Contribution ID: **240** Type: **Oral Presentation**

Thermodynamics of Ganglia in 2D Porous Media

Tuesday, 20 May 2025 14:20 (15 minutes)

Ganglia (bubbles, or droplets) are widespread in porous media of various industrial applications such as geological carobon dioxide storage. Thermodynamic properties of a ganglion, including its volume (V), surface free energy (F), and capillary pressure (P_c), play pivotal roles in determining its transport and reactive performance. Although these properties in homogeneous porous media have been recently resolved (Armstrong et al., 2018; Wang et al., 2021), quantitatively description of ganglia in heterogeneous media remains a challenge (Huang et al., 2023; Li et al., 2020).

In this study, we develop a pore-scale algorithm for determining the morphologies and thermodynamic properties of hydrostatic ganglia in heterogeneous porous media. By tracking cycles of quasi-static growth and shrinkage of a ganglion, we resolve the evolution of P_c (Figure 1a). During growth, the ganglion invades pore by pore, with the throat length as the primary length scale that controls P_c. In contrast, during shrinkage, the ganglion collapses inward as a whole, exhibiting multiple scales of P_c at different stages. Additionally, we identify a critical ganglion volume, V_{crit} (black dashed lines in Figure 1a). Beyond V_{crit}, the P_c of a growing ganglion consistently exceeds that of a shrinking ganglion with the same volume, indicating that the ripening of such ganglia is not kinetically favorable. While we provided a thermodynamic critical volume for ganglia ripening in InterPore2024, this work introduces a kinetic critical volume.

Furthermore, we compare behaviors of growing and shrinking gangion in different porous media with varying degrees of heterogeneity (Figure 1b). In both cases, the ganglion seeks the region of lowest energy, corresponding to areas with the smallest local pore-throat ratio in the porous medium. The greater the heterogeneity, the later the transition of the F-V relationship from sub-linear to linear (as referenced in InterPore2024), and the lower the final specific surface area. Although there are both narrow and wide throats in a heterogeneous porous medium, the behavior of the ganglion is consistently governed by the narrower throats.

This work provides insights for investigating quasi-static degassing, ganglia dissolution, and ripening processes, as well as to analyze the thermodynamic stability of dispersed fluid clusters in porous media. We believe that this work helps better understand the behaviors of the dispersed phase in porous media.

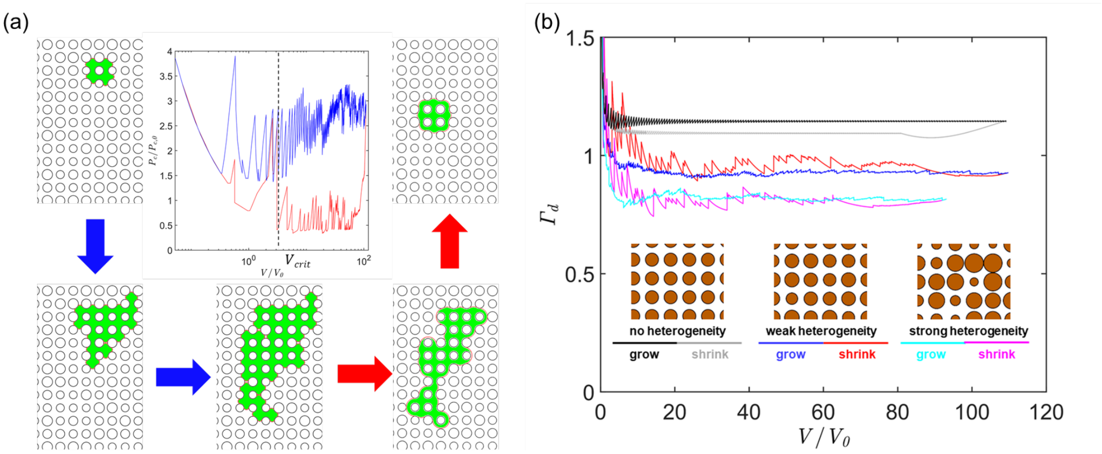

Figure 1: (a) Snapshots of ganglion growth and shrinkage in heterogeneous porous media. The relation between capillary pressure and ganglion volume. (b) Effect of heterogeneity on specific surface area.

Country

China

Acceptance of the Terms & Conditions

Click here to agree

Student Awards

Water & Porous Media Focused Abstracts

References

1.Armstrong, R.T., McClure, J.E., Robins, V., Liu, Z., Arns, C.H., Schlüter, S. and Berg, S. 2018. Porous Media Characterization Using Minkowski Functionals: Theories, Applications and Future Directions. Transport in Porous Media 130(1), 305-335. 2.Huang, R., Herring, A.L. and Sheppard, A. 2023. Investigation of supercritical CO2 mass transfer in porous media using X-ray micro-computed tomography. Advances in Water Resources 171. 3.Li, Y., Garing, C. and Benson, S.M. 2020. A continuum-scale representation of Ostwald ripening in heterogeneous porous media. Journal of Fluid Mechanics 889. 4.Wang, C., Mehmani, Y. and Xu, K. 2021. Capillary equilibrium of bubbles in porous media. Proceedings of the National Academy of Sciences 118(17), e2024069118.

Primary author: WANG, Chuanxi (Peking University)

Co-author: Dr XU, Ke (Peking University)

Presenter: WANG, Chuanxi (Peking University)

Session Classification: MS26

Track Classification: (MS26) Mechanisms Across Scales in Subsurface CO2 storage: A Special Session in Honor of Sally Benson