Numerical modeling of clastic sediment export to basins for reservoir and storage quality prediction (Arabian Plate, Cretaceous)

Rainer Zühlke and Nikolaos Michael*
Saudi Aramco EXPEC ARC, Geology Technology, Dhahran, Saudi Arabia

ABSTRACT

Objectives - Sediment supply from continental source areas represents an important control of large-scale sediment architecture on continental margins. The sequence stratigraphic concept of "lowstand shedding" for clastic depositional systems proposes that eustatic sea-level falls trigger a basin-ward migration of sand deposition and falls a continent-ward migration. The general objective is to analyze whether the export of sand-sized clastic sediment to basins on the Cretaceous Arabian Plate correlates with corresponding eustatic sea-level changes. A detailed understanding of sediment partitioning and the basin-ward limit of sand export is crucial for HC reservoir prediction and for the assessment of potential CO_2/H_2 storage units.

Methods - Data for sediment supply modeling are derived from more than 1500 wells (logs, cuttings) that cover wide parts of the Arabian plate. The total area of interest measures 1500x1700 km including proximal parts of the continental source area. Temporal resolution is at the level of geological stages in the Cretaceous with an average duration of 4.2 Ma (min. 1.3 Ma, max. 10.0 Ma). The key metric for the objective of the study is the lateral migration of the "sand front", defined as the distal 10% (fine) sand abundance contour line in shelf-interior basins. In order to obtain the best possible reference dataset of eustatic sea-level changes during the Cretaceous, this study processes and analyzes all datasets in the following way: 1) recalibrate existing data on eustatic sea-level changes to the same chronostratigraphic scheme (Cohen et al., 2013, updated; International Chronostratigraphic Chart v2023/09); 2) calculate average, minimum and maximum amplitudes for 3rd order eustatic sea-level changes; 3) sediment supply modeling using proprietary software for the Berriasian to Santonian for 14 individual time intervals based on formations/members, providing the position of the sand front for each time interval across the plate; 4) parametrization of the local distances between the sand front and a reference line to a single, representative distance per time interval; 5) comparison between basin-/land-ward migration of the sand front and eustatic sea-level fall/rise for the each time interval.

Results - A weighted analysis of existing eustatic sea-level data for the Cretaceous (Sahagian et al., 1996; Miller et al., 2004; Haq, 2014; Ray et al., 2019; Boulila et al., 2021) indicates average amplitudes of 20-25 m, interpolated over time intervals of 1.3 Myr to 10.0 Myr, i.e. at the temporal resolution of geological stages. However, uncertainties exist regarding the timing and amplitude of individual 3rd order sequences at sub-stage durations. Excluding extreme outliers, maximum amplitudes of eustatic sea-level changes during individual Cretaceous stages may reach up to 75 m. The majority of 3rd order eustatic sea-level changes during the Cretaceous feature amplitudes below 35-40 m. Across proximal continental source areas and shelf-top basins with an extension of 1500x1700 km, migration distances of the sand front reach up to +310 km (basin-ward migration) and -173 km (continent-ward migration) over time intervals of average 4.2 My). Rates of sediment input at plate scale show significant variations, between 2,741 km^3/My (Aptian) and 38,681 km^3/My (Barremian). Eustatic sea-level falls which (co-)control sand export to the shelf-interior basin, i.e. the position of the sand front, prevail during the early Valanginian to late Hauterivian and the latest Cenomanian to late Turonian. During these time intervals lateral migration of the sand front shows basin-ward migration during eustatic sea-level falls, continent-ward migration during eustatic sea-level rises respectively. During all other intra-Cretaceous time intervals, the sand front migrates in the opposite direction.

Significance and Perspectives - The widely held sequence stratigraphic concept that clastic and clastic-carbonate systems generally represent lowstand shedding systems cannot be confirmed for the Arabian Plate. During extended intervals in the Cretaceous, changes in sediment supply from continental source areas primarily controlled sand export to the basins. Uncertainties in the prediction, exploration and production of clastic reservoir and storage units can be reduced significantly with prior sediment supply modeling at basin to large prospect scale. The way forward is integrated process-based modeling, comprising sediment supply modeling (this study), process-based depositional-diagenetic modeling and flexural subsidence/uplift modeling for fully numerical 3D accommodation models.