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Pore-scale investigation of the displacement fluid mechanics during two-phase flows in natural porous media under the dominance of capillary forces

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Abstract

 This paper presents the results of numerical simulations of two-phase flows in porous media under capillary forces dominance. For modeling of immiscible two-phase flow, the lattice Boltzmann equations with multi relaxation time operator were applied, and the interface phenomena was described with the color-gradient method. The objec-tive of study is to establish direct links between quantitative characteristics of the flow and invasion events, using high temporal resolution when detecting simulation results. This is one of the few works where Haines jumps (rapid invasion event which occurs at meniscus displacing from narrow pore throat to its wide body) are considered in three-dimensional natural pore space, but the focus is also on the displacement mechanics after jumps. It was revealed the sequence of pore scale events which can be considered as a period of drainage process: rapid invasion event during Haines jump; finish of jump and continuation of uniform invasion in current pore; switching of mobile interfaces and displacement in new re-gion. The detected interface change, along with Haines jump, is another distinctive feature of the capillary forces action. The change of the mobile interfaces is manifested in step-like behavior of the front movement. It was obtained that statisti-cal distributions of pressure drops during Haines jumps obey lognormal law. When investigating the flow rate and surface tension effect on the pressure drop statistics it was revealed that these parameters practically don't affect on the statistical distribution and influence only on the magnitude of pressure drops and the number of individual Haines jumps.

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Keywords

Capillary forces, Color-gradient method, Haines jumps, Lattice Boltzmann equations, Two-phase flow, X-ray computed tomography

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