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Influence of wettability in immiscible displacements with lattice Boltzmann method

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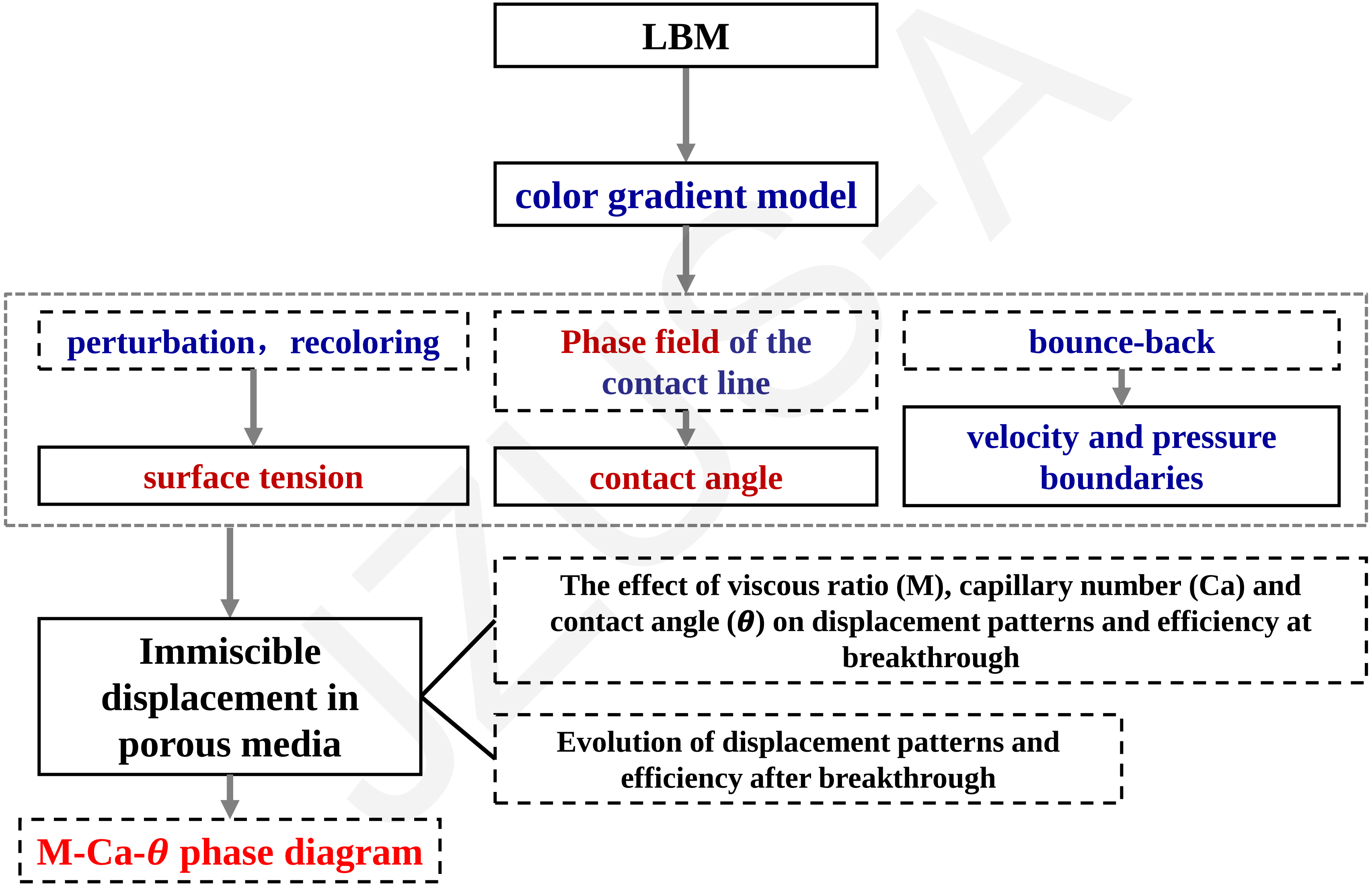
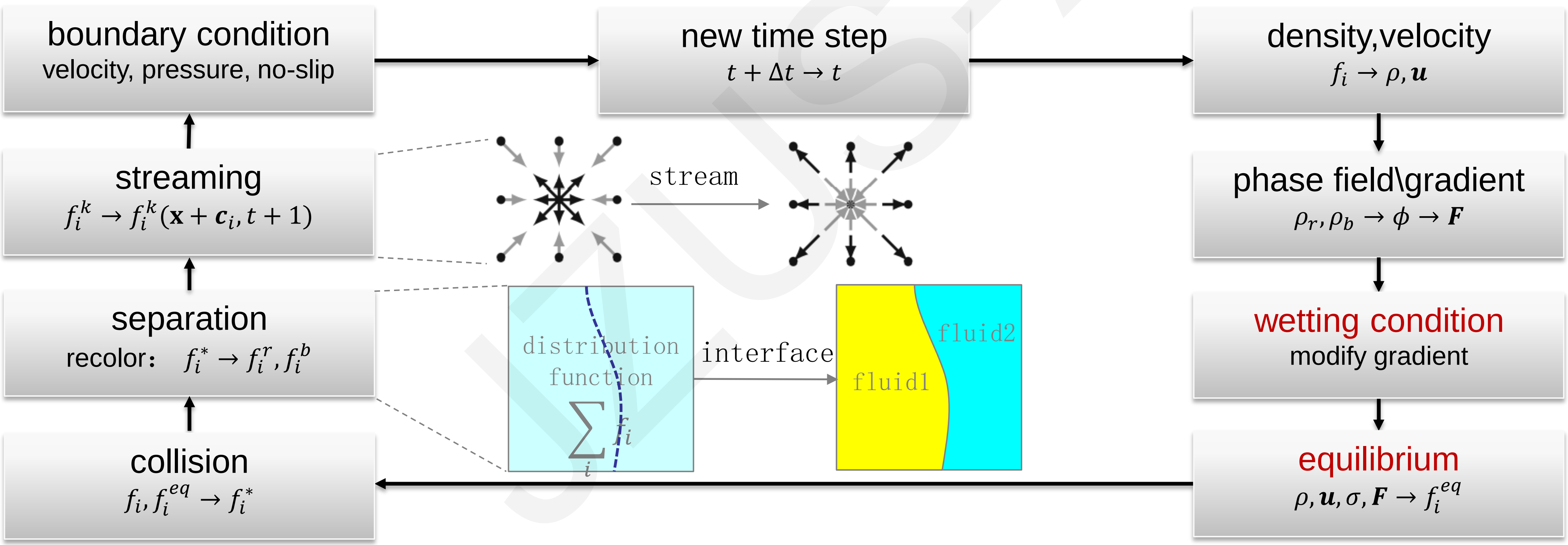
Technical Route



Lattice Boltzmann method

Calculation procedure

- The wettability condition must precede the calculation of the equilibrium distribution function.



Lattice Boltzmann method

Single channel displacement ($\theta = 90°$)

- The viscosity ratio and capillary number control the displacement morphology.
- Under M=1 and Ca=100, the displacement pattern is stable. The interface of the two phases is slightly curved and there is no fingering, and the sliding of the contact line is synchronized with the displacement front.
- Under M=0.01 and Ca=5, the displacement pattern is viscous fingering. The slip distance between the leading edge of the finger and the contact line is not synchronous, and the length of the interface increases with the evolution of finger.

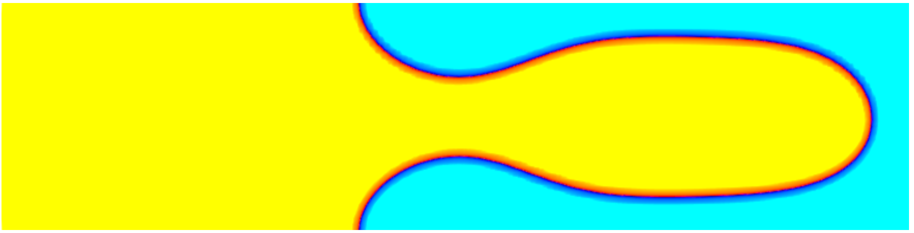
$$M = \frac{\nu_{\text{invading}}}{\nu_{\text{defending}}}$$

$$Ca = \frac{\mu_{\text{invading}} u_{\text{in}}}{\sigma}$$

M=1
Ca=100

stable displacement

M=0.01
Ca=5

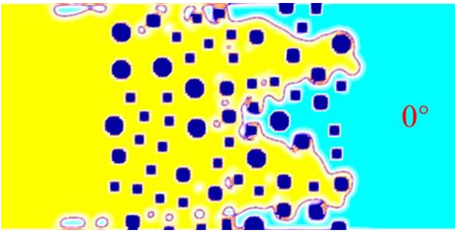


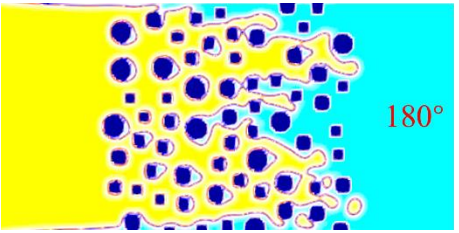
viscous fingering

Displacement simulation in a porous medium

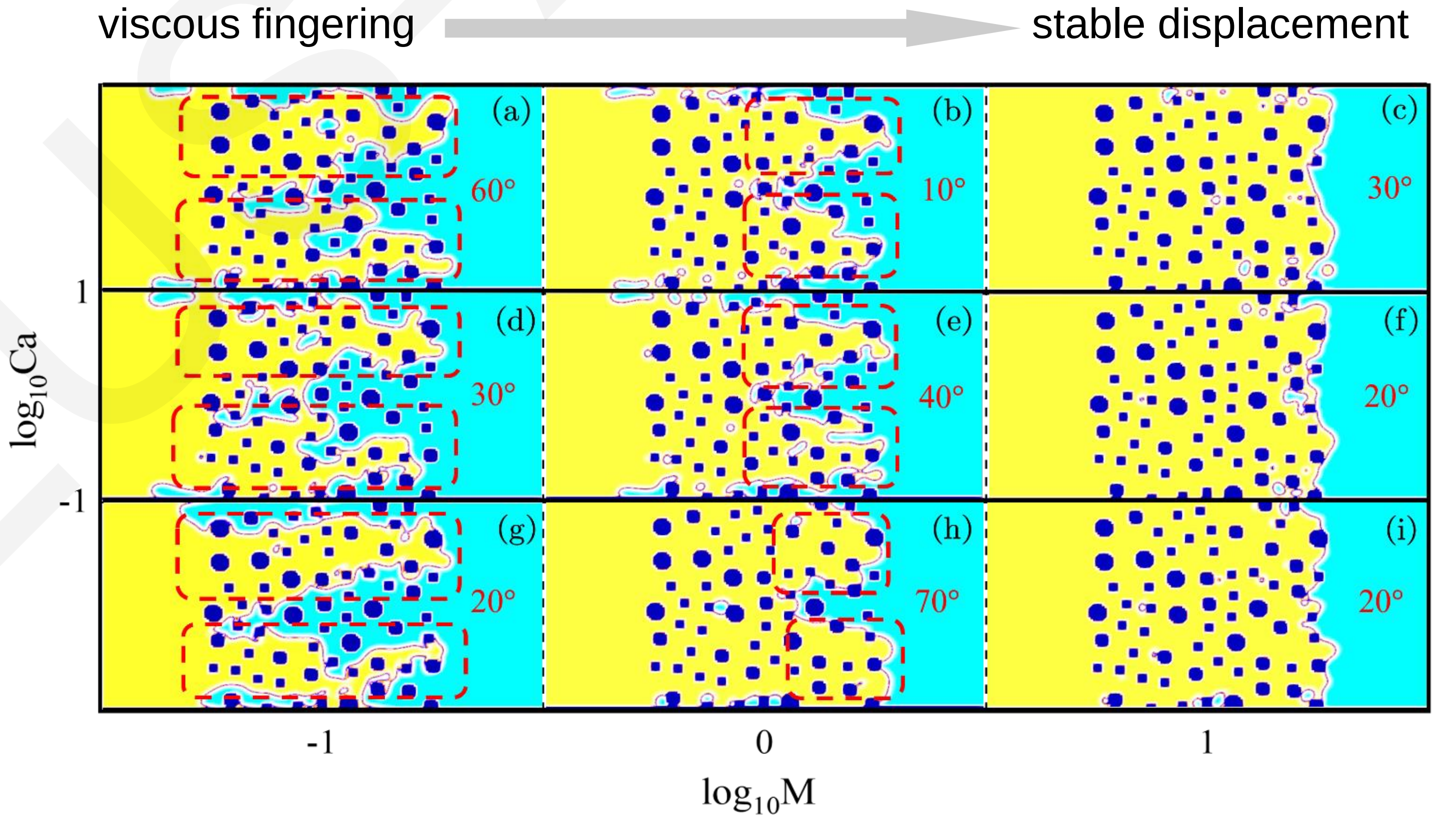
Effect of wettability on displacement patterns

- As the contact angle increases from 0 to 180 degrees, the invading front transforms from broad with few branches to narrow with many branches, and the quantity of the pinned pockets of the defending fluid around the solid particles increases.





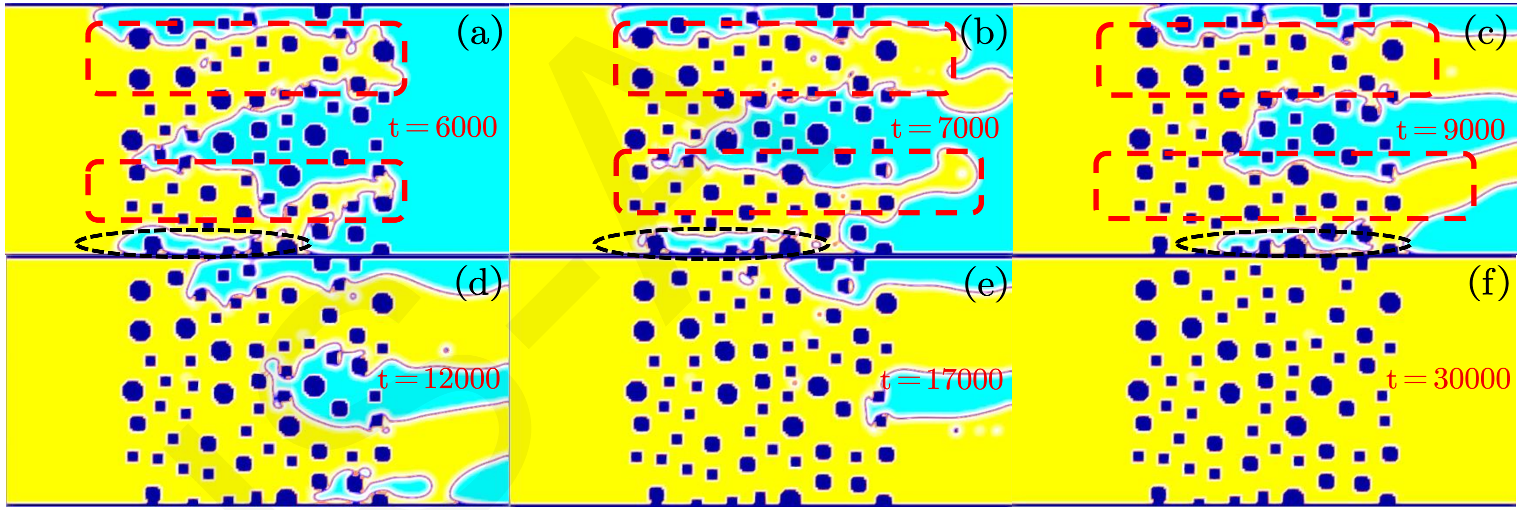
- These optimal contact angles ranged from 10 to 70, which were all hydrophilic. For the displacement patterns at the optimal angles, as the viscosity ratio M increased, the fronts transformed from tree-like patterns to rounded and broader fingers and eventually to the ideal pattern of stable displacement with fronts advancing abreast and near non-existence of trapped pockets of the defending fluid.



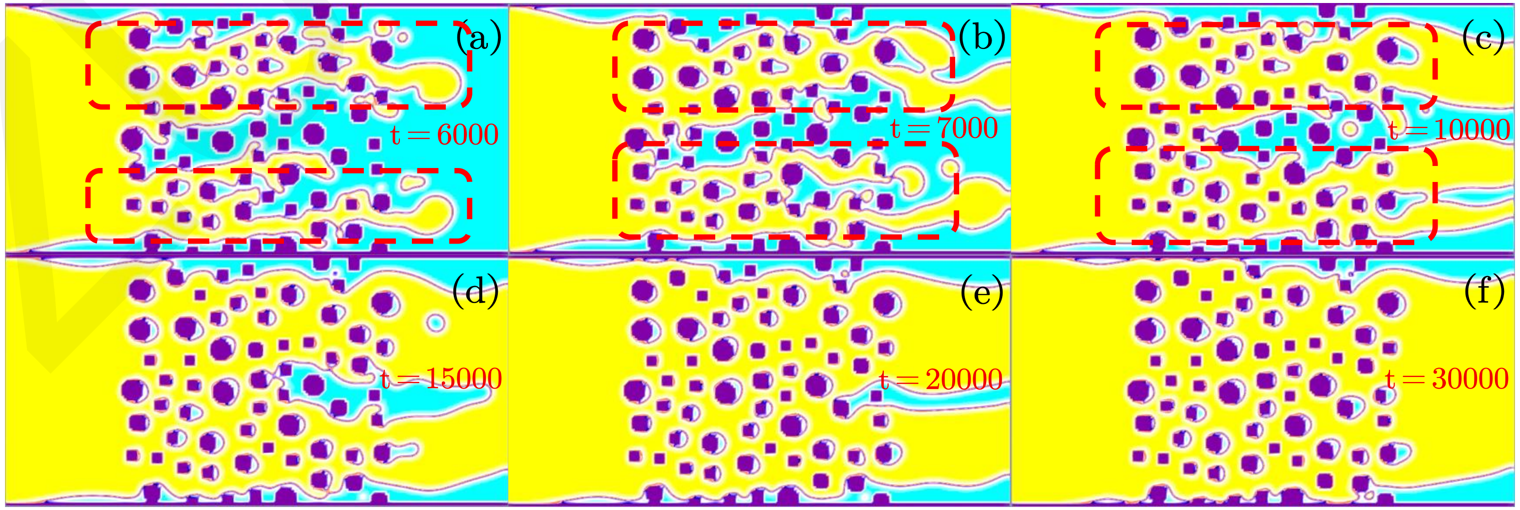
Displacement simulation in a porous medium

Development of displacement and flow after breakthrough

- For strong imbibition, the corner flow persistently crawled forward along the solid boundary and the trapped clusters of the defending fluid were gradually displaced by the wetting invading fluid.
- For strong drainage, the fingering developed into stable displacement, and the pinned defending fluid bubbles were distributed in isolation at the rear of each solid particle along the inlet velocity.



θ=10°, M=0.1, Ca=0.127



θ=170°, M=0.1, Ca=0.127