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Primary Productivity, Anoxia or Sedimentation Rate? Quantitative Modelling of Organic-Rich Carbonate Mudstones in the Arabian Intrashelf Basin with 3D Stratigraphic Forward Modelling

M. Rika Nanda Syahputra[1], Baharudin Fahmi[1], and Ardiansyah Koeshidayatullah[1,2]

[1]Department of Geosciences, College of Petroleum Engineering and Geosciences, King Fahd University of Petroleum and Minerals, 31261, Dhahran, Saudi Arabia.
[2]Center for Integrative Petroleum Research, College of Petroleum Engineering and Geosciences, King Fahd University of Petroleum and Minerals, Dhahran, 31261, Saudi Arabia

Abstract

The Mesozoic intrashelf basins (ISB) in the Arabian Plate exhibit unique carbonate sequences yet complex condition, allowing the development of source rock facies, reservoir intervals, and seal units simultaneously. In the Jurassic period, the Arabian Plate was situated under warm to arid climate and shallow, broad seas on western margin of the Neo-Tethys Oceans, creating favourable condition for the widespread deposition of thick organic-rich carbonate mudstones in the Arabian platform. While many studies have focused on the source rock characterization through method of sequence stratigraphy, geochemistry and hydrodynamic modelling, little information is available on the quantification of key factors during the deposition of organic-rich carbonate mudstones in the Arabian ISB. To address these issues, this study utilized a process-based stratigraphic forward modelling (SFM) approach which focused on several key input parameters to quantify processes governing the evolution of carbonate stratigraphic architecture as well as the accumulation and preservation of organic-rich carbonate mudstones in the Middle to Late Jurassic Arabian ISB. The results indicate that low to moderate primary productivity could have facilitated the accumulation and preservation of three distinct organic-rich intervals in the absence of persistent anoxic conditions. Nevertheless, to achieve consistency between the measured total organic content and the calibrated model outputs, this study incorporates scenarios of moderate to high primary productivity coupled with variations in the depth and intensity of oceanic oxygenation. Furthermore, the models reveal spatial-temporal heterogeneity on the richness and distribution pf organic matter which are linked to varied tectonic subsidence and sedimentation rates along the Arabia ISB. This study provides new quantitative insights into the mechanisms controlling the spatio-temporal variability of source rock quality within an intrashelf basin. The results highlight how subtle shifts in productivity, redox conditions, and sedimentation dynamics can significantly influence organic matter enrichment and preservation. These insights not only refine our understanding of source rock development but also offer a practical framework for pinpointing high-quality "sweet spots" in unconventional plays, ultimately improving exploration efficiency and reducing uncertainty in decision-making.