

The Importance of Regional Seals of Saudi Arabian Petroleum Systems: Insights from 3D Basin Modeling

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Abstract

Hydrocarbon seals are one of the critical play elements for defining the major proven petroleum systems in Saudi Arabia. A regional stratigraphic framework was unraveled by integrating geological and seismic interpretations, core descriptions, and petrophysical mapping of Pre-Khuff, Khuff, Triassic, Jurassic, and Cretaceous petroleum systems. Detailed structure depth grids, gross depositional environment (GDE) and lithofacies maps of source, reservoir and seals are taken as fundamental inputs for constructing a regional 3-D basin model. This paper focuses on the Permo-Triassic Khuff and Jurassic petroleum systems to demonstrate the importance of regional seals for hydrocarbon migration and charge through an integrated 3-D basin modeling.

The Triassic Sudair Formation is the ultimate regional top seal for the Khuff petroleum system. Several anhydrite intervals are potential regional top seals for Khuff-C, B, and A reservoirs within the Khuff sequences. The seal integrity varies from central Arabia, Ghawar, and Arabian Offshore over several thousands of square kilometers. Multiple hydrocarbon migration scenarios have been performed to match with known hydrocarbon accumulations and/or observed hydrocarbon shows in the Khuff reservoirs. The 3-D basin modeling results indicate that the interplay of regional top seals and possible deep-rooted fault systems was accountable for hydrocarbon migration and charge from proven Silurian Qusaiba source rocks.

The Upper Jurassic Hith anhydrite is the regional top seal of Jurassic oil accumulations. A number of evaporite successions (e.g., Arab-D, C, and B anhydrites) are also proven regional seals within the Upper Jurassic sequences. In particular, the pervasive Arab-D anhydrite proves to be a widespread cap rock, and prevents hydrocarbons migrating and charging into overlying Arab-C, Arab-B, and Arab-A reservoirs. Basin modeling results indicate that hydrocarbons generated from the Tuwaiq Mountain and Hanifa source rocks may have breached the Arab-D anhydrite and other possible seals over high-relief structures, and charged laterally into overlying Upper Jurassic and Cretaceous carbonate reservoirs.

This integrated 3D basin modeling has resulted in significant insights into hydrocarbon migration and charge of the proven petroleum systems. In particular, it has shown that regional seals not only play a considerable role as cap rocks for hydrocarbon accumulations, but also these seals significantly governed hydrocarbon migration pathways, and therefore leading to potential new play fairways and exploration concepts.