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Pore scale insights on multi-component multi-phase fluid transport phenomena in multi-scale shale pore-fracture system

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The heterogeneities of shale pore system are expressed in terms of the complex pore-fracture structure, different pore type and multi-scale pore size. Fluid transport mechanisms in shale nanopore space notably differ from that in conventional micro-scale porous media. Conventional core-scale multi-phase flow experiments are not applicable to shale because of the nanoscale pore size and the realistic multi-component multi-phase fluid flow patterns in shale are still unknown to a large extent. Therefore it is essential to study the pore-scale fluid transport mechanisms and establish the corresponding flow simulation method.
This work summarizes our recent study on multi-component multi-phase fluid transport mechanisms in shale by pore network modelling and level-set approach. We first constructed the multi-scale pore network model based on dual resolution scanning electron microscope images. The pore network multiphase flow model (PNMFM) in organic pore system is established considering nano-micro scale gas and water transport mechanisms. PNMFM in dual pore type (organic-inorganic) system is further proposed considering the influence of pore type and wettability on gas-water distribution. We further developed a general pore network-based three-phase thermodynamic equilibrium and transport model, which enables accurate prediction of multicomponent hydrocarbon–water transport properties in shale at different temperatures and pressures. Fluid flow in complex fracture systems near wellbore is influenced by heterogeneous fluid pathway structure, proppant distribution, and stress-induced fracture aperture change. To deal with this, we developed the physics-driven level set lattice Boltzmann method -coupled model to study multiphase flow properties in complex fractures during injected water flowback and proposed the upscaled relative permeability models of induced fracture network and hydraulic fracture with proppant.

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