Analysis of Sequence Stratigraphic Models for the Jurassic Cretaceous Sedimentary Fill of the Intrashelf Basins of the Eastern Margin the Arabian Plate

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Search and Discovery Article #30326 (2014)**
Posted April 21, 2014

*Adapted from poster presentation given at AAPG Annual Convention and Exhibition, Houston, Texas, April 6-9, 2014
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Abstract

Two critical conceptual sequence stratigraphic models for exploration and production were analyzed with sedimentary computer simulations of the Jurassic and Cretaceous sedimentary fill of the Intrashelf Basins (ISB) of the Eastern margin the Arabian Plate. One tracked the Hanifa Basin fill from Jurassic argillaceous carbonates to evaporites to the Cretaceous carbonates and the other the Aptian/Albian fill of the Bab ISB during a glacially induced sea level low. The Hanifa ISB simulation demonstrated Lower to Middle Jurassic sediments onlapped the uplifted eastern plate margin of the UAE and Oman as carbonates prograded and filled westward. Uplift ended Middle Jurassic accumulation with subaerial and progressive erosion of the Tuwaiq and Dhurma Formations on the eastern plate margin. Margin collapse caused a drowning unconformity. Westward of the platform margin the intra-shelf basin a base-level fall accompanied Arab and Hith evaporites accumulation. In the Early Cretaceous, the platform extended to North Oman with deposition of argillaceous hemipelagic carbonates of the Habshan. The lack of evaporites supports a climatic change from the Jurassic arid climate to a Cretaceous humid one. The simulation of the Mid Cretaceous carbonates supports division into Early Aptian and Late Aptian carbonate platform second order supersequences that aggraded and prograded to fill the Bab ISB. An unconformity initiates the sequence with westward prograding lowstand clinoforms onlapping eastward onto the Lower to early Upper Aptian carbonate platform of the SW margin of the Bab ISB. The simulation captures an initial sharp sea-level drop of 35–40 m from the early Upper Aptian shelf break to the topset of the first lowstand clinoform, and the sea-level drop by another 10 m during the progradation of following eight clinoforms. Each progradational pulse of the clinoforms is modeled over 405 k.y. Simulation illustrates the initial sharp sea-level drop of some 40 m followed by continued slow sea-level fall producing lowstand clinoforms prograding towards the ISB. Sedpak, developed at the University of South Carolina assumes clastic transport based on slopes and carbonate production based on water depth. Output geometries display a sequence stratigraphic framework of erosional and depositional surfaces of the simulated section enabling the extension of interpretation of depositional setting and predictions of lithofacies geometries away from well data.
Controls on Carbonate Accumulation

Cyclic Changes in Climate, Sea Level, Organic Productivity & Sequestration

Organic Matter and Plate Tectonic Evolution of Arabian Gulf

Plate Tectonic Evolution of Arabian Gulf

Plate Tectonic Evolution of southern Tethys

Cyclic Changes in Climate, Sea Level, Organic Productivity & Sequestration

Eustasy, Sediment Fines, salinity, and wave and wind actions controls on carbonate area

Eustasy, Sediment Fines, salinity, and wave and wind actions controls on carbonate area

Glacial Climate

Carbonate area

130%

15%

100%

500%

29%

25%

9%

30%

Aptian - Turonian

Upper Jurassic

Silurian

Evaporites through a prograding carbonate margin with basinal argillaceous carbonate capped by evaporites

The advantage of these simulations is that it provides a template to the production can be analyzed with sedimentary computer simulations of sedimentary fill of the intrashelf basins of the Eastern margin of the Arabian Plate. Examples from the Jurassic and Cretaceous sedimentary fill of the Eastern margin were simulated:

The region outlined by the red oval traces the evolution of the Southern Tethys basin seaway that has existed since the Cretaceous. This seaway has permitted the migration of Middle Eastern oil and gas fields.

Central and pre-existing topography were controls too within the intrashelf basins (ISBs)

The second order supersequences of Early Aptian and Late Aptian carbonate platforms aggrading and prograding while filling the basin.

During this time, aggradation on margin with a starved basin center. ISB margin then progrades and infills the basin, commonly less than 100 m deep.

In Early Cretaceous times the platform of the Arabian Shield extended to the shelf edge.

In the Jurassic and Cretaceous, carbonate platforms aggraded and prograded while filling the basin.

The development of post-rift systems through carbonate progradations and the development of shelf edge systems provide a significant opportunity for the development of such an environment. The history of the shelf progradation from the shelf break to the basin center can be described from the shelf break to the basin center.

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After Craig and Kendall, 2010

Christopher Kendall and Maurice Tucker, 2010

After Jones & Desrochers, 1992

Kendall and Alsharhan, 2013

Middle East Source Rocks, Reservoir and Seals (After Kendall and Alsharhan 2013)
Introduction to SEDPAK

The computer simulation sedimentary SEDPAK was developed at the University of South Carolina as a simulation tool that models the geometry of the generalized lithofacies of a basin, resulting from the interaction between the major geological processes including:

- Eustatic Sea Level
- Tectonic Movement
- Sediment Accumulation

SEDPAK constructs empirical models of sedimentary geometry. These sedimentary geometries are created by the inflating of a two dimensional basin from both sides with a combination of in situ carbonate growth and clastic sediment in the 15 steps outlined to the right.

Within each time step, a fixed sequence of operations creates or modifies the sedimentary geometries. First, tectonic adjustments change the accommodation at points defined by the user across the basin. Next, the intersection of the sea level position with the basin surface defines a bayline location ([formula]). Stepping the bayline location is added to the sediment supply. Stepping of the bayline, sediment intake or is deposited according to geometrical rules. After this step, the basin is defined by three curves: the bayline, wave base, and the sea level curve. Within the basin, carbonate and clastic sediment are removed from the sediment column to the right of wave base. The vertical axes show displacement occurring between two adjacent columns over time.

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The simulations suggest that the driving mechanisms behind accommodation, through sedimentation, are the formation of a pelagic carbonate bank with an associated lagoon. These lagoons prograde or forestep during the Aptian to Early Albian, leading to the accommodation of the basin. The simulations were conducted by assigning carbonate accumulation rates to different formations and adjusting the sedimentation rates accordingly. The carbonate bank forms a barrier that limits the accommodation of the basin. The simulations also show that the carbonate accumulation rates of Marrat ISB are similar to those of Hanifa ISB, suggesting a consistent sedimentation pattern. The simulations support the concept of eustatic subsidence and contribute to understanding the causes of accommodation.