Mesozoic Source-to-Sink Systems in NW Africa

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Summary

It has been widely admitted that post-Hercynian deformation in NW Africa has been limited to rifting in the Central Atlantic passive margin and the Atlas system in the Mesozoic, and to mountain building in the Atlas and the Tell-Rif in the Cenozoic. Domains like The Moroccan Meseta and the West African Craton were, for long time, interpreted as stable and to have experienced no (or very limited) structural deformation during Mesozoic to Cenozoic times. Recent studies based on low-T geochronology reveal, however, different and unexpected story.

Apatite Fission Track (AFT) combined with He(U/Th) ages document km-scale vertical movements affecting "stable" parts of NW Africa during Jurassic to Late Cretaceous times. Thereby, samples from the old (i.e. Precambrian–Paleozoic) basement, which outcrops in the Moroccan Meseta (i.e. Ancient Massif and Rehamna) and the High Atlas of Marrakech (i.e. Western High Atlas) indicate two phases of subsidence-exhumation. The first, unrecognized so far, lasted from the Jurassic to the Early Cretaceous. Rocks were buried to a maximum depth of 3–4 km in the Late Triassic-Middle Jurassic, and then exhumed to the surface in the Early Cretaceous. The second phase records 1–2 km of subsidence and exhumation between the Late Cretaceous and the Miocene. Furthermore, in the West African Craton, AFT results indicate that the Precambrian rocks exposed in the Anti-Atlas also uncover comparable upward movements between the Jurassic and the Late Cretaceous.

On the other hand, seismic and well data reveal the existence of an exceptional Lower Cretaceous silici-clastic sedimentary episode overlying the Mesozoic carbonate succession in the offshore of the NW African margin. It reaches a maximum thickness off southern Morocco and extends as south as offshore Guinea. These Lower Cretaceous terrigenous sands are believed to result from the erosion of the Paleozoic and Precambrian massifs of the Anti-Atlas and the Reguibat shield which could have been uplifted by that time.

The km-scale upward movements affecting proximal domains of the NW African rifted margin and the coeval subsidence in the distal margin have opened new horizons for the understanding of the post-Hercynian tectonic evolution of NW Africa. The age of these movements is indeed noteworthy as they are younger than the Hercynian orogeny and older than the onset of contraction and mountain building in the Maghrebian domain (i.e. Rif and Atlas mountain belts). It is particularly enigmatic as it followed the appearance of oceanic crust in the central Atlantic and occurred, therefore during the "passive" margin stage.

This Thesis focuses on the Atlantic rifted margin of Morocco, formed during Mesozoic times. To provide a kinematic and quantitative analysis of the evolution of the rifted margin, crustal sections crossing the Atlantic margin in the regions of Doukkala in the North and Tarfaya in the South have been constructed, and thermo-kinematic modeling of subsidence have been conducted (i) to test quantitative relations between amounts and distribution of thinning and related vertical movements, and (ii) to link the proximal onshore regions affected by upward motions to the distal offshore basins experiencing continuous subsidence.

Extensional basins formed along the future continental margin and in the Atlas rift system in association with the opening of the Central Atlantic. Rifting began in the Late Triassic and ended with the appearance of oceanic crust at 175 Ma. The syn-rift stage shows a two-phase evolution with an initial rifting ($\sim$ 228–200 Ma) marked by distributed crustal deformation and a final rifting ($\sim$ 200–175 Ma) characterized by localized strong necking of the mantle lithosphere which was exhumed prior to the final breakup.

The strong lithospheric thinning which took place before the first appearance of ocean crust ($\sim$ 175 Ma) involved significant heat input into the rifted system and led to substantial subsidence during the Jurassic. The high subsidence rate continued during the Early Cretaceous with deposition of thick clastic formation offshore the Moroccan margin, resulting from the erosion of the exhuming onshore domains to the East (e.g. the Meseta, the High Atlas of Marrakech and the Anti-Atlas). Thermo-mechanical modeling of lithospheric extension is used to understand the process responsible of the km-scale exhumation taking place during the Moroccan "passive" margin evolution. Based on constraints inferred from the Nova Scotia-Doukkala conjugate margins, the implications of late rifting small-scale mantle convection on surface topography have been investigated. The results show that mantle lithosphere flow is unable to explain an exhumation comparable to that documented onshore the rifted margins of the Central Atlantic.

To constrain the tectonics driving the Middle Jurassic to Early Cretaceous vertical movements, structures cropping out in the coastal Essaouira-Agadir basin have been investigated. The latter is a subsiding Mesozoic basin flanking the region of the High Atlas of Marrakech experiencing exhumation and where syn-sedimentary deformations can be identified and interpreted. Field observations indicate that the upward movements are driven by a roughly E-W to NE-SW trending shortening superimposed on the thermal subsidence of the margin. It is compatible with the widespread occurrence of contractional structures developed in Jurassic to Early Cretaceous times in the western parts of the High Atlas and surrounding areas.

Tectonically driven vertical movements and deformations are unusual during the post-rift stage, and not predicted by current quantitative models. The topic is even more interesting because possibly comparable motions were taking place as south as Sierra Leone where preliminary low-T thermochronology data from the Man-Lèo Shield show vertical movement patterns similar to that described in Morocco, some 2500 km to the North.