The Genesis, Compositional Heterogeneity, and Distribution of Shallow and Basinal Sediments of Epeiric Carbonate Platforms - New Insights from Paleo-Hydrodynamic Modelling

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Abstract

In carbonate systems, paleo-hydrodynamic conditions and component diversity are fundamental parameter behind textural classifications, the interpretation of depositional environments and geological sequences but also reservoir occurrence and quality. Yet, the actual understanding of current systems in ancient settings is rudimentary and often limited to crude applications of wind-direction and paleotopography. Utilizing boundary conditions from world-wide circulation models and paleo-topography scenarios we present a first assessment of the hydrodynamic circulation on the flooded shelf of the Arabian plate during the Late Jurassic Oxfordian (160 my bp). The simulation results provide models of paleo-current patterns on the shallow water platform and the deep water intrashelf basin with insights on sediment distribution and organic matter creation, transport, and deposition.

Models are based on hydrodynamic simulations, data from literature and outcrop investigations. Paleobathymetry maps were generated for the Oxfordian Hanifa Fm for an area covering the eastern boundary of the Arabian plate (3760 x 3360 km2). The initial ocean boundary conditions and atmospheric forcing are from a published global model for the Late Jurassic. A supercomputer was used to simulate hydrodynamics using the open-source MIT general circulation model (MITgcm). Paleobathymetry scenarios were evaluated to capture current scenarios for periods of low and high accommodation space during a 3rd order cycle.

The results show that in the shallow water regions of the platform, during periods of low accommodation space currents slow down, preventing effective mixing between platform and ocean. A strong salinity contrast develops (~55 ppt landwards versus ~45 ppt seawards) leading to the inboard deposition of barren muds during early transgressions and oncoidal facies during late regressions. In periods of higher accommodation space, strong currents develop that prevent the development of a salinity contrast. The entire shelf has near normal marine salinity of ~40 ppt. Open marine strata develop dominated by stromatoporoid-coral build-ups and grainstone/packstones facies. Currents also impact the spatial distribution of facies controlling compositional and ultimately reservoir-property heterogeneity.

During high accommodation space the intrashelf basin is in good communication with the open Tethys leading to significant surface and bottom currents and high-productivity upwelling zones. Localized distribution of upwelling sites impacts primary organic productivity along the margins of the intrashelf basin, resulting in regional patterns of organic matter generation and deposition. However, significant bottom

currents (~0.05 m/s) may cause redistribution of organic matter and mud-sized sediments along the seafloor. Basinal currents are confirmed by layers with erosional base, lag deposits, cross laminae, and starved to wavy ripples. When accommodation space is low (early transgression/late regression), connectivity between basin and Tethys is limited, surface currents do not support upwelling and bottom currents are too weak for re-sedimentation resulting in laminated organic rich mudstone layers.

Paleo-hydrodynamic modelling is a powerful new tool providing insights into the distribution and architecture of reservoir and source rock sequences developed in epeiric seas. Insights will benefit exploration, basin modelling and reservoir development studies.