Displacement mechanisms in micro-models from micro-fluidic experiments and pore scale lattice Boltzmann simulations

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For the purpose of CO2 storage in rock formations, it is important to enhance our fundamental understanding of the fluid displacement processes at the pore scale. This includes the injection of CO2 as a non-wetting fluid (drainage) followed by spontaneous imbibition of brine as a wetting fluid. These processes determine the initial and residual saturations of CO2 respectively. Obviously it is important to maximise the residual saturation for optimal CO2 storage. As it is difficult to visualise the displacement processes directly in real porous media, we have developed specific micro-fluidic models, with designs ranging from simple pore junctions to complex networks representing actual rock thin sections. First, we study drainage processes in single junctions and observe good agreement with Young-Laplace capillary filling rules, as shown by Lenormand et al. in their classic paper [1]. Then we investigate imbibition processes and confirm capillary filling rules are obeyed [2], in agreement with [1], provided that capillary pressure drop is sufficiently small. However, for larger capillary pressure drops, often associated with the process of spontaneous imbibition where the pressure drop cannot be controlled, we observe that the sequence of pore filling is determined by local pore geometry rather than the Young-Laplace law.

These new findings are confirmed by direct lattice-Boltzmann computer simulations in the same geometries. We are currently examining the consequences of these findings in complex etched micro-fluidic models. Our research suggests that imbibition displacement rules for CO2 sequestration may have to be revised. [3]

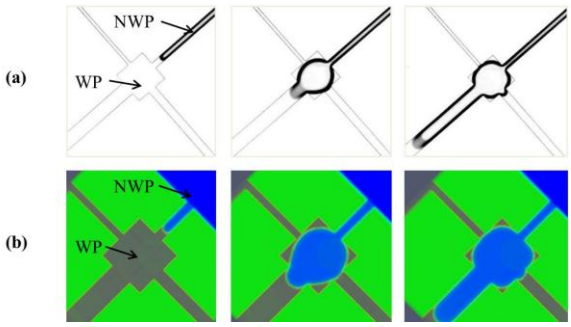

Figure 1: Dynamic drainage images: (a) experimental images of forced injection of non-wetting phase WP at 0.5ml/min (b) corresponding LBM simulations.

[1] G. Lenormand, C. Zarcone and A. Sarr, *J. Fluid Mech.* 135 , 337-353 (1983)
[2] E.Chapman, J.Yang, J.P.Crawshaw and E.S.Boek, *Energy Procedia* 37, 3680-3686 (2013)
[3] E.Chapman, J.Yang, J.P.Crawshaw and E.S.Boek, submitted for publication (2013)