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Spatial correlation of contact angle and curvature in pore-space images

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We study the in situ measured distributions of contact angles and curvatures within mm-size X-ray tomography images of rock samples from a producing
hydrocarbon carbonate reservoir imaged after waterflooding [1]. We analyse their spatial correlation on a pore-by-pore basis using automated methods for measuring contact angles [2], a new method for measuring curvatures, and by performing pore network extraction using generalized network modeling [3]. The automated methods allow us to study image volumes of diameter approximately 1.92 mm and 1.2 mm long, obtaining hundreds of thousands of values from a dataset with 435 million voxels. We calculate the capillary pressure based on the mode curvature value, and associate this value with a nearby throat, or restriction, in the pore space.
We demonstrate the capability of our methods to distinguish different wettability states in the samples studied: water-wet, mixed-wet, and weakly oil-wet. The contact angle is spatially correlated over approximately the scale of an average pore. There is a wide distribution of contact angles within single pores. A range of local curvature is found with both positive and negative values. However, there is only a weak correlation between contact angle and curvature with lower and negative values of the curvature associated with larger contact angles (more oil-wet conditions). We observed a weak correlation between average contact angle and pore size, with the larger pores tending to be more oil-wet.
Our analysis could potentially have large implications for pore-scale modeling of multiphase flow, in which methods using local curvature measurements could be directly used to calculate capillary pressures for displacement.

References

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[3] Raeini A. Q., Bijeljic B., and Blunt M. J. Generalized network modeling: Network extraction as a coarse-scale discretization of the void space of porous media. Physical Review E, 96:013312, 2017. https://doi.org/10.1103/PhysRevE.96.013312.

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