Dynamic pore-network modeling of compositional flow and nanoconfined phase behavior in shale rocks

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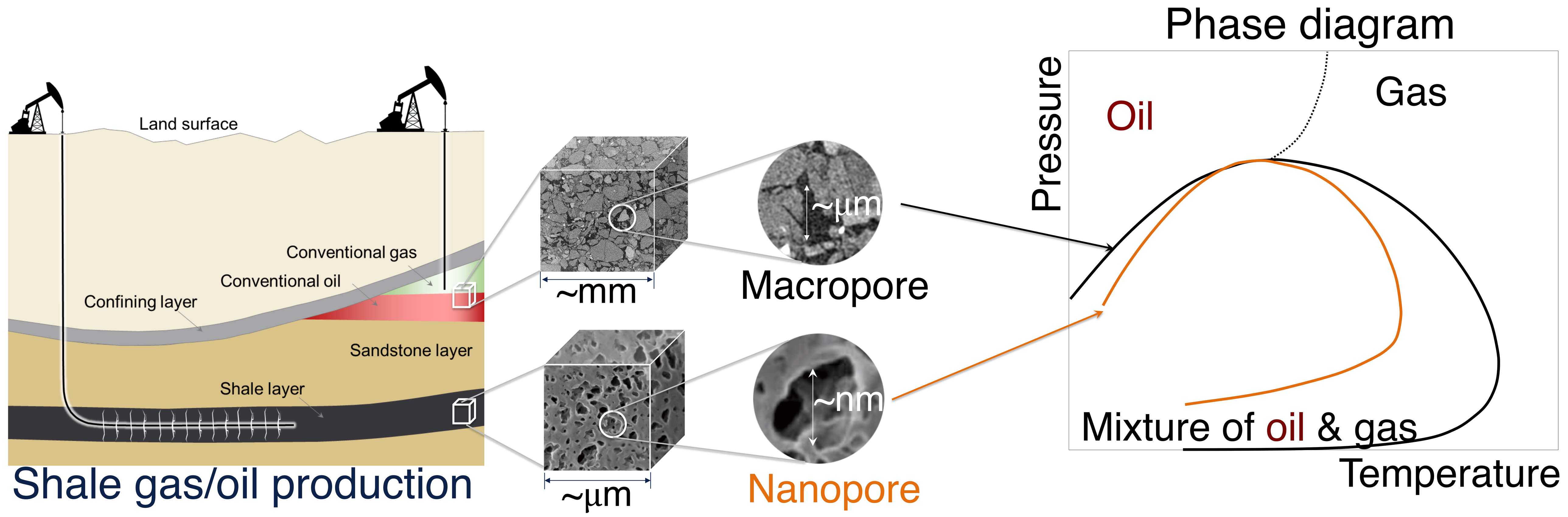
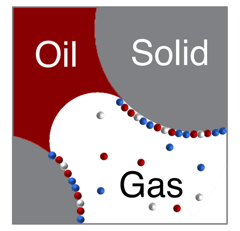
Phase behavior in shale rocks



Knowledge gaps

✧ Phase behavior becomes abnormal in nanopores due to nanoconfinement effects:

- ✓ capillary pressure at oil-gas interface (P^c)
- ✓ competitive adsorption on the solid surface



✧ The interactions among nanoconfined phase change behavior, two-phase flow dynamics, and multicomponent transport remain unknown.

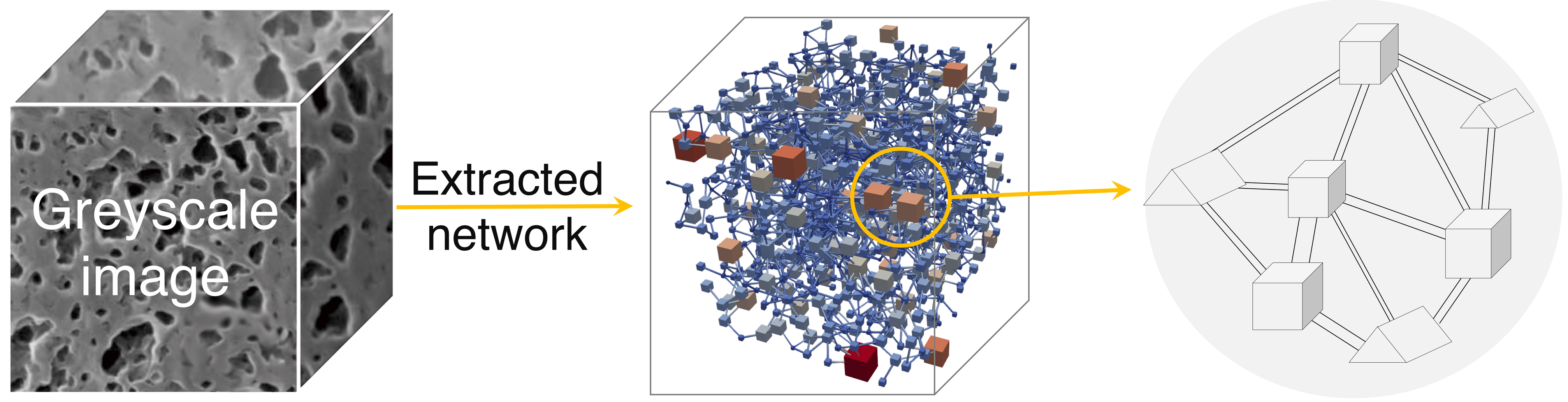
Objectives

✧ How can we formulate a new thermodynamic model to quantify the phase behavior of fluid mixtures in a single nanopore?

✧ Can we develop a pore-scale modeling framework to quantify the interactions among two-phase flow, multicomponent transport, and phase behavior in the complex pore structures in shale rocks.

Pore-network modeling framework

✧ Representing the pore structure

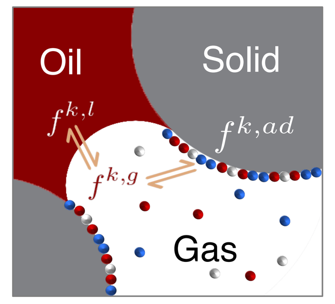


The extracted network replicates:
- ✓connectivity
- ✓size distribution
- ✓volume
- ✓surface area
- ✓shape factor

✧ Thermodynamic equilibrium inside a single pore

$$f^{l,k}(p^l, T, x^k) = f^{g,k}(p^g, T, y^k) = f^{ad,k}(p^{ad}, T, w^k)$$

Oil fugacity   Gas fugacity   Adsorption fugacity

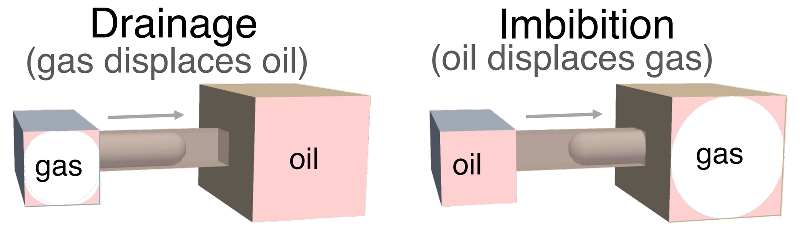


Single pore physics

✧ Mass transport between neighboring pores

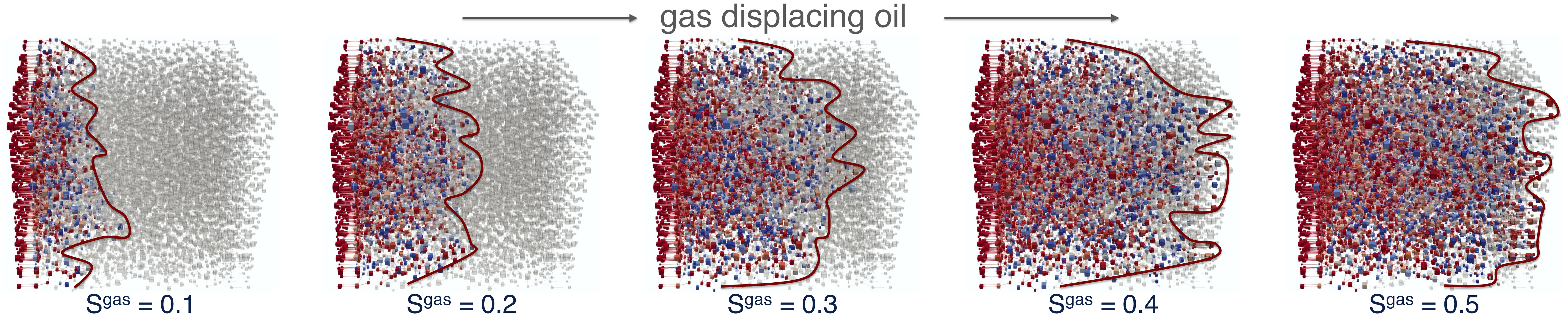
$$\frac{\partial}{\partial t}\left(V_i(x_i^k \rho_i^l s_i^l + y_i^k \rho_i^g s_i^g) + n^k\right) + \sum_{j=1}^{n_j} F_{ij}^{k,adv} + \sum_{j=1}^{n_j} F_{ij}^{k,diff} = 0$$

Mass in oil, gas, & adsorption   Advection   Diffusion

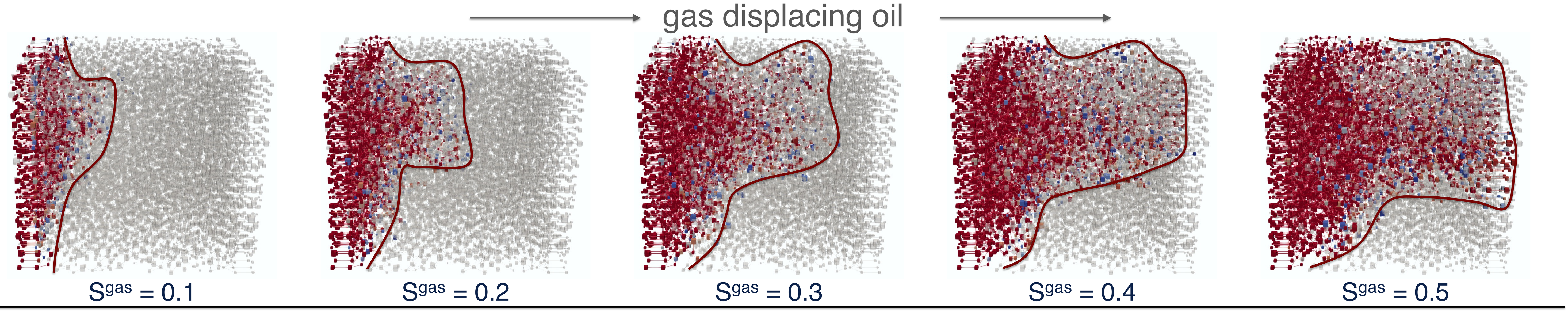


Example simulation: phase change suppresses fingering patterns

✧ w/o phase change (fingering patterns)



✧ w/ phase change (fingering patterns are suppressed)



Summary

I. A new dynamic pore-network model for two-phase flow, multicomponent transport, and nanoconfined phase behavior.

II. The model allows for simulating complex interactions among two-phase flow, multicomponent transport, and phase behavior in multiscale nanopore networks.