Hydrodynamic Conditions on Late Jurassic Arabian Shelf and its Impact on Facies Architecture—Insights from Hydrodynamic Simulation and Outcrop Investigation

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Abstract

This study presents a first attempt to model paleo-hydrodynamic conditions on Late Jurassic Arabian shelf and understand the impact of shallow water currents on sediment distribution and facies architecture. A well constrained 3D outcrop analogue was used to provide ground truthing for this simulation exercise.

The Late Jurassic shallow water carbonate sequences of the Arabian plate form major hydrocarbon producing reservoirs in the Middle East including super giant fields (Ghawar, Khurais; Berri) of Saudi Arabia. Several studies in the past have aimed at characterizing the heterogeneity of these reservoirs. However, no study has ever attempted to assess the impact of hydrodynamic circulation within the Jurassic paleo-ocean on heterogeneities found in these reservoirs.

We employ MIT general circulation model on Shaheen (HPC system at KAUST) to model the ocean circulation for the Late Jurassic Arabian shelf and adjacent parts of the Tethys Ocean. Paleobathymetry maps were generated for the Oxfordian/Kimmeridgian Hanifa Fm by integrating data from published facies maps and well log data. The initial, ocean boundary conditions (current velocity, salinity and temperature) and atmospheric forcings were obtained from a published global model. Various paleo-bathymetry scenarios were evaluated to capture most likely and most extreme cases and assess their impact on modelled current patterns.

The simulation result indicates the presence of strong surface current on the Late Jurassic Arabian shelf. The overall current pattern is highly heterogeneous with no unique trend and suggests strong sensitivity towards variation in bathymetry. However, the pattern seems to organize and become distinctive in the region with little or no bathymetry variations. In the shallow region between the Arabian-Nubian craton and the Arabian intrashelf basin, the current patterns have a strong and distinct N-S trend. Outcrop investigations in the Tuwaiq Mtn escarpment provide an opportunity to investigate whether current features can be distinguished in rocks of the same age. At Wadi Birk, shallow water carbonate deposits of the Hanifa Fm including stromatoporoid/coral reef facies have been investigated in detail for indications of currents. The close agreement between the modelled current patterns and orientation of stromatoporoid/coral reefs supports the outcome of the hydrodynamic modeling and underlines the usefulness of employing such models to understand and characterize sedimentary architecture in ancient sequences.

This study shows that paleo-hydrodynamic models can be extremely useful for understanding the facies architecture of shallow water carbonates. An improved understanding of paleo-hydrodynamics could be used as a constraint to model realistic distribution of reservoir facies in subsurface models. This may prove crucial for generating optimized reservoir development plans.