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Tracking the diffusion of hydrogen rich liquids in shale rocks

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Understanding flow of hydrogen rich liquids in shale rocks is critical for the recovery of unconventional hydrocarbon resources. The most common hydrogen rich liquids pertaining to shale rocks are water and oil. The extensive research on water and oil flow in shale rocks has not yet been able to explain the significant uncertainties and discrepancies in reported experimental data. Specifically, what has perplexed the research community is that despite oil spreading more than water on shale surfaces in an inviscid medium, its uptake by shale pores under pure capillary forces is much less than water contrary to theoretical expectations. This causes misjudgement of shale wettability and the underlying physical phenomena.
Therefore, in this study, we have used neutron computed tomography (CT) in combination with other experimental and digital rock methods to investigate water and oil flow in an organic-rich shale from the Beetaloo sub-basin in Northern Territory, Australia. The experimental techniques included, in addition to neutron CT, contact angle and spontaneous imbibition tests, X-ray CT, and small angle X-ray scattering. We also used non-equilibrium thermodynamics to theoretically derive constitutive equations to support our experimental observations of configurational diffusion.
The results of this study indicated that the pre-existing fractures imbibe more oil than water consistent with theory. However, theoretically in contrast, the overall imbibition was higher for water than oil. The reason for this was revealed by neutron CT to be greater water diffusion into the shale matrix (second continuum) from the fractures. It was shown that more water uptake into shale was controlled by pore size and accessibility in addition to capillary or osmotic forces i.e. the diffusion type is configurational where water molecules have easier access to smaller pores due to their smaller molecular size compared to larger oil molecules. Thus, even the inorganic pores which seem more oil-wet in an inviscid medium, easily allow water molecules to pass through them compared to oil. On the other hand, strongly oil-wet pores possessing strong capillarity cannot even imbibe oil simply due to its large molecular size and physical inaccessibility to the micro-pores. A combination of neutron and x-ray CT methods revealed that different flow mechanisms are dominant in different continua of shale rocks - and that these mechanisms are dependent on the relative sizes of liquid molecules and pores. The results provide new insights into the previously unexplained discrepancy regarding water and oil uptake capacity of shale rocks.

Speakers Gender

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Level of Expertise

Student

Do you wish to take part in the poster slam

No

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