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The Upper Jurassic-lower Cretaceous Siliciclastic System in the Morocco Offshore - Prevenance, Transport and Deposition

G. Bertotti* (Delft University of Technology), A. Arantegui (University of Manchester), R. Charton (Delft University of Technology), T. Luber (University of Manchester) & J. Redfern (University of Manchester)

SUMMARY

The Morocco segment of the Central Atlantic passive continental margin experienced km-scale exhumation during the early post-rift (late Jurassic-Early Cretaceous). In the Meseta and the High Atlas this led to the development of a N-S trending ridge sourcing terrigenous sediments which were brought to the Atlantic sea via wide rivers flowing on fairly flat plains. In correspondence with the W termination of the High Atlas, waters were deeper and no terrigenous sediments are found in the Lower Cretaceous. South of the High Atlas, exhumation followed a different pattern and led to the formation of a WSW-ENE striking topgraphic high which formed the first order divide of the region. Coeval sediments along the coast are sands to conglomerates deposited mainly in fluvial systems.
The source-to-sink approach helps in predicting offshore distribution and characteristics of the sand bodies which form one of the most interesting reservoirs along the coast of NW Africa

Introduction

The break-up of Pangea in Triassic to Jurassic times led to the development of extensional basins presently along the coasts of NW Africa and Canada-US and, in the Middle Jurassic, to the opening of the Central Atlantic. Differently from what generally expected for passive continental margins, large parts of Morocco experienced in Late Jurassic to Cretaceous times, that is during the post-rift stage an event of exhumation and erosion which produced large amount of terrigenous deposits (Bertotti and Gouiza, 2012) that were transported through fluvial systems to the W, formed coastal and deltaic systems in the present coastal region and eventually were deposited in the deep offshore. A distal portion of the turbiditic system is exposed in the Canary Islands. These sediments form potential reservoirs all along the coast of NW Africa from Morocco to Senegal (Davison, 2005).

To predict the distribution and sedimentological characteristics of relevant sand bodies in the Morocco offshore, geologists the University of Manchester and the Delft University of Technology under the umbrella of the North Africa Research Group (NARG) have started a source-to-sink project characterizing the source area, the fluvial to shallow marine distribution system and eventually the deep system.

The first part of our studies addresses the source-to-sink evolution of the northern part of Morocco, inclusive of the Meseta and the future High Atlas; the second one focuses on the less known southern region (Anti-Atlas and Reguibate). In both regions the onshore and offshore geology are addressed. The study involves a combination of different tools ranging from low-temperature geochronology, sedimentological studies and seismic analysis.

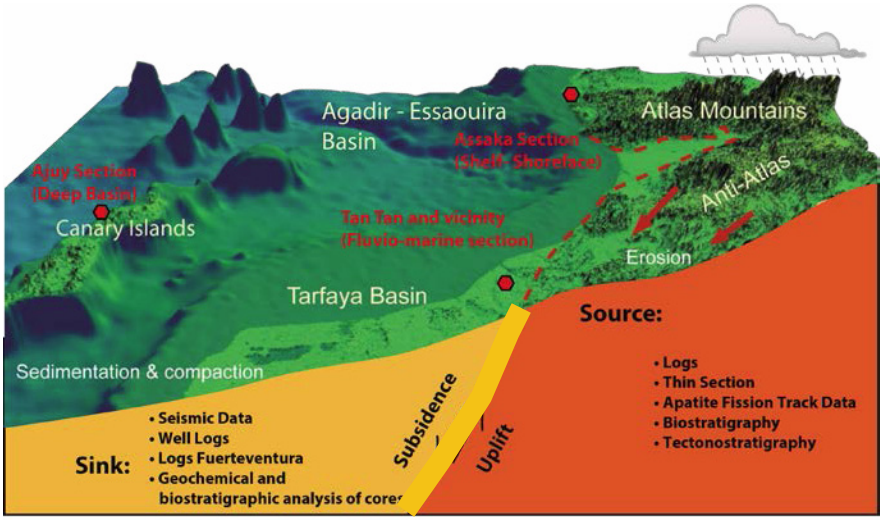

Figure 1 *– Source-to-sink analysis between the western termination of the High Atlas and the Canary islands. Red dots indicate the main section logged and sampled*

The northern domain: Meseta to High Atlas

The kinematics of exhumation in this northern region is fairly well documented by a significant number of low-temperature geochronological studies (Bertotti and Gouiza, 2012; de Lamotte et al., 2009; Ghorbal et al., 2008). Following the Variscan orogeny, the entire region was peneplained and began subsidence possibly in relation with Central Atlantic rifting allowing for the deposition of Triassic to Jurassic clastics and carbonates. In the Middle Jurassic an area elongated in N-S direction, ca. 200km wide stretching from Rabat to the *Massif Ancien de Marrakech* and, further to the S, to the Siroua Plateau inverted the sense of vertical movements and started moving upward causing erosion

and sediment production. Triassic to Jurassic sediments presently found in the Meseta are then remnants of the erosion event.

The area experiencing exhumation was flanked by subsiding domains in the E and, more importantly, to the W (Essaouira and Agadir basins) (Hafid, 2000). Here, subsidence has been continuous through Permian to Cretaceous time although an increase in subsidence rates has been observed starting at around 150Ma (Bertotti and Gouiza, 2012). These movements, which have been tentatively associated with E-W shortening (Bertotti and Gouiza, 2012) ended in the middle Cretaceous when the central area was exposed, began subsiding and was covered by Upper Cretaceous shallow water carbonates. Possibly the only tectonic model proposed to explain these observations suggests that the upward moving domain of the *Massif Ancien de Marrakech* and the subsiding region of the Essaouira-Agadir basin were linked by internally weakly deformed region gradually titling towards the W (Bertotti and Gouiza, 2012).

Analysis of the paleotopography of the Meseta region prior to the onset of Upper Cretaceous sedimentation documents the absence of significant relief thereby suggesting the absence of localized river systems. Possibly, some relief was present to the N in the Rohamni region.
Coastal to shallow marine sediments have been analysed in a number of sections along the present day coast of Morocco and document fluvial to continental conditions during the early Cretaceous in the region N of the High Atlas and frankly marine environments at the transition between the High Atlas and the Atlantic ocean (Figure 2).

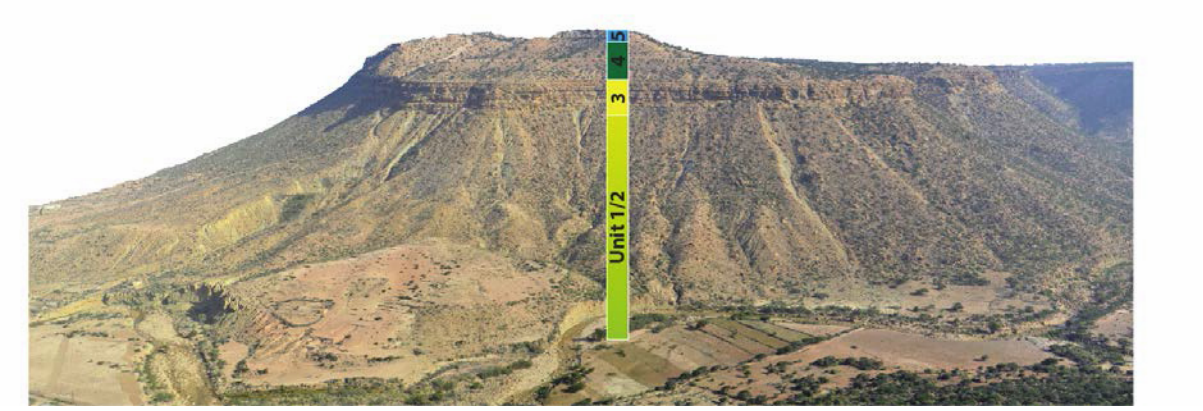

Figure 2- *The Lower Cretaceous to Albian Assaka section (W continuation of the High Atlas).*

The resulting paleo-geographic picture in the Meseta – High Atlas region during the Early Cretaceous would then envisage the presence of a roughly N-S trending ridge between Siroua and Rabat forming the regional water shed separating sediments being discharged in the Atlantic from those ending in the Tethyan domain. The resulting deltas along the coast were probably influenced by onshore Atlantic currents.

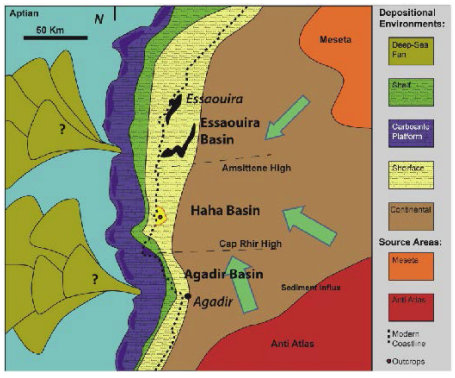

Figure 3 *Tentative paleogeography of the W High Atlas termination in Aptian times. Compiled by T. Luber*

The Southern domain: Anti Atlas to Reguibate

The area south of the High Atlas includes very large domains of outcropping predominantly pan-African pre-Cambrian to Palaeozoic rocks, namely the Anti-Atlas and the Reguibate Massif. The two domains stretch several hundreds of kms in WSW-ENE direction and are separated separated by the gently folded Tindouf (Zag) basin.

A significant number of low-temperature geochronological studies has been performed in the Anti-Atlas mountains in the last years (e.g. Ruiz et al., 2011; Sebti et al., 2009; Sehrt, 2014). Resulting ages are fairly homogeneous along the axis of the Anti-Atlas and range, depending on the method, cover the entire range of values from 300Ma to 50Ma. Time-temperature curves constructed for a number of samples show that this distribution is associated with continuous exhumation of the Anti-Atlas from the through Triassic to Tertiary times. Geological information suggests that the amount of exhumation was decreasing to the WSW and to the ENE.

The overall picture, admittedly not very well constrained, suggests the presence through a long period of time of a mountain chain being constantly rejuvenated by slow but persistent upward movement. This topographic relief might then have formed a major morphologic barrier and a first-order water shed. Waters precipitating to the N of the watershed would have formed rivers moving northwards and being deflected by the N-S trending ridge passing through the *Massif Ancienne de Marrakech*.

All along the coastal domains of Central Morocco from Agadir southward, to Sidi Ifn and Foum Draa sediments are found which are generically dated as Lower Cretaceous in the Geological Map of Morocco. Such dating, however, should be considered with care as the sediments have an extremely poor fossil content. As a result, correlations and the development of a consistent paleogeographic scheme remain challenging.

Sediments are very coarse and immature in the Sid Ifni area and were deposited in fluvial environments (Figure 4). Moving southward, towards Foum Draa sediments become finer grained and are frankly marine moving away from the Anti-Atlas (Figure 4).

Figure 4- *Lower Cretaceous sediments along the coast S of Agadir; left, Sidi Ifni area; right, Foum Draa.*

These studies, although only recently started make it possible to propose some ideas on the topography of the area during the Triassic of Early Cretaceous and, thereby, some very preliminary ideas on fluvial patterns and associated amounts of sediments delivered to the Morocco offshore. Integrating further low-T geochronology data, more sedimentological studies and provenance analyses, we will be able to provide a more detailed picture. The resulting tectono-sedimentary model will be eventually further expanded towards the S.

Acknowledgements

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