Multi-Scale Digital Rock Analysis of Jurassic Carbonates for Exploration Support in Saudi Arabia

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Abstract

Digital rock physics (DRP) analysis is a proven method for obtaining high-resolution rock images detailing the internal fabric of rock samples at micron scale (typically 0.5 to 20 microns). DRP is a multidisciplinary field that requires expertise in 3D imaging, image processing, fluid mechanics, numerical modeling, computational physics and petrophysics. This technology is particularly useful in complex reservoirs where subtle changes in the fabric lead to variations in pore connectivity and fluid flow. In this work, the DRP analysis has been specifically targeted at providing rock properties of carbonate rocks due to their complex depositional and diagenetic history. Diagenesis often overprints the depositional fabric and can create isolated pores bounded by rims that isolate formation fluids. This can lead to erroneous hydrocarbon saturation and permeability estimates from wireline logs. The current study examines the electrical conductivity and absolute permeability models in moldic porosity Jurassic carbonates in eastern Saudi Arabia through the use of DRP analysis. Pore-scale permeability controls were studied with DRP as part of the pretesting petrophysical analysis to compute absolute permeability. An evaluation of the pore structure, types and hydraulic tortuosity led to an improved permeability log estimation. The petrophysical algorithm was calibrated using rock images in comparison with conventional core analysis. The DRP models generated from the core samples were used as an input to simulate the hydraulic tortuosity and grain-sizes profiles for the entire logged interval. These properties together with total and effective porosities were considered as the main variables of the permeability function. The DRP analysis resulted in an improved electrical model that take into account the properties of the rock with isolated porosity providing a better match between saturation calculations from wireline logs and well tests/production data. This study confirms the feasibility of combining the DRP technology with well log data to enhance the prediction of petrophysical properties, which are not directly measured from downhole tools, and led to optimization of workflows for exploration and production.