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Influence of reservoir conditions on CO2-brine behavior in natural sandstone: Insight from lattice Boltzmann method

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In CO2 geological storage, the behavior of CO2 inside a reservoir can be characterized as two-phase flow in a porous media system. Microscopic two-phase fluid behavior in porous media is influenced by temperature, interfacial tension, pore structure, and porous medium characteristics (e.g., wettability), which vary significantly from one reservoir to the next. Pore-scale interfacial instabilities, such as snap-off and fingering phenomena, influence the stability, injectivity, mobility, and saturation of CO2 within the reservoir. Therefore, understanding microscopic CO2 flow in porous media is crucial to estimating CO2 critical reservoir-scale characteristics, including storage capacity, leakage risk, and storage efficiency. Here we calculated fluid displacements within 3D pore spaces of Berea sandstone using two-phase lattice Boltzmann (LB) simulation, in order to characterize the influence of reservoir conditions upon multiphase flow. We classified the two-phase flow behavior that occurred under various conditions into three typical fluid displacement patterns on the diagram of capillary number (Ca) and viscosity ratio of the two fluids (M). We then characterized dynamic pore-filling events (i.e., Haines jumps) from the fluid pressure variation. The results revealed the onset of capillary fingering in natural rock at a higher Ca than previously reported for homogeneous porous media, with the crossover region between typical displacement patterns much broader than in a homogeneous granular model. These differences between two-phase flow in natural rock and in a homogeneous porous structure could be the result of the heterogeneity of the natural rock. Capillary fingering at higher Ca indicates that the dominant fluid displacement mechanism in most parts of the reservoir is likely capillary fingering. The simulation results reveal the influence of reservoir conditions on saturation of the CO2. Therefore, we have clarified suitable conditions for CO2 storage.

Keywords: Multiphase flow, 3D digital rock, Lattice Boltzmann simulation, Displacement patterns, Heterogeneity