EVALUATION OF HETEROGENEOUS CARBONATE ROCKS WITH DIGITAL MODELING AND NUMERICAL SIMULATION

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ABSTRACT: The Pre-salt carbonate reservoirs have introduced heterogeneous carbonates as a major target for new interesting research. The construction of an appropriate detailed geological model based on petrophysical parameters from heterogeneous carbonate rock samples has several difficulties. Reservoir engineering also requires modeling and the necessary information for a reliable field-scale fluid flow simulation based on geological information. Due to their huge complexity, understanding heterogeneous carbonate rocks petrophysical parameters and flow properties is a fundamental and a major challenge.

A stromatolite rock sample from Lagoa Salgada, a hypersaline system in the State of Rio de Janeiro and coquina rock samples from Morro do Chaves Formation, Northeast Brazil, were studied and evaluated using Digital Rock Physics in this work. Stromatolites and coquinas are carbonate rocks with complex porosity systems. These rocks have been studied due to their morphological analogy to pre-salt reservoirs.

During the first part of the study, three distinct morphological internal structures in the stromatolite were identified and the porosity of each layer was estimated using well-defined segmentation procedure (thresholding method) to isolate the pores in the X-Ray Computed Tomography (Micro-CT) images and subsequent three-dimensional (3D) model reconstruction. The study defines a workflow methodology for 3D pores modeling and numerical simulation of a single-phase fluid flow in micro scale using Finite Element Method (FEM) in highly heterogeneous core samples. The work also presents a comparison with different automated thresholding techniques (histogram shape-based, clustering-based, local-based and region-based thresholding methods) and their impact in the values of petrophysical properties. The importance of Representative Elementary Volume (REV) to predict these properties is discussed using a different sample subvolume from a region of interest (ROI) in the stromatolite sample.

The second part includes the evaluation of nine different coquinas samples also using the Micro-CT and digital reconstruction techniques with two different automated segmentation methods. Their estimated total porosity using digital rock physics were analyzed and the values confronted with measures obtained from a porosimeter. Their connected porous systems were 3D modeled and the results of the numerical simulation of a single fluid flow in some chosen regions of each sample were also evaluated using FEM-based software. An attempt to estimate the absolute permeability of each sample was performed based on the digital rock physics.

The results show that digital rock physics based on highly heterogeneous carbonate rocks can be extremely useful to evaluate and understand the porous systems in these rocks, including the simulation of fluid flow in the 3D reconstructed porous systems, but some important steps shall be followed. They also present that each important step during the digital rock physics studies presents several challenges which requires further investigation.

KEYWORDS: CARBONATE, PETROPHYSICS, DIGITAL, MODELING