Contribution ID: **318** Type: **Oral Presentation**

Re-evaluation of the evolution and hysteresis of relative permeability in gas-brine systems: time to shift the paradigm?

Wednesday, 2 June 2021 20:20 (15 minutes)

Predicting injectivity, well productivity, trapping effectiveness and storage efficiency in subsurface reservoirs or saline aquifers requires a good understanding of how relative permeability changes with fluid saturation. While exact values of gas permeability at any given saturation are unknown, practitioners often assume that the general form of relative permeability curves are predictable and unlikely to deviate from the norm.
The "norm"for gas-brine relative permeability curves we call the Brooks-Corey-van Genuchten Paradigm:
1. Drainage gas-brine relative permeability curves for both the non-wetting gas phase and for water have a concave-upwards shape and can be fit with a power law function.
2. Imbibition relative permeability curves for the gas phase have the same concave upwards shape (possibly with a different exponent).
3. Imbibition curves for gas relative permeability always lie below the primary drainage curve, terminating in a value of residual saturation that depends on the maximum saturation of gas reached during drainage.
We examined the evidence for the universality of the B-C-vGn paradigm, based on understanding gained from recent literature, by revisiting alternative concepts and by reviewing experimental and modelling studies. We found good evidence for drainage relative permeability curves that commence with a concave-upwards shape but that flatten off towards irreducible water saturation to have an overall 'S' shaped profile. Network models suggest this shape is prevalent in strongly water wet systems. We have also measured directly brine-gas imbibition relative permeability curves in sandstones and found a convex-upwards shape that loops back over the primary drainage curve to the end point marking residual gas saturation. We found several published experimental curves with this pattern in a range of soils and rocks, and validation from from percolation theory and network modelling that this form is to be expected in water wet systems including many methane, hydrogen and CO2 storage scenarios.

Time Block Preference

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

References

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Primary authors: CLENNELL, Michael (CSIRO); JACKSON, Samuel (CSIRO); SEYYEDI, Mojtaba (CSIRO)

Presenter: CLENNELL, Michael (CSIRO)

Session Classification: MS6-A

Track Classification: (MS6-A) Physics of multi-phase flow in diverse porous media