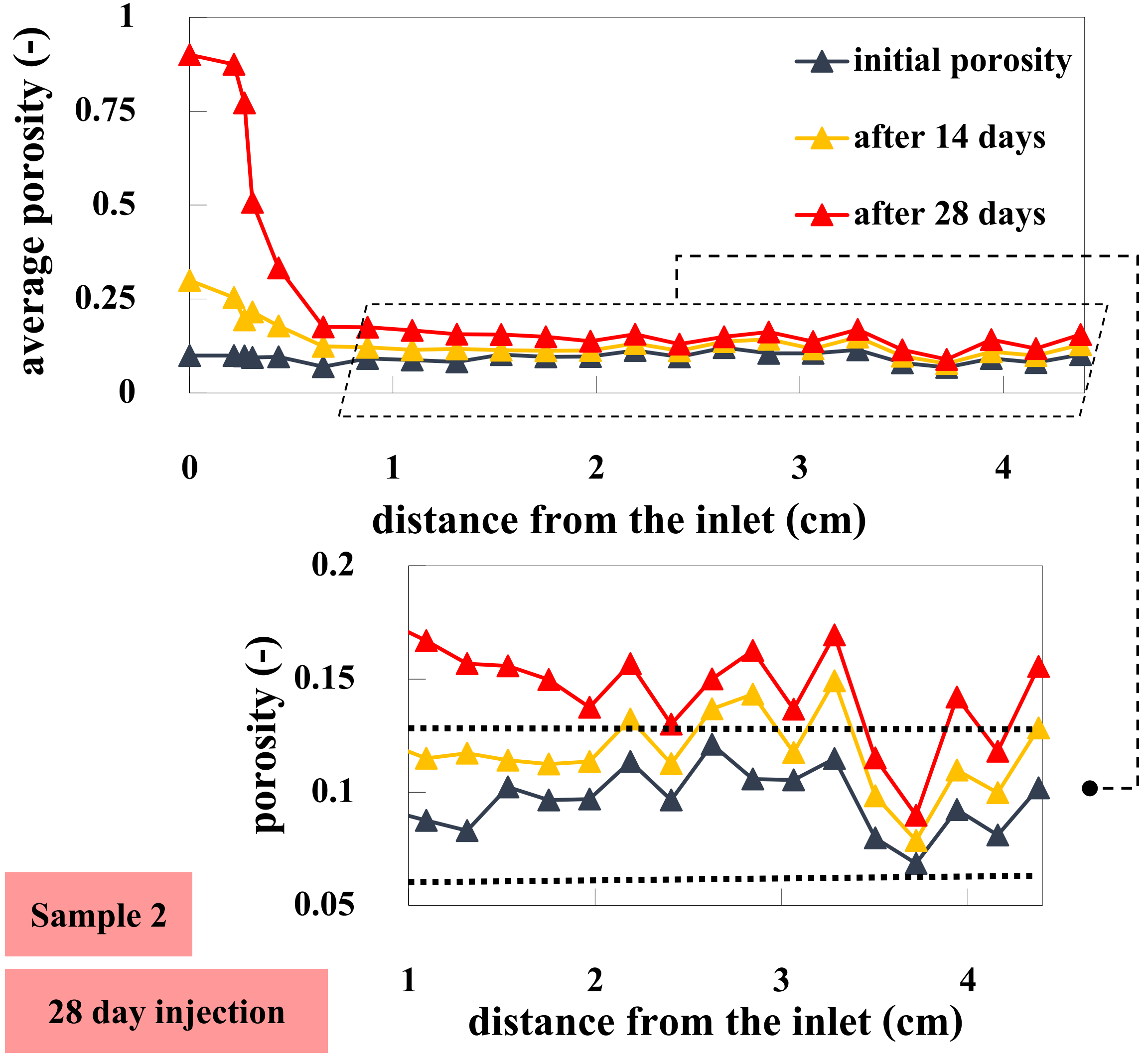
CT porosity profiles disclose the initial heterogeneity of the limestone specimens!



Sample 1

14 day injection

Average porosity profiles along the core length before and after injections reveal significant enhancement in porosity. Increase is however more pronounced at the inlet!

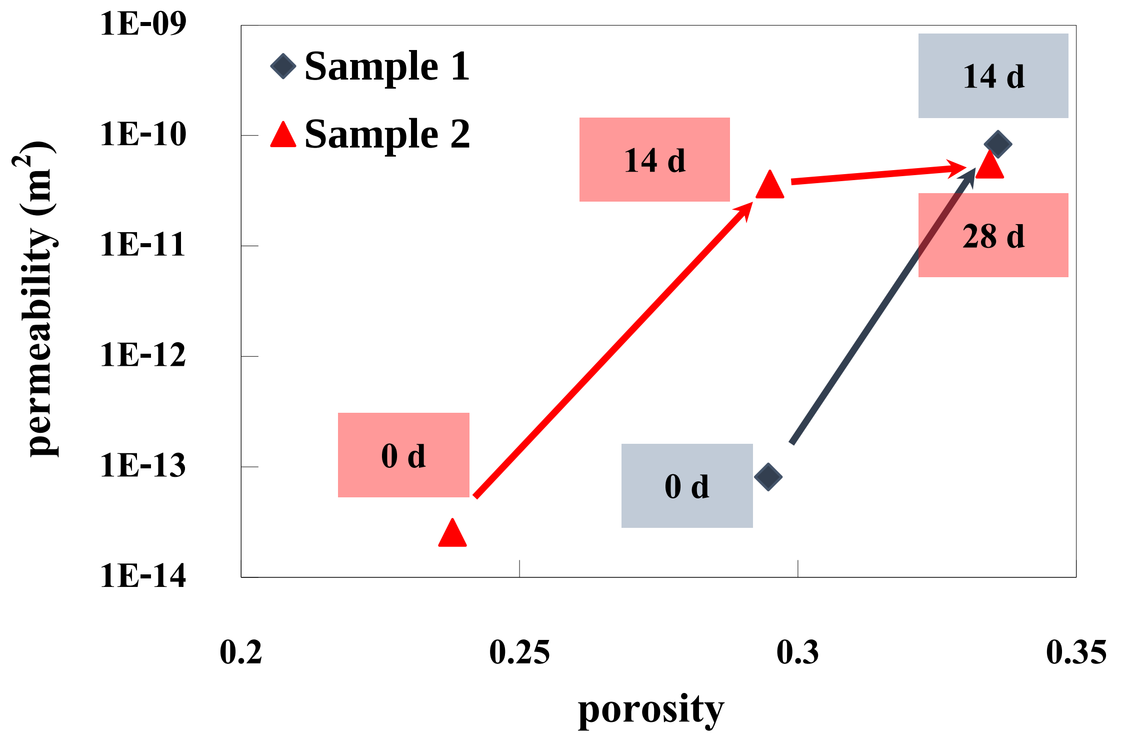


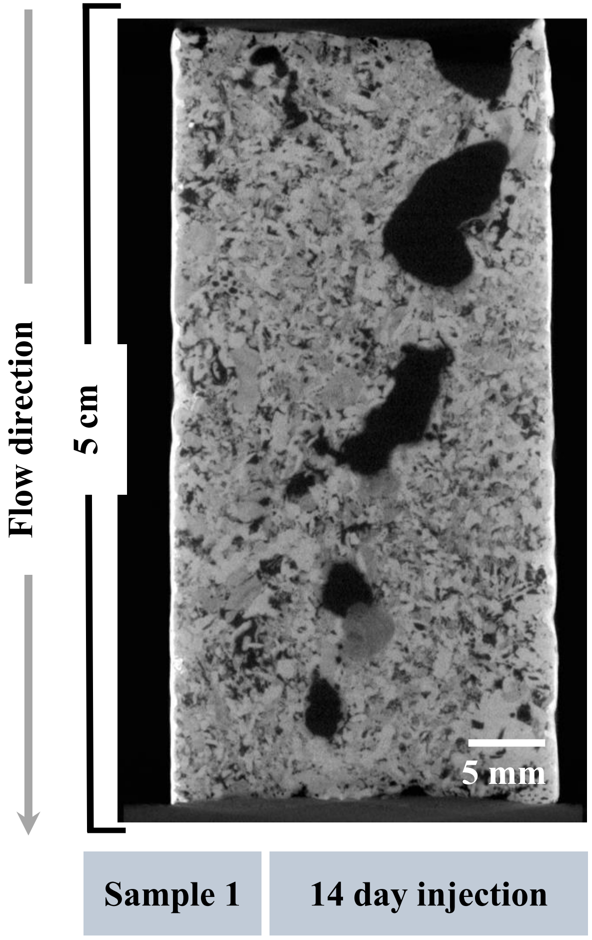
Sample 2

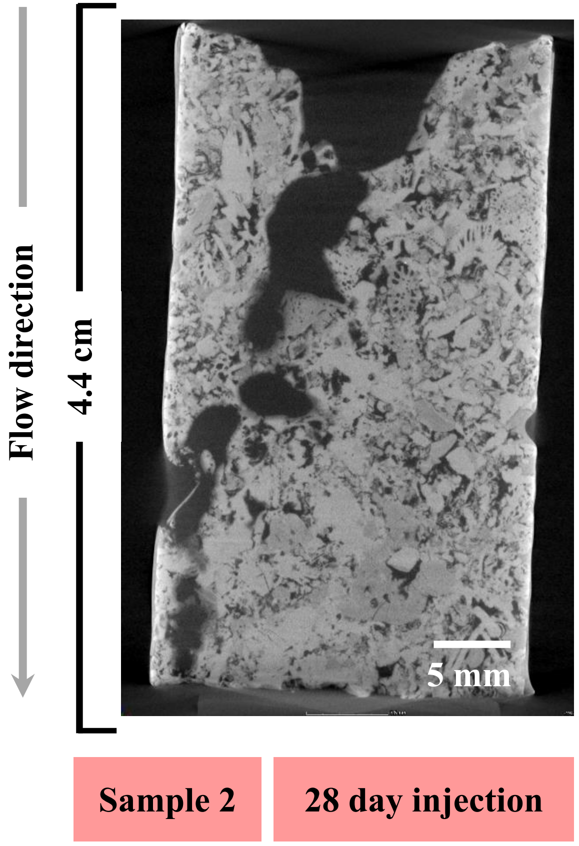
28 day injection

Porosity enhancement is associated with sharp permeability increase caused by wormhole formation!

Wormhole originates from the rapid dissolution rates of calcite and heterogeneous flow profiles!



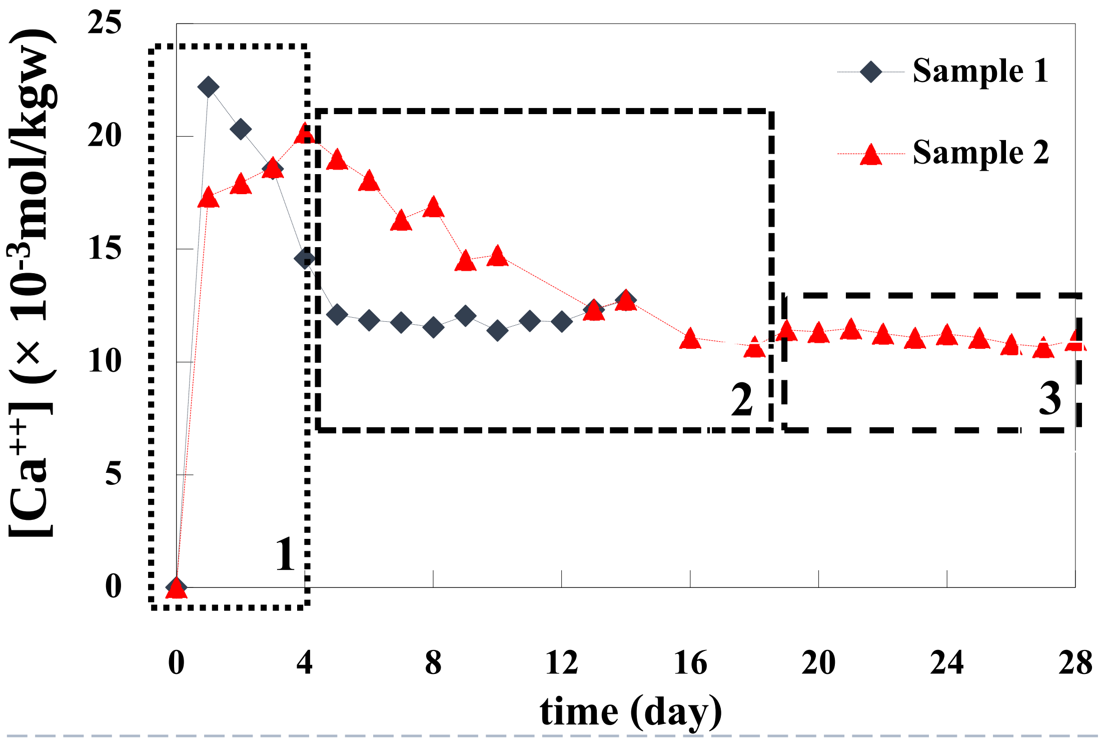


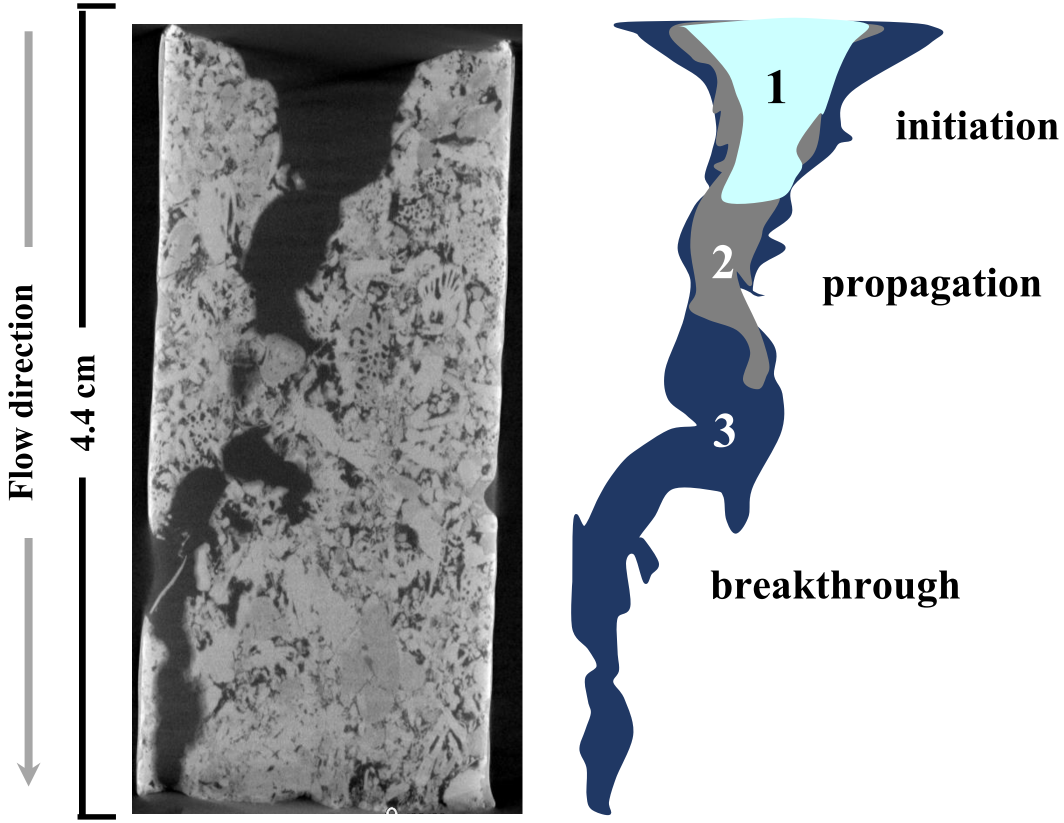


Formation of highly conductive wormholes is a challenge to predict permeability variation using general power-law porosity-permeability relationships!

Aqueous chemistry correlates with wormhole formation phases!

Distinct phases of initiation, propagation, and breakthrough are determined using the evolution of Ca concentration!

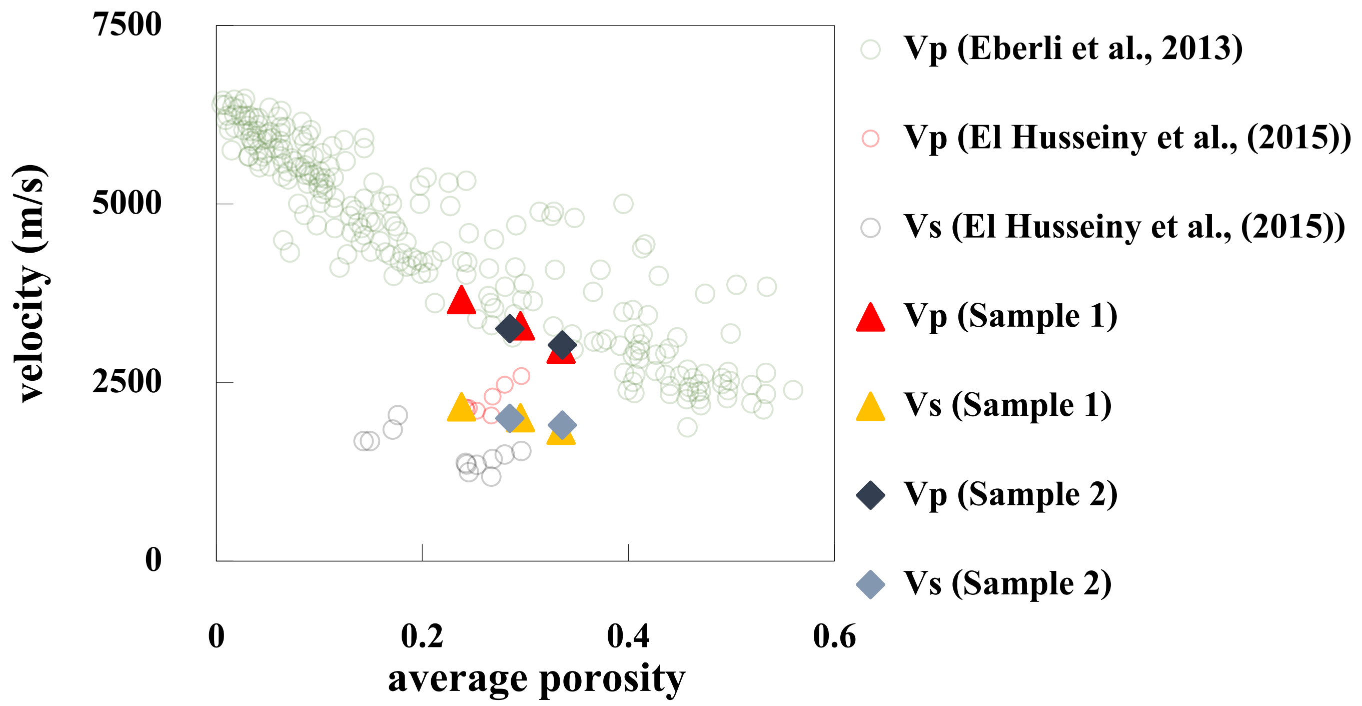


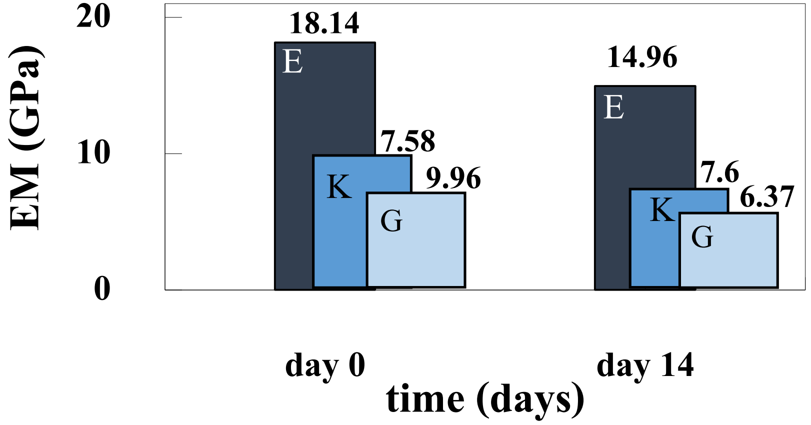


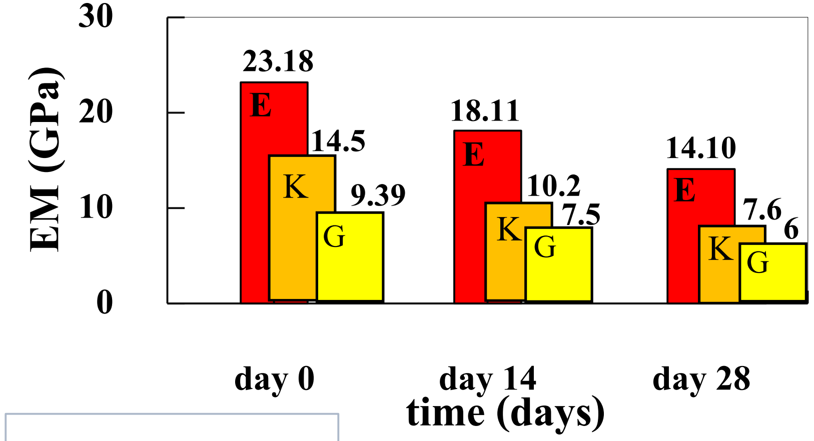
Propagation of wormhole throughout the core reduces effective/accessible reactive surface area and, thus, the net calcite dissolution rate!

Dissolution-induced enhancement in porosity diminishes acoustic velocity and rock stiffness!

Velocity reduction upon dissolution follows the general velocity-porosity trend in carbonates!







E: Young's modulus

K: Bulk modulus

G: Shear modulus

Wormhole creation is also a challenge to evaluate the rock mechanical properties! We need to build a physics-based model to predict elastic properties evolution and its effect on reservoir integrity, which is currently underway!

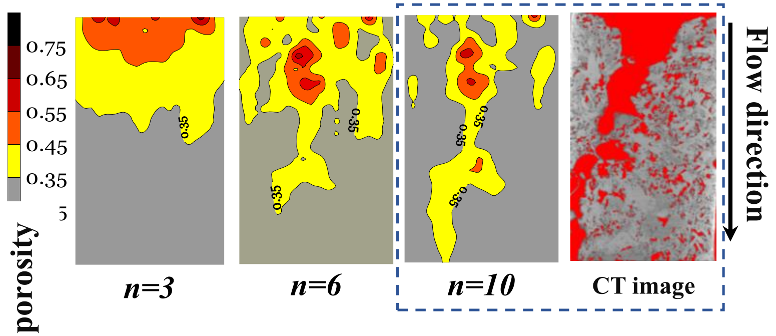
Key findings and outlook

Transport and reaction of CO_2-rich brines results in substantial increase in porosity and permeability of highly reactive carbonates.

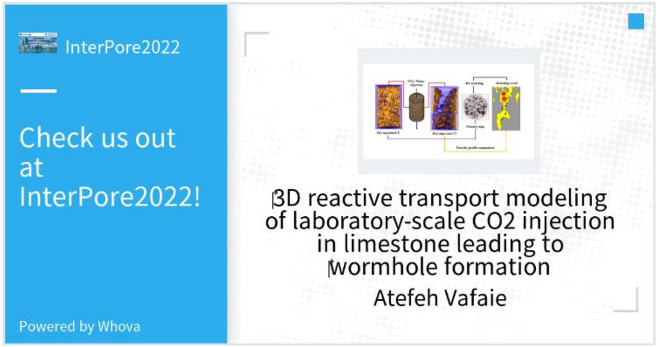
Porosity enhancement commonly coincides with creation of highly conductive channels (i.e., wormholes), weakening the rock framework.

Wormhole creation makes prediction of permeability changes difficult.

- **Modified power-law porosity-permeability relationships are required to capture the pore-space evolution in carbonates.**



$$\frac{k}{k_0} = \left(\frac{\emptyset}{\emptyset_0}\right)^n \times \left(\frac{1-\emptyset_0}{1-\emptyset}\right)^2$$



Physic-based models are also required to predict the evolution of carbonates' elastic properties when interacting with CO_2 .

Acknowledgments

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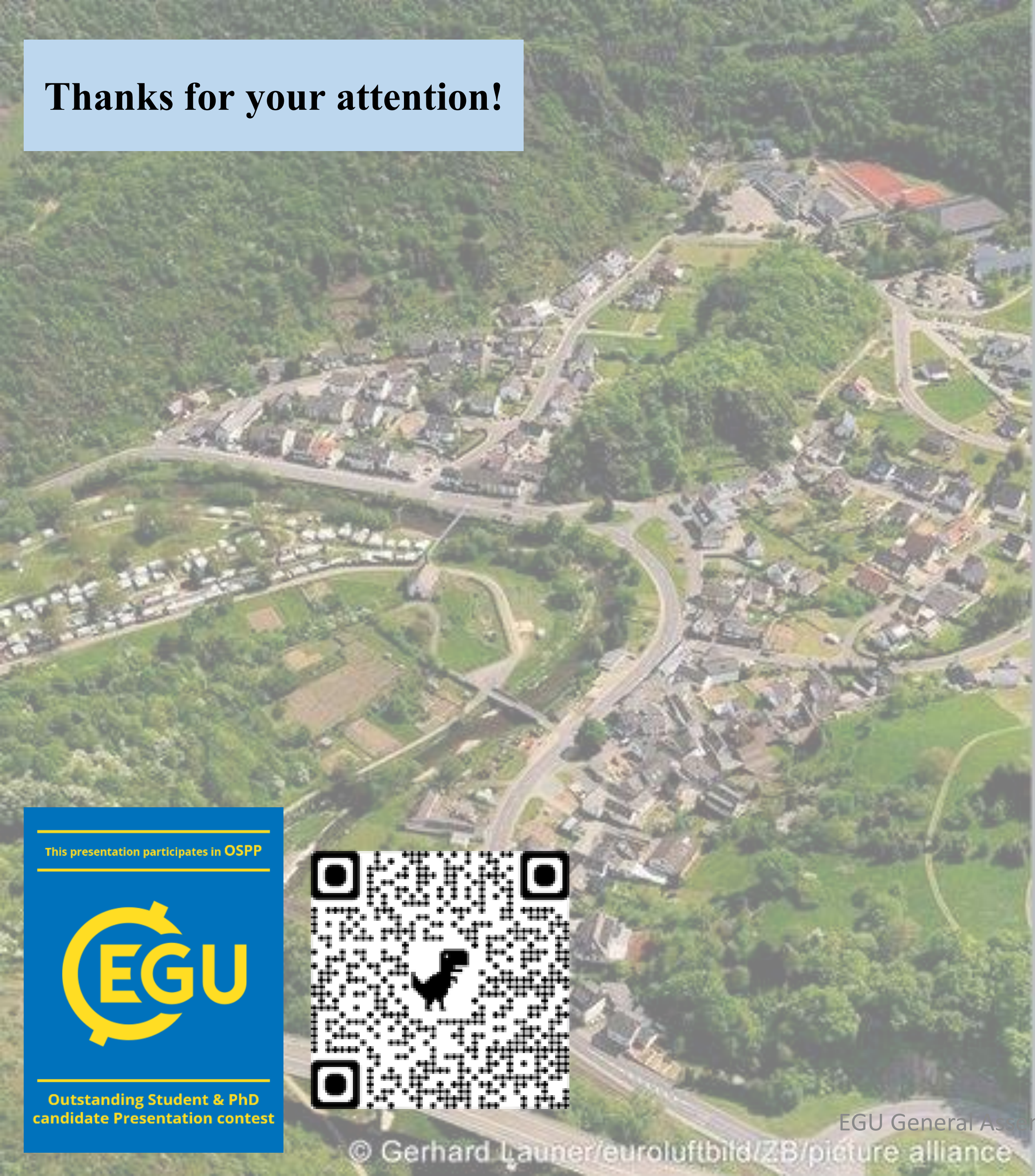
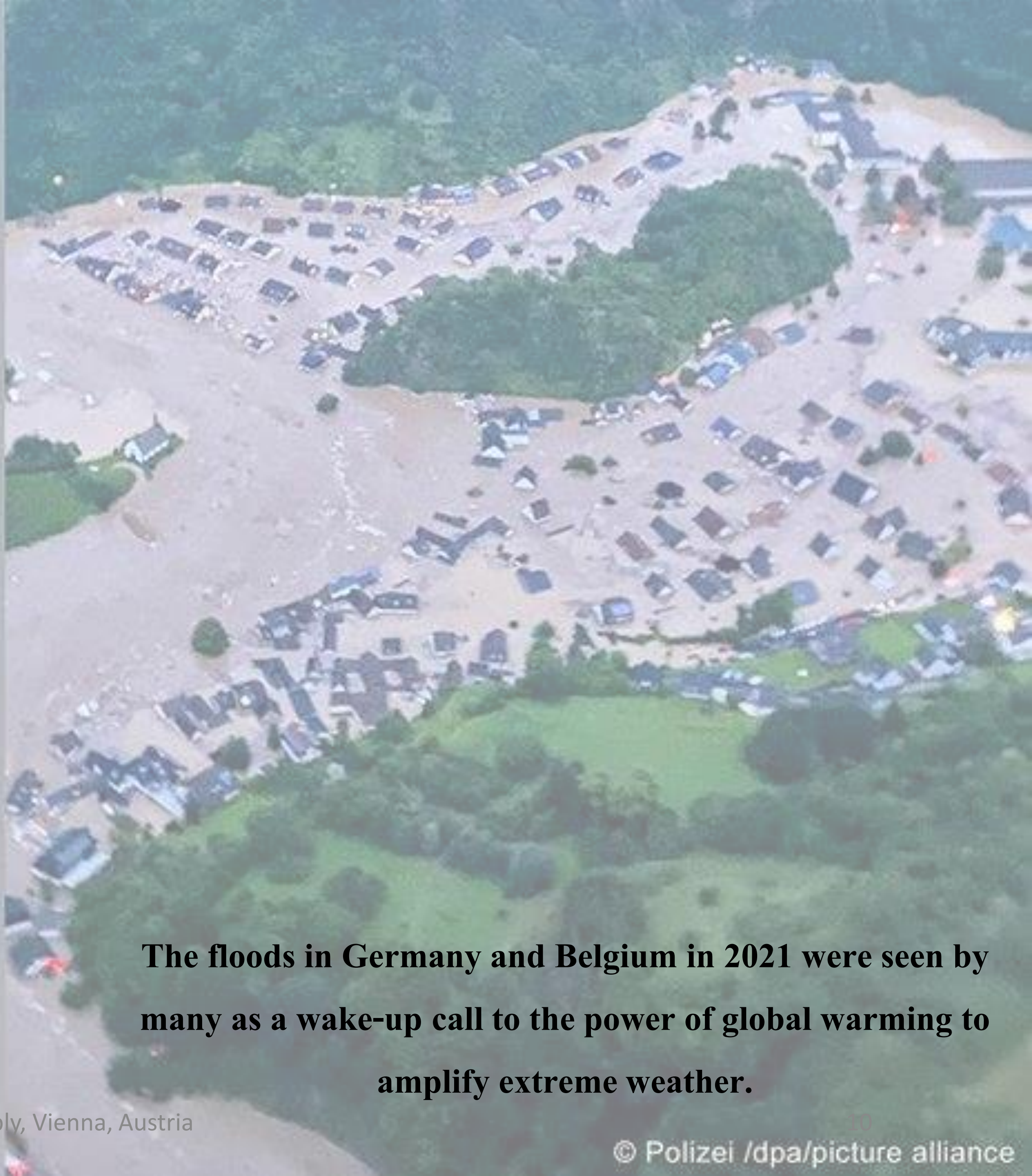
Thanks for your attention!





The floods in Germany and Belgium in 2021 were seen by many as a wake-up call to the power of global warming to amplify extreme weather.

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