AAPG Datapages/Search and Discovery Article #90318 ©2018 AAPG/Middle East GTW, Carbonate Reservoirs of the Middle East & Their Future Challenges, Abu Dhabi, UAE, January 30 – February 1, 2018

Diagenetic Evolution and Timing of Oil Emplacement in the Arad-D Carbonate Reservoir, Saudi Arabia

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ABSTRACT

The Upper Jurassic (Kimmeridgian) Arab-D reservoir of the Arab Formation in the Arabian Peninsula is considered to be the largest hydrocarbon carbonate reservoir in the world. Petrographic, cathodoluminescence and ultra-violet light fluorescence microscopy analyses of the Arab-D reservoir in Saudi Arabia have been combined with isotope geochemistry ($\delta^{13}C$, $\delta^{18}O$ and $^{87}Sr/^{86}Sr$) to decipher the sequence of diagenetic events affecting the reservoir before and during oil emplacements, and the impact of depositional mineralogies and their modifications during the diagenesis on the reservoir quality and heterogeneity.

The diagenetic products and reservoir quality are distributed heterogeneously in the reservoir, being controlled primarily by the dominant original mineralogy (microfacies type), and its later modifications during diagenesis. In the grain-dominated facies, reservoir quality is worse in grainstone microfacies rich in aragonitic components and better in grainstone and packstone microfacies poorer in aragonitic grains due to excess of cementation. Three stages of carbonate dissolution (d1 to d3), four stages of calcite cements (C1 to C4) and 5 zones of replacive dolomite and dolomite cement (D1 to D5) have been documented from diagenetic environments ranging from marine to late burial. Based on analysis of fluorescence, the presence of hydrocarbons (oil) entrapped in various carbonate cements (C3, D5 and C4) have been determined, suggesting at least two phases of oil charging. The oil inclusion-rich cements are located in the flanks of the structure, whereas cements from wells located in the centre of the structure are largely oil-inclusions free. This distribution suggests that the former cements happened within the oil-water transition zone of the reservoir during the oil infilling of the structure. Burial porosity enhancement occurred by fracturing and pervasive dissolution (d3) by ascending of acidic, corrosive fluids in advance of hydrocarbon arrival. Dissolution was followed by formation of dolomite and calcite cements (C4), which exhibit a scattered distribution with a little effect in the destruction of the reservoir properties. Precipitation of the later cements (D5, C4) was contemporaneous with the main phase of oil emplacement. ($\delta^{13}C$, $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ isotope values of different cements suggest precipitation from Jurassic or evolved Jurassic marine pore waters, except for C4, which suggests a source from fluids that interacted with siliciclastics or clay-rich sequences. The integration of all these data resulted in a more precise understanding of the reservoir quality and heterogeneity.