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Marangoni Effect Reshapes Drying Pattern in Porous Media

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Drying or evaporation in porous media is always modeled as special scenario of classic fluid-fluid displacement. However, when the evaporation is extensive, the temperature at drying front can be much lower than other regions in the porous media and thus resulting in significant temperature gradient. Consequently, Marangoni effect may appear and reshape the fluid flow pattern, which has not been well investigated before. Such extensive drying in porous media normally occurs in CO2 sequestration, gas condensate reservoir and shale gas recovery, fuel cell, water management, etc.

In this study, we conduct micromodel experiments to visualize the Marangoni effect during extensive drying in porous media. We fabricate a 2D transparent porous medium with an adjacent open fracture. The porous medium is saturated first with pentane, and air is then continuously injected to flow through the open fracture at different rates to control the pentane evaporation rates. Direct microscopic visualization is conducted to analyze the fluid flow pattern, and infrared camera is used to record the real-time temperature distribution.

We show that the drying pattern could be reshaped by the interplay between evaporation-induced Marangoni effect and viscous dissipation for liquid to supply the drying front. At high evaporation rate extreme, the main drying front stably moves inward to deep porous medium, as evaporation is much faster than liquid supply from deep; at low evaporation rate extreme, the main drying front moves in a classic capillary fingering pattern, as both the viscous dissipation and Marangoni effect are negligible. However, at intermediate evaporation rate, the air first invades deep into the porous medium through one single preferential path, and then scatters from the tip of this path to inner porous medium, while the main drying front keeps unmoved. In other words, the drying and displacement front are separated. Infrared camera records this phenomenon and support the above hypothesis of mechanism.

We further quantify the relationships of invaded pore sizes and distance from the initial invading front, with pore invasion trajectory, which illustrates the mechanisms laying under these three drying patterns. Dimensionless criterion that depicts the transitions among these regimes and therefore a phase diagram is yielded that matches experimental observation well. Further research will focus on how this Marangoni effect can impact Darcy-scale flow pattern.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

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Student Poster Award

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