Integrated Basin Analysis of the Atlantic Margin, Tarfaya Basin, Morocco

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Introduction

The technique of numerical stratigraphic modelling has been introduced with the refinement of sequence stratigraphic concepts and the advent of powerful computer technology. Since approx. 15 years, this technology is now widely distributed in both academia and industry. It is especially suited for assessing and ranking exploration targets and is illustrated with a case study from a mixed carbonate/siliciclastic sedimentary environment–the Cenozoic Atlantic margin in the Aaiun-Tarfaya basin sector.

The Moroccan margin exhibits a complex structural evolution that can be schematically subdivided in three major episodes: pre-rift, synrift, post-rift. During the post-rift period (Jurassic to recent) several abrupt changes in drift direction affected African plate's motion. To the south of Tarfaya, geodynamic evolution of the continental margin appears homogeneous and represents the typical rifted Atlantic passive continental margin. Northwards, the creation of the basin between the Canary Islands and the African continent was subsequently overprinted by effects of the Tertiary alpine orogeny, antithetic rotation of tectonic blocks at the continental margin induced by rifting motion along the master detachment fault, and episodic salt-induced movements which made geometry and structural patterns of this passive margin very complex.

In the onshore part of the Aaiun-Tarfaya basin, thicknesses of Lower Cenozoic lithological units vary significantly (0-1100m;). In most cases, they unconformably overlie Upper Cretaceous strata. A major input in clastic sediments during the Eocene indicates either a sea-level fall, an increased sediment flux from the hinterland or the combination of both. The basal Oligocene transgression is recorded by limestones of a coastal playa lake, followed by red siltstones characteristic of a playa plain. This succession is overlain by a regionally known Lower Oligocene angular unconformity. Sedimentation continues with a siliciclastic fining-upward megasequence, comprising of alluvial fan to playa plain facies. Major depositional breaks (Oligocene to Lower Miocene) can be traced towards the shelf. Especially in the northern coastal basin, the Oligocene is missing due to widespread erosion during this interval. Miocene deposits thicken considerably towards the south and west, they are mostly transgressive and characterised by sandy lime- or claystones. The Upper Miocene is characterised by a regressive phase (5.3 Ma, Messinian event) and represented in the offshore basin by a strongly bedded acoustic unit.

Numerical modelling

The particular feature of sequence stratigraphic forward modelling is the simulation of sedimentary facies patterns depending on the creation/destruction of accommodation space. This accommodation development of the Tarfaya sector of the Atlantic margin was determined beforehand during an inverse modelling procedure taking into account lithological and crustal parameters. Calibration of the modeled section was realised by visual comparison with seismic and well data. Several models with different sets of input parameters were run simultaneously in order to achieve a best fit and min-max scenarios.

Results

The sedimentary and stratigraphic framework of the Tarfaya margin is characterised by its complex structural history and also by global eustatic sea-level change. The Middle and Upper Cretaceous shelf deposits are marked by a general transgression and sea-level highstand. During the entire Cenozoic the shelf is characterised by tectonic instability and high-amplitude glacio-eustatic sea-level fluctuations which started in the Oligocene. This interaction is represented by numerous unconformities within the sedimentary deposits on the shelf as well as by erosion surfaces and lack of Tertiary sediments on land.

The course of sequence stratigraphic forward modeling made clear that a basal unconformity (i.e. basal Cenozoic U/C) existed at shallower levels than the seabottom is observed today and this basal Cenozoic unconformity lay bare in distal areas for several millions of years. After this period of submarine exposure combined with non-deposition and the local development of hardground features, the margin is characterised by:

progradation of shaly sediments into the basin over this presumed hardground surface,

influx of sand and abundant mass transport complexes during an Eocene to Oligocene interval and

progradation of shaly sediments with significant carbonate and sand content from Upper Miocene onwards triggered by climatic factors (erosion history of hinterland), tectonic factors (uplift of shelf and hinterland) and SL change (SL fall, global lowstand during Plio-, Pleisto- and Holocene).