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The injection of carbon dioxide (CO_2) into geological formations - carbon geo-sequestration (CGS) has been recognized as an efficient method to reduce anthropogenic CO_2 emissions (1). During CGS, an invading fluid phase displaces a second resident fluid from a porous rock. Successful implementation and optimization of CGS operations requires a thorough understanding of pore-scale fluid displacement behaviour in porous media. The contact angle at the CO_2−brine−mineral interface is one of the many factors that influence pore-scale fluid displacement processes pertaining to carbon geo-sequestration (2). Likewise, in order to predict residual trapping capacities in geological formations, it is crucial to understand role played the wettability of the CO_2/brine/mineral systems. Direct numerical simulations (DNS) are a useful tool in bridging the gap between pore-scale -governing mechanisms and field-scale observations. The objective of this work is to ascertain the effects of surface wettability on fluid invasion patterns and pore-scale fluid displacement phenomena through DNS using OpenFOAM (3).

Two-phase phase flow simulations of displacement of a non-wetting phase by a wetting phase were conducted in a highly permeable porous medium with a uniform pore network made up of a staggered array of circular grains 40µm in diameter with the distance between grains being 140µm in the y-direction and 190µm in the x-direction. The depth of the porous medium was 50µm. Conditions of wettability investigated ranged from 60° (weakly water-wet) to 110° (weakly oil-wet). Capillary numbers for the simulations were in the order of 10^{-4}.

This work provides an in-depth insight of two-phase flow displacement processes at variable wetting conditions. From the simulation results, it was found that two-phase flow through porous media is strongly correlated to the wetting characteristics of the solid phase and the fluid phases involved. Efficiency of the fluid displacement process was greatest under intermediate wetting conditions (alphaContactAngle equal to approximately 90°) with a compact and stable propagating fluid front observed. This was attributed to the fact that fluid displacement under such conditions occurred through a series of cooperative pore-filling events. When alphaContactAngle in the simulations was changed to being either weakly water-wet (60°) or weakly oil-wet (110°), finger-like fluid invasion patterns were observed.

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