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Editorial

Recent Advances in Multiscale Petrophysics Characterization and Multiphase Flow in Unconventional Reservoirs

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Petrophysics in unconventional reservoirs, especially multiscale characterization and multiphase flow, is relevant to multi-disciplinary porous media research (e.g., hydrocarbon extraction, environmental issues, and hydrology). Reliable characterization at different scales, effective theoretical modeling, and numerical approaches to multiphase flow are crucial for many applications, including residual oil in hydrocarbon reservoirs and the long-term storage of supercritical CO_2 in geological formations [1,2]. This Special Issue contains eleven research papers that cover scales from the molecular and pore scales to the core scale; several studies reveal the pore-fracture structure evolution and the multiphase flow mechanism in unconventional reservoirs (containing coal, deep shale, and tight sandstone) under multiphysics. Rapid progress has been observed in multiscale petrophysics characterization and multiphase flow in unconventional reservoirs.

Multiscale characterization of adsorption, desorption, and multiphase flow. Chang et al. [3] analyzed methane adsorption in organic matter and clay minerals in deep shale under high-temperature and high-pressure conditions using the Monte Carlo method and molecular dynamics method and elucidated the effects of pore shape and size on adsorption. Wang et al. [4] experimentally explored the influencing factors of methane adsorption in marine shale. They demonstrated that the specific surface areas of micropores and mesopores are mainly controlled by organic matter, which significantly influences methane adsorption. In contrast, clay minerals have little effect on methane adsorption. Dang et al. [5] demonstrated that the influencing factors of different imbibition stages are different, and they analyzed the effects of initial oil saturation, interface characteristics, and salinity on imbibition. Wang et al. [6] performed an oil–water two-phase flow simulation using a pore network model to analyze the evolution of oil–water relative permeability in different displacement stages.

Multiscale fluid flow characteristics under multiphysics. Zhang et al. [7] conducted Lattice Boltzmann flow simulations on fractal geometric models with different complexities. They evaluated the influence of grid resolution and structural complexity on permeability calculation accuracy and stability. Liu et al. [8] used X-ray CT imaging to analyze crack expansion and permeability changes in coal during cyclic loading and unloading, which is of great significance to the development of coalbed methane. Zhang et al. [9] proposed a three-dimensional surface fitting calculation method with high correlation and low error rates to determine the stress coefficient of permeability, which improved the calculation accuracy of the effective stress coefficient for permeability. Chen et al. [10] explored the shear failure mechanism of rock joint surfaces and proposed a roughness evaluation method with non-equal spacing sampling which could preserve the original profile. Furthermore, they analyzed the effect of roughness anisotropy on the shear failure of the joint plane.

Multiscale and multiphysics characterization of fracture networks and their flow. Zhang et al. [11] proposed an integrated learning algorithm with high accuracy to predict the fracturing time of horizontally fractured wells in tight oil reservoirs. Duan et al. [12] established a temperature prediction model for multistage fractured horizontal wells considering the stress sensitivity effect. They analyzed the influence of fracture parameters and water cut conditions on wellbore temperature. Du et al. [13] constructed a multiscale fracture model in a fractured shale reservoir and carried out a fluid flow simulation in a mixed multiscale fracture system; furthermore, the results were compared with the field data to verify the reliability of this model.

Exploring and developing unconventional resources is important in the alleviation of energy shortages and reductions in CO_2 emissions. This Special Issue covers the hydrocarbon microscopic occurrence, multiphase flow in complex pore networks, and the fracture propagation mechanism under multiphysics, which is helpful for the development of hydrocarbons. However, multiscale petrophysics characterization and multiphase flow in unconventional underground reservoirs are complex, involving physical and chemical changes, and there are still many unknowns that need to be explored further.

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