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Application of a Fourth-Order Stratigraphic Framework for the Mishrif Member: A Basis for Mapping Lithofacies Variability & Petroleum Systems in the Rub'Al-Khali Basin of Saudi Arabia

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SUMMARY

New biostratigraphic interpretations have provided a basis for identifying fourth-order cycles within the Mishrif Member, and can be tied to log and seismic data, allowing construction of chronostratigraphic lithofacies maps. Higher-frequency depositional cyclicity is also observed, and it is possible to interpret individual geobodies in areas with 3D seismic coverage and well control.

The Cenomanian – Turonian-age Mishrif Member of the Wasia Formation in Saudi Arabia represents a time of shallow-water carbonate progradation directed northeasterly into an intra-shelf basin. Up to 150 km of lateral progradation is observed on the more windward western side of the intra-shelf basin, terminating with a rimmed carbonate shoal platform with up to 900 ft of relief. New biostratigraphic interpretations have provided a basis for identifying third- and fourth-order cycles within the Mishrif Member, and can be tied to log and seismic data, allowing construction of chronostratigraphic lithofacies maps. Higher-frequency depositional cyclicity is also observed, and it is possible to interpret individual depositional assemblages, comprising bioclastic shoals and rudist-bank facies, in areas with 3-D seismic coverage and well control.

Based on new micropaleontological data, the Mishrif Member consists of up to four fourth-order depositional sequences. Each sequence commences with a planktonic foraminiferal-dominated biofacies that represents deep-marine conditions related to the transgressive system tract (TST). Highstand system tract (HST) associated foraminiferal and rudist biofacies are represented by shallow-marine carbonates typically deposited in shoal and localised rudist-bank settings. These deepening and shallowing cycles have been correlated across the eastern Rub' Al Khali basin, and designated Mishrif TST1-HST1, TST2-HST2, TST3-HST3 and TST4-HST4 in ascending order. Mishrif source rocks correspond to the Mishrif TST1 sequence (Natih B equivalent of Oman). The overlying Mishrif HST1 reservoir sequence (Natih A equivalent) is sealed by the next transgressive cycle, Mishrif TST2. This reservoir-seal cyclicity continues in some places up to TST4-HST4, which is ultimately sealed by regionally extensive shales of the Aruma Formation.

There are two proven petroleum systems within the Wasia Formation, the Safaniya-Mauddud system and the self-sourcing Mishrif petroleum system. Safaniya lime-mudstone source rocks were deposited in a regionally extensive intra-shelf basin where anoxic conditions existed. Kerogens are oil-prone Type II-Sulphur requiring a low activation energy equivalent to a vitrinite reflectance of 0.60%. Based on thermal maturation modeling, the Safaniya entered the oil window 65 million years ago and is currently in the oil generation window. Oil sourced from the Safaniya is typically 30o API. The Safaniya conformably underlies the Mauddud Reservoir. Mishrif source rocks were deposited in a similar setting to the Safaniya but are marlier and contain less net source thickness. Mishrif source rocks are presently within the oil generation window, and reservoired oil is typically 38o API.