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Assessing water damage to gas permeability using bundle-of-tubes with triangular cross-section

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Water damage to gas permeability significantly impacts hydrocarbon recovery in gas reservoirs by altering the flow dynamics of gas and water phases within porous media. Addressing this challenge requires a deep understanding of fluid flow and distribution in porous structures to optimize hydrocarbon recovery strategies. Traditional bundle-of-tubes models often assume simplified circular pore geometries, which can lead to inaccuracies in predicting multiphase fluid flow and distribution. To overcome these limitations and enhance the accuracy of assessing water damage to gas permeability, a bundle-of-tubes model with triangular pore cross-sections was developed. By assuming that the cross-sections of all pores are equilateral triangles, a capillary pressure-non wetting phase saturation relationship was derived first for a single pore and then for a tube bundle. The types, quantities, and tortuosity of pores in the bundle were then adjusted to fit experimental mercury injection capillary pressure (MICP) curves and the actual porosity and permeability of the gas reservoir. The gas and water phases within the pores generated were distributed according to the wettability angles and surface tensions obtained from molecular simulations. Two distribution methods were investigated: one hypothesizes a uniform distribution of the wetting phase in all three corners of the pore under varying saturation and wettability conditions, and the other employs the lattice Boltzmann-Shan-Chen method to compute distributions of phases within the pore. Computational fluid dynamics (CFD) simulations were then conducted to evaluate gas permeability variations influenced by water saturation under both hypothetical and computed distribution scenarios. This study reveals that the wetting phase can distribute unevenly in the three corners of pores, rather than evenly as previously assumed. This difference can generate rather significant effects on the quantification of the effect of water saturation on gas permeability.

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References

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