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The Petroleum Engineering Department Presents

Application of Lattice Boltzmann Simulation on Hydrate Bearing Sediment Permeability Estimation During Dissociation Processes

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Location: ERP 9, 124

Teams: Link

Committee Chair:

Guan Qin, Ph.D.

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Abstract

Natural gas hydrate, which is plentifully distributed in ocean floor sediments and permafrost regions, is considered a promising unconventional energy resource. The investigation of permeability estimation during hydrate dissociation is essential to evaluate the economic feasibility for production. Given that the hydraulic conductivity and the capillary behavior of fluids are highly dependent on the pore structure of hydrate-bearing sediment (HBS), geometric evolution of HBS during dissociation is considered an important influential factor on permeability estimation. Recent advancements in imaging technology have enabled pore-scale numerical simulation to become a powerful tool for estimating HBS permeability, complementing laboratory experiments. The lattice Boltzmann (LB) method is a widely applied numerical method to characterize permeability in porous mediums honoring the real pore geometry from the digital rock samples. In this dissertation, I have developed a coupled multiphase hydrodynamic and thermal LB model for modeling the coupled processes of mass transfer, conjugate heat transfer, and fluid transport. Based on the coupled LB model, I conducted numerical simulations on the

hydrate dissociation processes considering three typical hydrate distribution morphologies: pore-filling, grain-coating, and dispersed. The coupled LB simulations are capable of rigorously characterizing the evolution processes of normalized permeability and relative permeability for multiphase flow during the dissociation processes.

Simulation results indicate that there is a potential formation of high-flow channel during dissociation processes with considering the thermal intervention. Consequently, the normalized permeability of HBS can be quasi-linearly increased as hydrate saturation (S_{hyd}) decreases, which deviates from exponential form obtained in isothermal conditions. Furthermore, thermal intervention has the potential to generate hydrate-free zones that reduce capillarity and Jamin effect on gas phase, which ultimately results in easier accumulation of the gas stream and significantly improves the relative permeability of gas. The thermal intervention is inevitable during dissociation processes due to the heat transfer from sensible heat or artificial heat source, and the reactive latent heat. The coupled LB simulation is essential for accurate estimation of normalized permeability and relative permeability during dissociation processes.