Diagenesis and Reservoir Quality of the Neoproterozoic Ara Carbonates in the South Oman Salt Basin

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Abstract

Intra-salt carbonate stringers are distributed in various basins globally and play crucial roles as source rock, reservoir, and seal within the petroleum systems of the respective basins. In the Interior Oman Salt Basins, the Ara intra-salt carbonates represent one of the significant petroleum systems. The Intra-salt carbonate stringers belong to the Ara Group, comprising six cycles of evaporites and carbonates. The intra-salt carbonate reservoir lithofacies are microbial laminate, different types of grainstones, and thrombolitic boundstone. A primary challenge to hydrocarbon production from these stringers is posed from the pore-filling halite in some areas of the South Oman Salt Basin. A comprehensive understanding of the diagenetic effect is essential to predict the reservoir quality. This study aims to improve the understanding of the diagenesis and reservoir quality of the Ara carbonates of the Ara Carbonates in the Birba and Harweel clusters.

This study relies on subsurface data obtained from five wells, namely, B in the Birba Cluster and D1, D2, M, and R in the Harweel Cluster. Fifty-three blue epoxy-impregnated and stained thin sections were described under microscopy. The diagenetic alterations and porosity were quantitively assessed using the point counting technique by counting 500 points in each thin section. Scanning electron microscopy and energy-dispersive X-ray analysis were conducted on 10 representative samples from the Harweel Cluster to study the paragenetic sequence, porosity, and chemical composition of the grains. The X-ray diffraction method was applied on 10 samples to estimate their mineralogy. The inductive coupled plasma optical emission spectroscopy was done on 7 samples from halite and anhydrite cement to analyze their chemical compositions. The study further encompassed the examination of porosity and permeability using 53 thin sections, SEM analysis on 10 samples, core porosity, and permeability measurements from 308 samples, and wireline logging data from the five wells. Ara carbonates in the Birba and Harweel clusters were affected but in various degrees by diagenesis. For instance, micritization, dolomitization, replacement of dolomite by evaporitic minerals, pore and fracture-filling halite, anhydrite, and solid bitumen, silicification, pyritization, multiple dissolution events, mechanical and chemical compactions, and two generations of fractures, which are opened and cemented fractures. Exclusive authigenic minerals, namely phosphorus-rich carbonate, strontianite, and illite were observed solely in the samples of the Harweel Cluster. The number of replacive evaporites, and cementation by halite, anhydrite, and solid bitumen, along with silicification was more pronounced in the Harweel compared to the Birba Cluster. The reservoirs in the Birba Cluster have a better reservoir quality than the Ara carbonate reservoirs in the Harweel Cluster in which their pore spaces are not strongly plugged with halite, anhydrite, and solid bitumen. Among the lithofacies associations in the Harweel Cluster, those of intertidal, and slope basin lithofacies display higher porosity in comparison to the rest of the lithofacies associations. The lithofacies with lower porosity values in the Harweel Cluster, including shallow subtidal, open marine thrombolites, shoal, and offshore transition zone lithofacies association are impacted mostly by the pore-filling halite (most dominant), anhydrite, and solid bitumen.