X-ray micro-tomography of intermittency in heterogeneous carbonates in multiphase flow at steady state

Ying Gao[1,2], Branko Bijeljic[1,2], Martin J. Blunt[1,2]

[1]Department of Earth Science and Engineering, Imperial College London, London, SW7 2AZ, United Kingdom

[2]Qatar Carbonates and Carbon Storage Research Centre, Department of Earth Science and Engineering, Imperial College London, London SW7 2AZ, United Kingdom

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Introduction

We imaged dynamic flow of oil and brine in porous media at steady state by micro-CT, at a resolution of 3.5 μm during the co-injection into Estaillades carbonate. An experimental method based on X-ray differential imaging was used to examine how changes in flow rate impact the pore-scale distribution of fluids during co-injection under dynamic flow conditions. In this experiment, oil and water were injected at the same time into the core, which can mimic the same subsurface processes. Estaillades carbonates is a heterogeneous rock consisting of non-microporous grains, microporous grains, micro pores and macro pores. The resolved pores are the main targets for this study because resolved pores form the significant flow channels for fluids, which make the most contribution to the oil recovery.

As an important dimensionless value to evaluate the ratio of capillary to viscous forces, capillary number indicates the threshold where the viscous forces begin to dominate the capillary forces, which has a large impact on capillary trapping and remobilization. Two sets of experiments at high and low flow rates are provided to explore the time-evolution of the non-wetting phase clusters distribution under different flow conditions. Different flow regimes were elucidated at two capillary numbers, namely 2.0×10-7 and 8.0×10-6. At the lower Ca, the two phases appear to flow in connected unchanging sub-networks of the pore space. At the higher Ca we observed that some of the pore space contained sometimes oil and sometimes brine during the half-hour period of the scan, a phenomenon called intermittency. With the images we scanned at different Ca, we measured the water saturation at different fractional flow. This phase was segmented from the differential image between the 30wt% KI brine image and the scans taken at each fixed fractional flow. Using the grey-scale histogram distribution of the raw images, the oil proportion in the intermittent phase was calculated. During the experiment, the pressure drops at each fractional flow at low and high flow rates were measured by high-precision pressure differential sensors. Thus, the relative permeabilities and fractional flow can be obtained at the mm-scale scale. We present and quantify the impact of pore-scale heterogeneity on intermittency by comparing the experiment on Estaillades carbonate with that conducted on Bentheimer sandstone.