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Experimental and numerical studies of spontaneous imbibition in sandstones

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Spontaneous imbibition (SI) driven by the capillary force is pivotal to diverse earth science applications. To elucidate the interplay between capillary and viscous forces during spontaneous imbibition in porous media, the pore-network model proves to be an efficient tool. We initially verify our dynamic pore-network model against a series of water-air spontaneous imbibition experiments on three sandstones with distinct pore structures, which can be established under both constant and distributed contact angles. We then compare spontaneous imbibition with reduced viscosity ratios and quasi-static imbibition. However, we observe discrepancies in pore-filling events and the associated average transport properties under these two wettability conditions, leading to disparate imbibition rates and wetting saturation at lower viscosity ratios. Furthermore, when comparing spontaneous imbibition experimental data across a spectrum of nonwetting phase viscosities from the literature, we find superior model fitting with a constant contact angle. Although recent findings suggest that contact angles in pore spaces tend to follow a lognormal distribution, such a distribution may not be appropriate for the pore-network model with already simplified geometric pore characteristics. Our research also indicates that the correspondence in imbibition rate and wetting saturation against experiments at each viscosity ratio is the definitive validation criterion for the pore-network model of spontaneous imbibition.

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