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Characterizing the Morphology and Permeability of Multiscale Pore System of Carbonate Rocks

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The pore structure of carbonate rocks is intrinsically heterogeneous, with pore sizes ranging several length scales due to the depositional and diagenetic processes. It strongly influences the morphology and connectivity of the pore system and the petrophysical properties of these rocks. Because of this multiscale characteristic, the pore network characterization and the prediction of macroscopic properties remain challenging. In the past two decades, digital rock analysis (DRA) has gradually become an important approach for permeability (and other rock properties) prediction. Indeed, using X-ray imaging techniques and numerical modelling, it is possible to estimate petrophysical properties in 3D microtomography images using fundamental physical equations applied to the pore scale. Beyond estimating properties in representative elementary volumes (REV) of the rock, this approach can improve our knowledge of the relationship between properties and pore structure. This work implements a workflow including laboratory experiments, image acquisition and processing, and analysis to characterize the multiple porosities of samples of Coquinas from Morro Do Chaves formation (CIMPOR Quarry outcrop, São Miguel dos Campos, Alagoas, Brazil). A central aspect of the workflow is the data integration obtained from entire core-plug and sub-samples micro-CT images and mercury intrusion capillary pressure (MICP) measured at core-plug subsamples, aiming for a more accurate estimation of the absolute permeability. The images acquired by X-ray microtomography are limited to a voxel size of about 1 mm; in general, a significant fraction of the pore volume is below this size and is not clearly defined (or resolved). In our workflow, the MICP data supply the description of the sub-resolution porosity; do not consider this sub-resolution porosity can lead to underestimated permeability values. The Stokes-Brinkman equations modelled the single-phase fluid flow in the pore space, including the sub-resolution porosity. This hybrid model solves the Stokes equations in the resolved pore regions and Darcy's law in the sub-resolution regions. Applying the present workflow to Morro Do Chaves´s samples demonstrates the importance of a multiscale treatment of these rocks using appropriate analysis techniques for each spatial scale. The rock permeability results are related to the size distribution and connectivity of the pore network of each scale.

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References

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