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Wettability and flow rate impacts on immiscible displacement: a theoretical model

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When a more viscous fluid displaces a less viscous one in porous media, viscous pressure drop stabilizes the displacement front against capillary pressure fluctuation. For this favorable viscous ratio conditions, previous studies focused on the front instability under slow flow conditions but did not address competing effects of wettability and flow rate. Here we study how this competition controls displacement patterns. We propose a theoretical model that describes the crossover from fingering to stable flow as a function of invading fluid contact angle θ and capillary number Ca. The phase diagram predicted by the model shows that decreasing θ stabilizes the displacement for θ>45° and the critical contact angle θc increases with Ca. The boundary between corner flow and cooperative filling for θ<45° is also described. This work extends the classic phase diagram, and has potential applications in predicting CO2 capillary trapping and manipulating wettability to enhance gas/oil displacement efficiency.

References

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