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Pore-scale Simulations On The Impacts Of Hydrate Production Approaches On Gas And Water Transport In Hydrate-bearing Sediments

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OBJECTIVES/SCOPE
Gas and water transport, which is controlled by the pore characteristics and capillarity in hydrate-bearing sediments (HBS), is one of key factors affecting the gas production. Hydrate production approaches (HPA) can significantly influence the dissociation pattern, affecting the pore structures and the transport of fluids. To elucidate the impacts of HPA, a reactive-transport lattice-Boltzmann (LB) model is applied to describe dissociation evolutions. Then, a phase-field LB model is developed to describe the fluids transport.
Methods
To simulate the dissociation evolutions under different HPA, a reactive-transport LB model, which can describe the hydrodynamic process, conjugate heat transfer and chemical reactions, is applied. To simulate the transport of immiscible fluids, which exist obvious density contrasts, a phase-field LB model with the conservative form of interface-tracking equation is developed to suppress the spurious currents at phase interfaces. To describe the fluid-solid interactions, the bounce-back condition is applied for both solid phases (hydrate and grains) to achieve the non-slip condition and the wettability condition is applied for grains and hydrate to describe the wettability behavior.
Results
After the validations for the LB models, the synthetic structures of HBS were applied in our simulations. Two most common HPA, which are called as depressurization (DP) and thermal stimulation (TS) approaches, were respectively considered to stimulate the hydrate dissociation. The dissociation processes were simulated by the reactive-transport LB model to capture the geometric structure evolutions. Then the steady-state relative permeability measurement processes were simulated by the phase-field LB model for two HPA cases under several hydrate saturations (Shyd). The results showed that because of different dissociation patterns under two HPA, the relative permeability of gas in the TS case is obviously larger than that in the DP case at the same Shyd. This indicates that the TS approach is more conducive to gas production. The reason for this phenomenon is that the void spaces formed in the DP case were dominated by small pores, whereas wide connected paths can be formed in the TS case. In the hydrophilic HBS, water is prone to occupy small pores under capillary pressure, separating the gas and suppressing its transport in the DP case. In the TS case, gas is easily accumulated in connected paths, resulting in higher gas permeability.
Novelty
The phase-filed LB model applied in this study is capable to handle and suppress the spurious currents at phase interfaces, ensuring a satisfactory numerical stability and accuracy. Thus, the real density contrasts between the water and gas under the in-situ thermodynamic conditions can be considered in the simulation. The impacts of HPA on the gas and water transport were quantitively analyzed by simulating multiphase flow processes in HBS.

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