Contribution ID: **621**

Type: **Oral 20 Minutes**

Characterising multiphase flow functions with hysteresis from the mm to m scale in heterogeneous sandstones

Thursday, 17 May 2018 10:02 (15 minutes)

Incorporating sub-metre scale capillary pressure heterogeneity into upscaled numerical models is key to the successful prediction of low flow potential plume migration and trapping at the field scale. At low flow potential, nearing the capillary limit, the upscaled equivalent relative permeability incorporating capillary pressure heterogeneity is far from that derived at the viscous limit [1], dependent on the heterogeneity structure and flow rate, i.e. dependent on the capillary number [2].

To derive upscaled multiphase functions for field scale modelling, numerical or analytical methods are generally used either with statistical realisations of the permeability-capillary pressure field [3] or with simplified layered systems [4]. However, no protocol currently exists to efficiently derive these upscaled functions on heterogeneous rock cores directly from the subsurface, i.e. cores which are truly representative of the system under consideration. Experimental observations must be combined with numerical upscaling so that subsurface rock cores can be directly characterised and used to accurately inform further modelling efforts.

In this work, we present a characterisation approach that incorporates experiments and numerical simulations to accurately characterise drainage and imbibition multiphase flow functions from the mm-m scale on heterogeneous subsurface rocks. We make use of a rich experimental core flood dataset obtained on N_2-DI water and CO_2-brine systems across multiple fractional flows, total flow rates and drainage-imbibition cycles. The experiments are performed on three distinct sandstones; a relative homogeneous Bentheimer outcrop core, a Bunter core from the Southern North Sea subsurface and a composite Captain core from the Northern North Sea subsurface.

Through characterisation of the mm scale capillary pressure heterogeneity and the viscous limit relative permeabilities we create parametrised 3D numerical rock cores. We build on the recent work of [5] and [6] by incorporating imbibition cycles into the characterisation approach, allowing the hysteretic nature of the systems to be analysed. The numerical cores are validated by simulating core flood experiments across a wide range of flow conditions, showing that mm-m scale experimental saturations and equivalent, low flow potential relative permeabilities can be accurately predicted for both drainage and imbibition cycles.

The numerical cores are then used to derive equivalent relative permeabilities across a wide range of conditions representative of flow regimes from the well to the far field in the subsurface, incorporating mm scale capillary pressure heterogeneities and saturation hysteresis. These functions show significant deviation from those derived in the viscous limit (orders of magnitude at some points), and highlight the impact that heterogeneity and hysteresis have on low potential fluid flow. We show that under this new approach, equivalent relative permeabilties can be effectively derived for drainage and imbibition cycles on heterogeneous rock cores, and that a relatively simple entry pressure scaling (or permeability-porosity scaling with the Leverett J-function) can be used to uniquely describe the capillary pressure heterogeneity with hysteresis.

References

[1] C.A. Reynolds and S.C. Krevor. Characterizing flow behaviour for gas injection: Relative permeability of CO2-brine and N2-water in heterogeneous rocks. Water Resources Research, 51:9464-9489, 2015.

[2] A. Rabinovich, K. Itthisawatpan, and L.J. Durlofsky. Upscaling of CO2 injection into brine with capillary heterogeneity effects. Journal of Petroleum Science and Engineering, 134:60-75, 2015.

[3] A. Rabinovich, B. Li and L. Durlofsky. Analytical approximations for effective relative permeability in the capillary limit. Water Resources Research, 52:7645-7667, 2016.

[4] L. Odsæter, C. Berg and A. Rustad. Rate Dependency in Steady-State Upscaling Transport in Porous Media, 110:565-589, 2015.

[5] S.J. Jackson, S. Agada, C.A. Reynolds and S. Krevor. Characterising Drainage Multiphase Flow in Heterogeneous Sandstones. Under review, Water Resources Research, 2017.

[6] R. Pini and S.M. Benson. Capillary pressure heterogeneity and hysteresis for the supercritical CO2/water system in a sandstone. Advances in Water Resources, 108:277-292, 2017.

Acceptance of Terms and Conditions

Click here to agree

Primary authors: JACKSON, Samuel (Imperial College London); Dr KREVOR, Sam (Imperial College London)

Presenter: Dr KREVOR, Sam (Imperial College London)

Session Classification: Parallel 9-D

Track Classification: MS 3.08: From microns to meters: Heterogeneity across laboratory scales