Lithofacies, Paleoenvironments, and Diagenesis of the Middle Jurassic Carbonate Dhruma Formation: Implications on Reservoir Quality, Outcrop Analog, Central Saudi Arabia

Ibrahim Yousif[1], Osman Abdullatif[1], Mohammed Makkawi[1], Waleed Abdulghani[1], and Lamidi Babalola[2]

[1]Geosciences Department, College of Petroleum Engineering & Geosciences, KFUPM, Dhahran, Dhahran, Saudi Arabia.
[2]Center for Integrative Petroleum Research (CIPR), College of Petroleum Engineering & Geosciences, KFUPM, Dhahran, Dhahran, Saudi Arabia.

ABSTRACT

The Middle Jurassic carbonate Dhruma Formation hosts important oil reservoirs in the eastern Saudi Arabian oil fields and the Gulf region. However, the complexity of carbonates and the limitations of subsurface data and techniques hinder detailed understanding and prediction of its reservoir heterogeneity. This study characterizes the detailed lithofacies, paleoenvironments and related diagenesis in Dhruma Formation outcrops in central Saudi Arabia. Microfacies analysis based on field observations and petrography revealed eight lithofacies types namely: skeletal peletal spiculitic wackestone, peloidal echinoderm packstone, fissile shale, peloidal spiculitic echinoderm pack-grainstone, cross-bedded peloidal skeletal oolitic grainstone, oolitic grainstone, skeletal peloidal foraminiferal packstone and skeletal foraminiferal wackestone. These lithofacies were grouped into five major carbonate ramp environments that range from distal to proximal carbonate ramp setting. Diagenetic evolution study supported by isotope analysis showed different effects on reservoir quality. Diagenetic processes, that have significantly affected reservoir quality include meteoric dissolution, meteoric cementation, and to a less extent, micritization, dolomitization, and dedolomitization. Meteoric cementation is the main porosity reducing process by calcite cement occluding most of the original pore spaces. However, meteoric dissolution played a positive role in reservoir quality enhancement. The variability in porosity profile along composite vertical stratigraphic section shows a positive pattern of correlation with carbon and oxygen isotopes signatures. These variabilities are due to the effects of depositional texture and later diagenetic overprint. The isotope signatures along the composite stratigraphic section are relatively depleted in transgressive dominated compared with that in regressive dominated part. Porosity types are dominated by intraparticle, moldic and fracture porosities with minor intercrystalline and interparticle porosities. Moreover, SEM photomicrographs also revealed the presence of moldic and micro porosity in the uppermost part of the studied section, which has the highest porosity values as a result of intensive meteoric dissolution. The findings of this high-resolution diagenetic analysis within the stratigraphic framework of Dhruma carbonates and it is impact on reservoir quality might help to understand the reservoir complexity and heterogeneity.