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Evaluation of a Proposed Workflow for Digital Petrophysics of Coquinas Involving Experimental Data and 3D Digital Models Using PNM- and FEM-Based Simulations

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Heterogeneous carbonate rocks, especially coquinas, present several challenges regarding their morphological characterization, petrophysical parameterization, and obtained a more complete understanding of their fluid flow properties. Within this context, a workflow is proposed and analyzed for digital petrophysics using a combination of experimental data and numerical 3D fluid flow simulations. The proposed workflow is applied to coquinas (Brazilian Pre-Salt analogue carbonates) in efforts to evaluate their petrophysical properties.

The workflow involves basic petrophysics as well as state-of-the-art approaches in digital analyses, to characterize coquina samples. Outcrop coquinas samples were for this purpose selected from the Morro do Chaves Formation in Northeastern Brazil, which has been studied as analogue rocks of Santos Basin Pre-Salt carbonates. Important steps in the workflow are the geological and morphological analysis of the selected coquinas samples (including basic petrography), acquisition of data through X-ray computed microtomography using different spatial resolutions, three-dimensional reconstruction and modeling of the coquinas and their pore systems, and numerical simulation of fluid flow in the porous media. Experimental data were obtained using permeametry, porosimetry, NMR, and SEM in support of several key steps of the workflow, such as segmentation procedures. Numerical simulations were used to estimate absolute and relative permeabilities using PNM- and FEM-based approaches. We used for this purpose commercial and in-house codes developed at both Utrecht University (Netherlands) and the University of Rio de Janeiro (Brazil).

All digital and numerical steps within the proposed workflow are being validated against experimental data to understand the limitations and uncertainties of the various steps. We highlight the main challenges and uncertainties encountered during each step, including challenges related to proper estimation of the microporosity of coquinas, and appropriate definition of the REV (Representative Elementary Volumes) based on mathematical and statistical analyses. The workflow identified several important issues related to the digital petrophysics experiments of the coquina samples, including major challenges to properly characterize the porosity and related PNM- and FEM-based fluid flow simulations. Conclusions from this study will enable improved tailoring and optimizations of digital petrophysics predictions of Brazilian Pre-Salt carbonate reservoirs, based on a well-structured workflow that is self-correcting when combined with a range of experimental data.

References

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