University of Stuttgart

InterPore
May 2025, Albuquerque

Phase redistribution in heterogeneous porous media during periods of no flow

Amir Reza Zargar and Maartje Boon

Institute of Applied Mechanics & SC SimTech, University of Stuttgart, Germany

amir-reza.zargar@mib.uni-stuttgart.de

Motivation

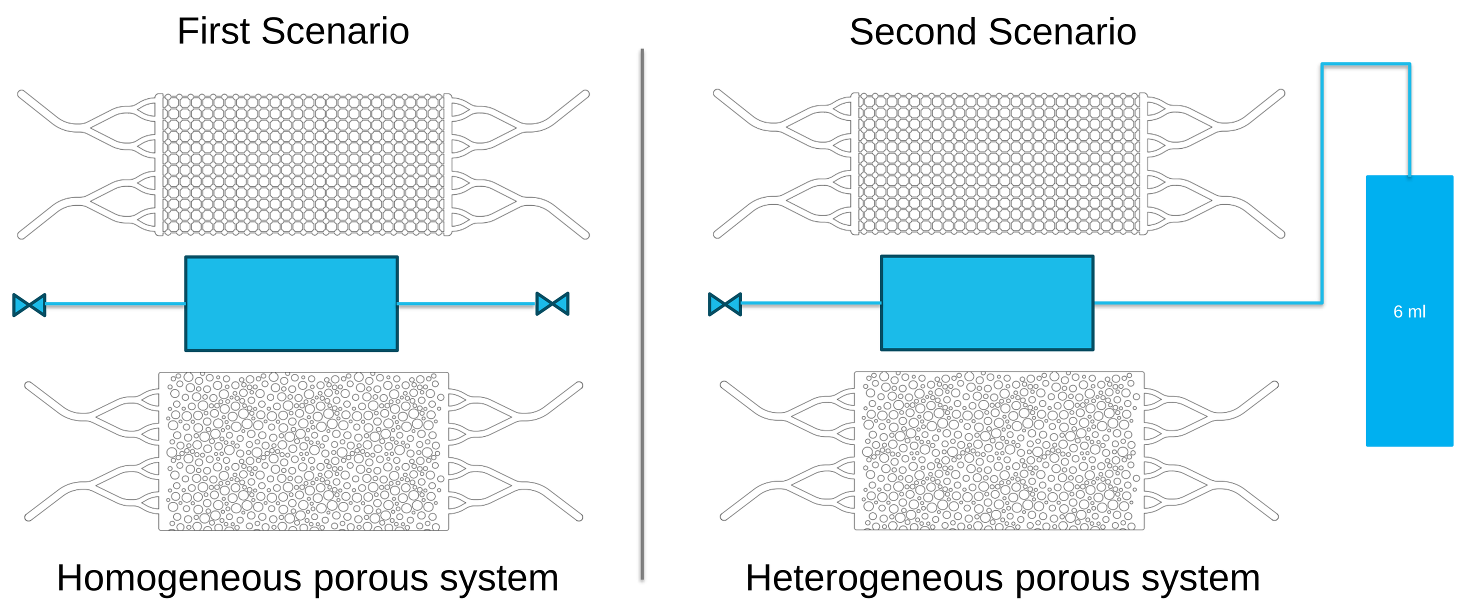
- Geological carbon sequestration and underground hydrogen storage in heterogeneous porous reservoirs could play a key role in the transition toward clean energy production.
- Next to the periods of injection and production, there are periods of no flow.
- During periods of no flow, dissolution and exsolution processes can lead to the redistribution of the liquid and gas phases.

Objective: Study phase redistribution in homogeneous and heterogeneous (fracture or very coarse sandstone) porous media during periods of no flow.

Current state of work

Microfluidic experiments:

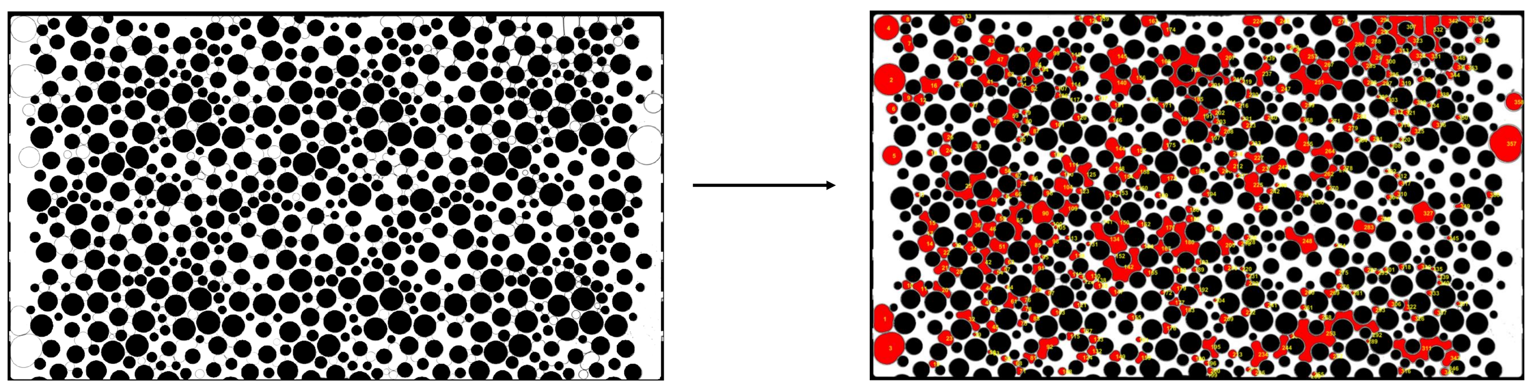
I. Material and Methods



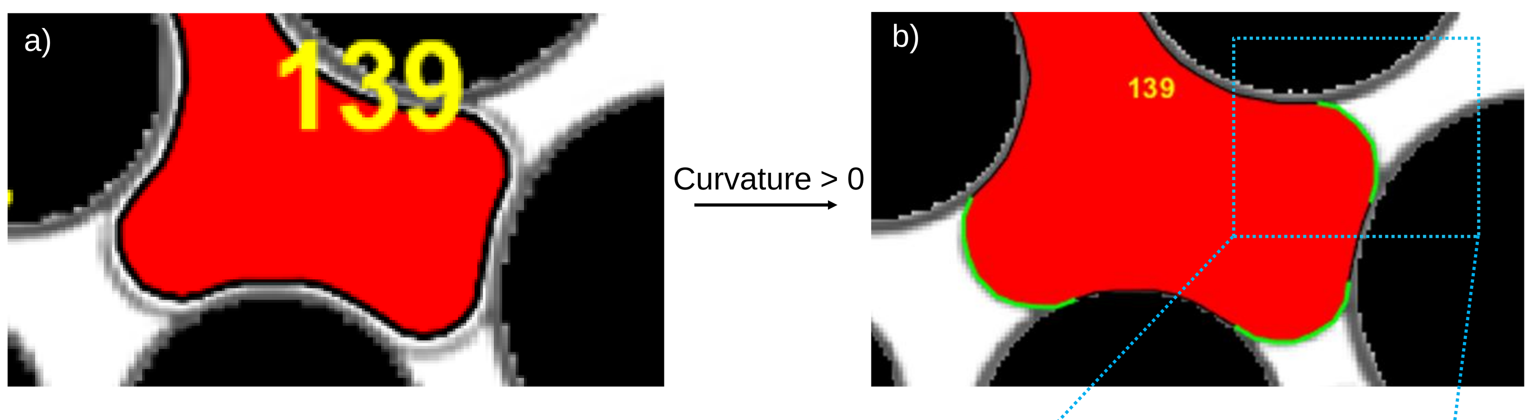
- CO_2/water system. Bromothymol blue pH indicator is added to the water to characterize the dissolved CO_2 concentration.

Image processing tool developed in MATLAB

- Gas ganglia identification and labelling



- Gas/water interface identification, contact angle and capillary pressure measurement



- Average contact angle of each interface

$$\theta_{avg,i} = \frac{\theta_1 + \theta_2}{2}$$

- Capillary pressure of each interface

$$P_{c,i} = \sigma^{\omega n}\left(k_i + 2\frac{cos\theta_{avg,i}}{d}\right)$$

- Area of interface of each interface

$$A_i^{\omega n} = \frac{L_i d}{cos\theta}\left(\frac{\pi}{2} - \theta\right)$$

- Capillary pressure of each ganglia

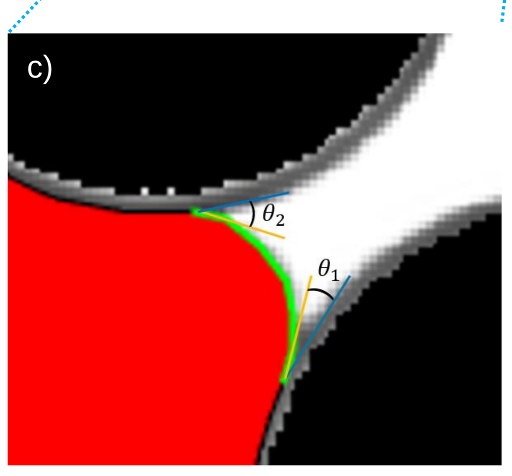
$$P_{c,gan_i} = \frac{\sum (P_{c,i} A_i^{\omega n})}{\sum A_i^{\omega n}}$$

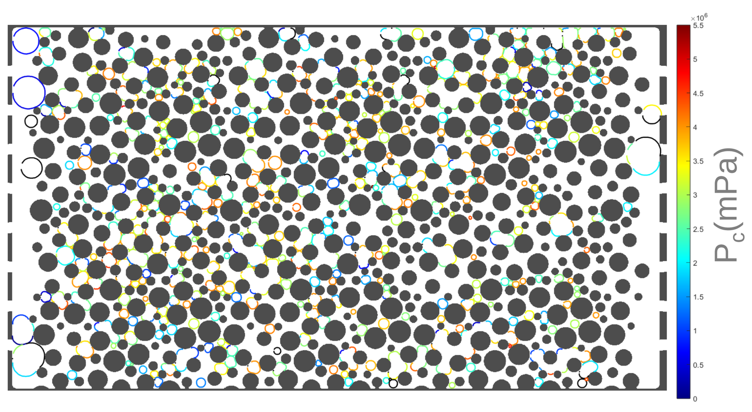
- Total area of interface of each ganglia

$$A_{gan_i}^{\omega n} = \sum A_i^{\omega n}$$

- Average capillary pressure of the system

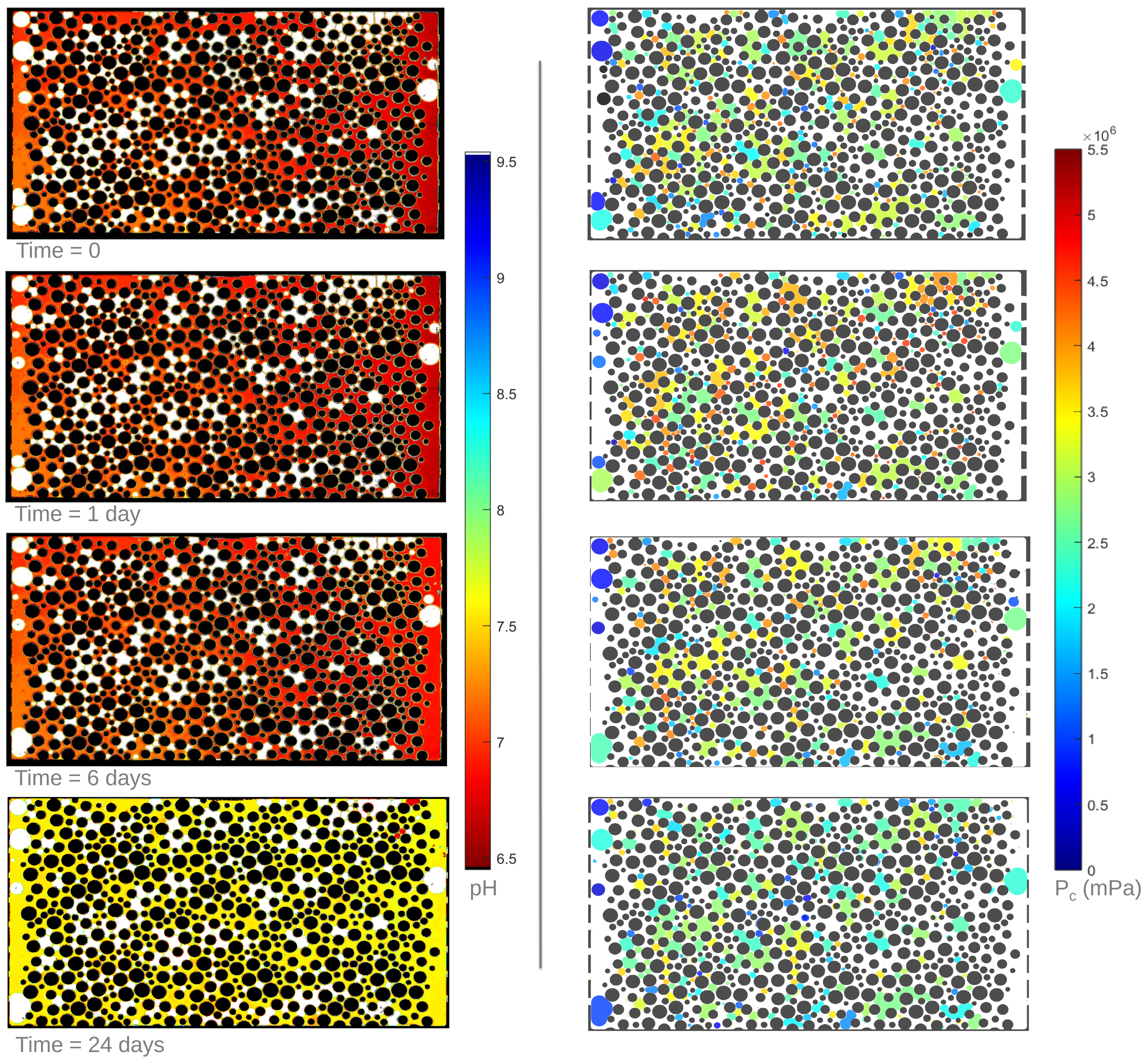
$$P_{c,avg} = \frac{\sum (P_{c,gan_i} A_{gan_i}^{\omega n})}{\sum A_{gan_i}^{\omega n}}$$

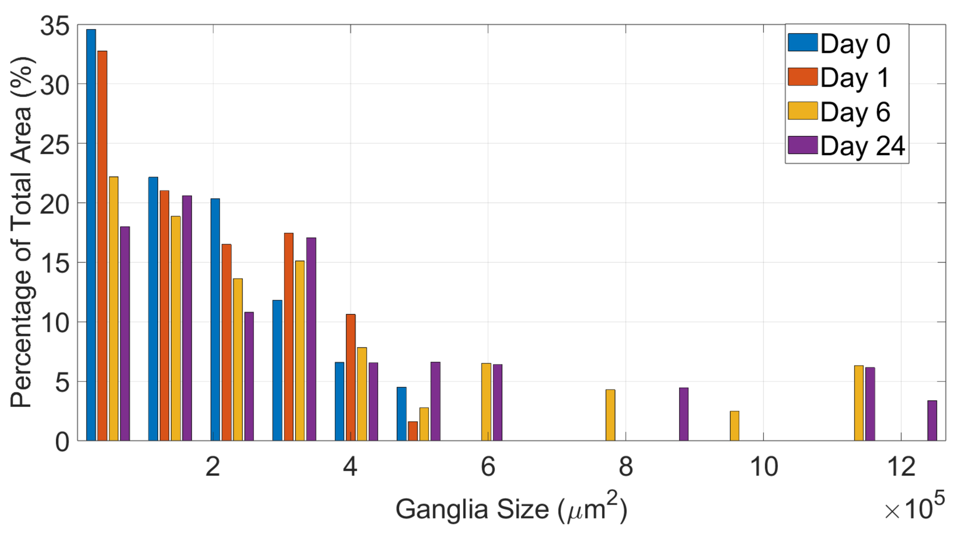


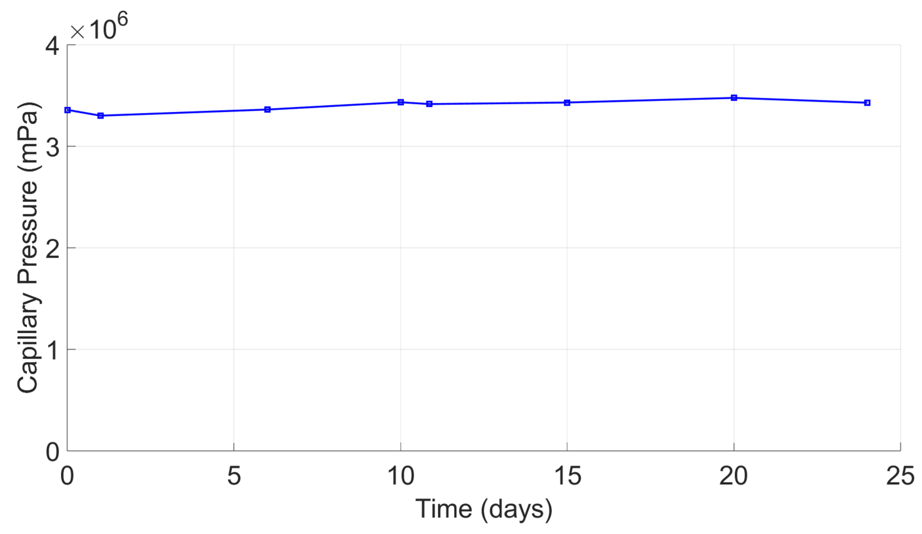


II. Results

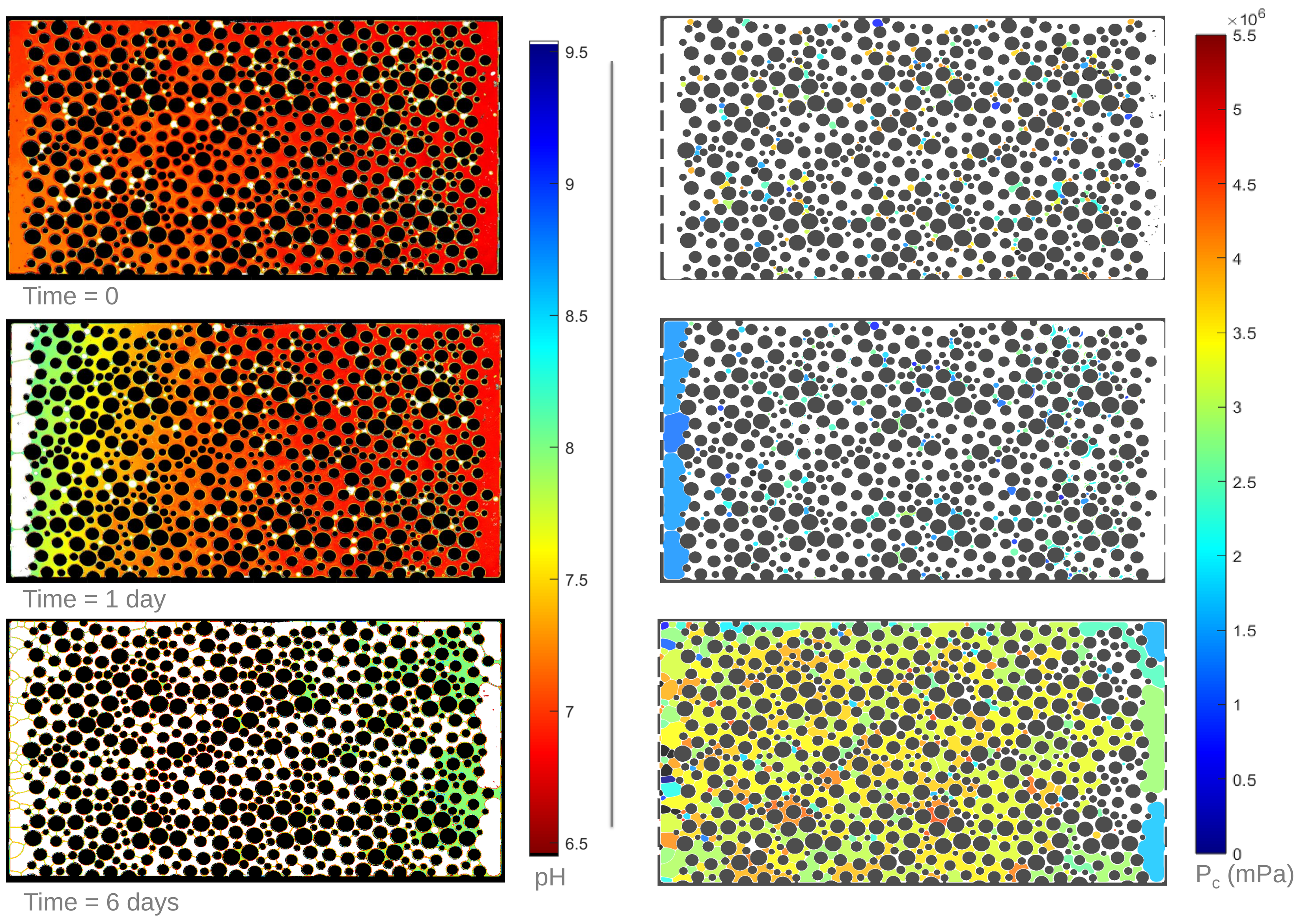
Homogeneous porous system







Heterogeneous porous system



Conclusion

- In our homogeneous system, the average capillary pressure of the system stays relatively constant over time because curvature in the z-direction is the dominant curvature. However, local redistribution can be observed with smaller ganglia disappearing and larger ones growing in size.
- In the heterogeneous system, gradual gas exsolution occurred over time. This suggests that local pressure variations arising from rock heterogeneity make redistribution during periods of no flow significantly more complex than can be explained by Ostwald ripening alone.

P|M|L Porous Media Lab

SimTech

SFB 1313