Enhanced Evaluation and Identification of Various Lithofacies Through Integrative Characterization: A Case Study

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Abstract

In the field of subsurface characterization, litho-facies identification along with quantification of porosity and permeability are crucial parameters for better understanding reservoir properties and optimizing hydrocarbon recovery. This paper presents a comprehensive method to analyze various lithofacies from an unconventional reservoir, particularly the Qusaiba Member of the Qalibah Formation. Nuclear Magnetic Resonance (NMR) T2 relaxation time data from the GeoSpec 2 NMR Core Analyzer was used along with X-ray diffraction (XRD), helium-gas porosimeter, and gas-permeability measurements.

The main goal of this research is to assess the sensitivity of NMR measurements to the variations in porosity and pore size distribution among different lithofacies and to understand the unique responses of unconventional shale samples, specifically when compared to He-porosimeter results.

The NMR data, known for its ability to detect and analyze the properties of pores, was used as the primary method for evaluating the porosity in certain facies. The validation was conducted using X-ray diffraction (XRD) analysis, which offered crucial mineralogical observations in conjunction with porosimetry and permeability investigations that provided further information on physical property.

The findings of the study show that there is a strong link between the porosity and pore size distribution found using NMR data and the mineralogical characteristics observed using XRD. Additionally, porosity and permeability tests were compared to aid interpretation of the T2 time relaxation data. For instance, explaining the decrease in pore size distribution is most likely result of increase in clay minerals associated with sand-rich zones of the Qalibah Formation. This shows bimodal pore size distribution which in transition from siliciclastic to carbonate dominant litho-facies. The unconventional shale samples displayed distinct NMR responses, which differed from the results obtained through helium porosimetry. Suggesting significantly higher porosity, however, it can be explained in our case by the pore size distribution that showed bimodality with longer T2 relaxation time for the majority of cumulative porosity, which was mostly explained by exaggeration in shale fissility during saturation.

The integrated approach not only validated the NMR's accuracy using the XRD, He-Porosimeter, and permeability data but also revealed subtle differences between various litho-facies and unconventional shale samples that conventional single-method analysis might have missed, with the possibility of adding gamma ray measurements and petrographic analysis to this work to have the ability to visualize the change in pore space to establish an alternative perspective for a comprehensive method of litho-facies classification and evaluation utilizing NMR data.