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Spontaneous Imbibition in Sandstones: From Pore Scale to Darcy Scale

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Motivation

spontaneous imbibition is capillary-driven invasion of the wetting phase displacing the nonwetting phase, which is governed by the interplay of capillary force and viscous force. As a typical two-phase flow process, it plays an important role in many applications such as shale and tight oil production, residual trapping in CO_2 sequestration, inkjet printing, and paper sensors.

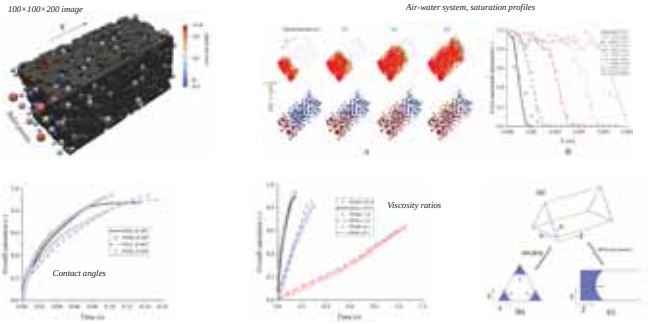
In this work, we are interested in the following questions:

- What are the fundamental differences among cocurrent, countercurrent, and quasi-static imbibition processes?
- How do pore structure (even multiscale pore structures), viscosity ratio, and wettability influence imbibition rate, nonwetting entrapment, and broadening of imbibition front?
- Can we predict spontaneous imbibition at the Darcy scale?

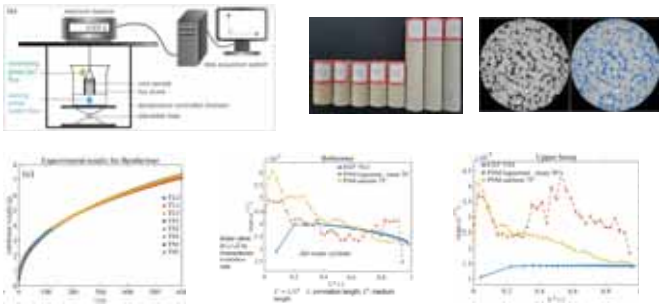
Pore-scale modeling:

model development and its validation

- A dynamic pore-network model is developed which incorporates the competition between corner flow and main terminal meniscus movement, and it has been verified against VOF simulations.

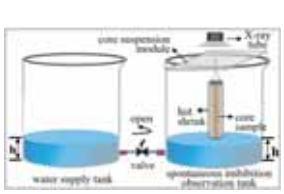


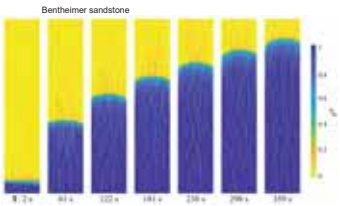
- The model is validated against experiments in in terms of imbibition rate and residual saturation. The uncertainty comes from the determination of effective contact angles for the pore-network modeling.



Darcy-scale modeling:

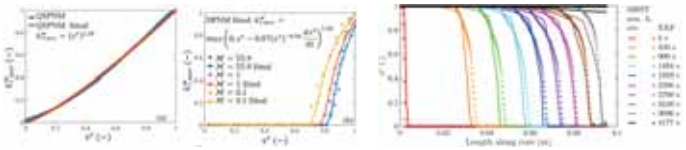
Non-equilibrium relative permeability and validation





Clinic CT images of effective water saturation

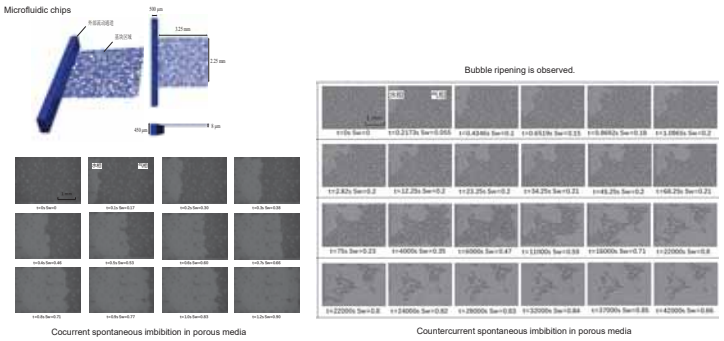
- A nonequilibrium model for wetting relative permeability is proposed. The two-phase Darcy equation with the nonequilibrium model can well predict the saturation profiles from the CT scanning.



Microfluidic experiments

Comparison between cocurrent and countercurrent

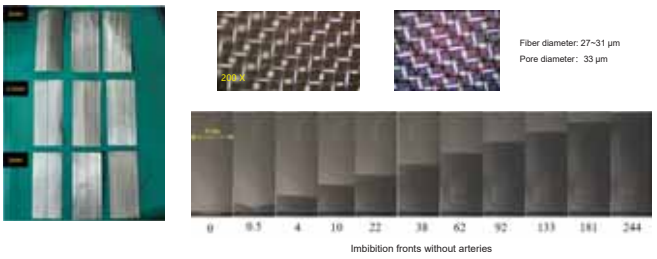
- We create the idealized conditions for cocurrent and countercurrent SI in microfluidics. We illustrate the differences in pore-scale filling events and nonwetting entrapment.



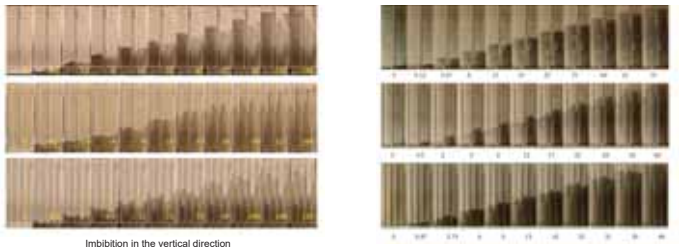
Cocurrent spontaneous imbibition in porous media

Countercurrent spontaneous imbibition in porous media

Spontaneous imbibition in arterial wicks



Imbibition fronts without arteries



Imbibition in the vertical direction

Imbibition in the horizontal direction

Ongoing work

- Large-scale simulator for spontaneous imbibition.
- In-situ CT imaging of spontaneous imbibition.
- Imbibition in fractured and multiscale porous media.
- Applications in electrochemical devices.

References

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