

Digital Rock Analysis of Bioturbated Carbonates in the Cretaceous Formation of Saudi Arabia

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Abstract

Textural and mineralogical modifications of the original sedimentary fabric by organisms at the time of sediment deposition is known as bioturbation. Biogenically driven chemical and physical alteration of the primary sedimentary fabric due to burrowing infauna in carbonate reservoirs can result in fabric-selective dolomitization. Recent studies have demonstrated that in tight carbonate reservoirs this type of modification can lead to the enhancement of reservoir permeability.

Development associated with bioturbation can be expressed as dual-permeability flow-media. Commonly, biogenically induced dual-permeability flow media exhibits poor reservoir characteristics owing to the fact that only trace fossils are able to transmit fluids, with little to no interaction with the tighter matrix. This requires detailed understanding of the geological heterogeneities to characterize their impact on petrophysical and reservoir engineering studies.

This paper documents the influences of bioturbation on reservoir quality from the Cretaceous formations in Saudi Arabia. Permeability distributions were investigated using digital and conventional techniques to refine different rock types through three-dimensional (3D) X-ray computed tomography (CT), acquired at multiple scales for digital rock characterization supported by mercury injection capillary pressure (MICP) experiments and high-resolution scanning electron microscopy (SEM) imaging. The comparison of permeability at different scales is necessary for upscaling laboratory-measured properties to grid cells of the geological models.

The coarse imaging helped to identify bioturbated sections to select samples for sub-micron resolution tomography. The 3D sample tomograms were segmented to define burrows and matrix distributions, where samples were extracted for thin-sections, SEM and MICP analyses to refine the pore sizes and rock types. The analysis showed an intricate, highly connected, mixed horizontal and inclined burrow system dominated by *Thalassinoides*. Intergranular porosity, associated with the fill of *Thalassinoides* constitutes a mechanism for permeability enhancement in an isotropic tight matrix. Permeability of the burrows is one to three orders of magnitude greater than the matrix permeability; the results show enhanced burrow permeability with higher dolomite content. The flow between dead-end burrows occurs through the matrix as presented by the digital models. Increased permeability associated with the higher dolomite content resulting from intensely bioturbated intervals might be used as sweet spot identifier from wireline logs.