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Stability Analysis of CO_2–Brine Immiscible Displacement

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The viscous stability of the primary drainage process is of major interest for the injection of carbon dioxide (CO_2) in saline aquifers, since it determines the spread of the CO_2 plume in the target aquifer and consequently the initial utilization of the pore space for CO_2 storage. In order to analyze the stability of the displacement process, the relative permeability saturation functions must be known; these are usually derived by experiments under conditions representative for the field. It is therefore very important to characterize the flood front stability, not only on the field scale but also on the experimental scale, in order to judge the validity of the experimental results as a precondition for reliable field simulations. Here we investigate the onset of viscous fingering, thereby studying under what conditions CO_2–brine displacement remains stable. We discuss the role of relative permeability and the stabilizing effect of capillary pressure at different length scales by means of numerical simulations. The results allow us to assess different definitions of the mobility ratio and establish criteria for judging the stability of the displacement process. We further show that in cases where gravitational forces are important, the gravity tongue dominates the fingering pattern, and unstable situations can occur where stability would be predicted, by considering viscous and capillary forces only. The application of our findings is not limited to CO_2–brine displacement. The criteria for stability can be applied to most two-phase flow problems in reservoir engineering in general ranging from water flooding to low interfacial tension surfactant flooding.