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Tectonics

New tectono-sedimentary evidence constraining the timing of the positive tectonic inversion and the Eocene Atlasic phase in northern Tunisia: Implication for the North African paleo-margin evolution

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Abstract

The Medjez-el-Bab (MEB) box anticline, northern Tunisia, gives new evidence allowing us to precise the tectonic agenda of the North African paleo-margin inversion. On the one hand, the examination of this structure permits us to show that the inversion began approximately by the transition between the Lower and Upper Senonian. On the other hand, it highlights the occurrence of a Middle-to-Late Eocene compressive tectonic phase (the so-called Atlas or Atlasic phase), which is well recorded by reworking material within the Middle Eocene deposits as well as by the angular unconformity of the Late Eocene beds, supporting the hypothesis of compressive Eocene phase (Atlasic phase) generalized all over the Maghreb. ***To cite this article: A. Masrouhi et al., C. R. Geoscience 340 (2008).***

Résumé

Nouvelles données tectono-sédimentaires sur l'inversion tectonique et la phase atlasique éocène de la Tunisie du Nord : implication sur l'évolution de la paléo-marge nord-africaine. L'anticlinal coffré de Medjez-El-Bab (MEB) en Tunisie du Nord permet l'acquisition de nouvelles données tectono-sédimentaires, grâce auxquelles il est possible de dater le début de l'inversion tectonique positive de la marge nord-africaine, dans son tronçon tunisien, probablement à la transition Sénonien inférieur et Sénonien supérieur. Dans cette structure, la révision de l'âge des barres carbonatées tertiaires, considérées toutes comme yprésiennes dans la littérature, nous a permis d'identifier deux unités litho-stratigraphiques distinctes : (i) la première est effectivement yprésienne ; (ii) la deuxième est d'âge Éocène moyen. Cette dernière, qui remanie des éléments crétacés et yprésiens, enregistre un soulèvement dû à une tectonique compressive contemporaine. L'intervention d'une phase éocène (Éocène moyen à terminal) compressive est bien fossilisée aussi par la discordance angulaire ($\sim$20°) de l'Éocène terminal. Ces données sont en faveur

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de l'hypothèse de la généralisation de la phase éocène (atlasique) sur toute la marge nord-africaine. ***Pour citer cet article : A. Masrouhi et al., C. R. Geoscience 340 (2008).***

Keywords: Tectonic inversion; Atlasic phase; Northern Tunisia; North African paleo-margin

Mots clés : Inversion tectonique ; Phase atlasique ; Tunisie du Nord ; Paléo-marge nord-africaine

1. Introduction

The Cenozoic geodynamic evolution of the North-African paleo-margin in its Tunisian part is still the subject of several discussions [9,26,27]. Indeed, in northern Tunisia, the beginning of the positive tectonic inversion and the age of the major tectonic events remain a matter of debate [9,17,26,27,41,44–46,52,53]. By contrast, in Algeria, the tectonic agenda is quite well-established with, in particular, an important tectonic event during the Middle-Late Eocene [3,6,8,12,13,16,23,28,35,39,48].

In the Tunisian Atlasic foreland, the studied NE-SW trending Medjez-el-Bab box anticline (MEB) (Fig. 1) is one of the rare structures, in which the youngest sediments have not been completely eroded. Elsewhere, in the Atlasic domain of northern Tunisia, the structures show often an inverse morphology with perched synclines and deeply eroded anticlines. In addition to this structural particularity, several other sedimentary features were observed in the MEB anticline: remarkable thickness variations, sedimentary hiatuses, reworking material and conglomerates.

In this paper, we present new tectono-sedimentary data to support the occurrence of a Middle-to-Late Eocene compressive phase in northern Tunisia and to reliably approximate the age of the beginning of the tectonic inversion of the North-African paleo-margin.

2. New tectono-stratigraphic data

2.1. Mesozoic series

The core of the MEB anticline structure (Fig. 2) is occupied by Barremian marls with rare blackly limestone intercalations, which have been dated by *Lenticulina eichenbergi*, *L. barremiana*, *Dorothia oxycona*, *D.* sp. [18]. On these series lie clayey and marly sediments with some quartzitic layers. These sediments, which were dated as Upper-Middle Aptian according to their facies [31] and microfauna [18], are overlaid by marly layers with continuous quartzitic intercalations (Fig. 3). They correspond to the Late Aptian and are well dated by *Planomalina chiniourensis*. The late thirty meters, on which reposes an exotic sheet made of Triassic salt and dissociated elements, is represented by clay deposits showing some limestone intercalations exhibiting slumps and septaria. These intercalations reveal *Favusella wachitensis* only, characterizing the Lower Albian.

The Lower Cretaceous series described above are either limited by east-west right lateral strike-slip faults (Figs. 2 and 3) or covered by a Triassic body under which they plunge systematically along the two limbs of the MEB fold [31,32]. This Triassic salt geometric configuration, already shown on the El Ouradi geological cross-sections ([18], Figs. 40–41) made in the J. Bou Rahal, which is the southern limb of the MEB fold, corresponds to a simple ''salt glacier''. This type of Triassic salt outcrop is relatively well-recognized in the north-eastern Maghreb salt province [21,50,51]. The interstratified position of the Triassic material is well illustrated throughout its cartographic outline (Fig. 2), its sedimentary contacts and the stratigraphic continuation between the upper and late series (Fig. 3). This interstratified position of the Triassic material became visible thanks to the trenches of a new highway (Fig. 2), which crosses the structure south-east of the J. Bou Mouss and north of J. El Mourhra [31,32].

The Middle-Upper Albian to Senonian series are themselves either limited by strike-slip faults or, contrarily to the series described above, superimposed onto the Triassic materials with a stratigraphic contact with conglomeratic insoluble Triassic lenses. On the latter is developed an Upper Cretaceous series showing, in the J. Bou Mouss as well as in the J. Bou Rahal, from the late to the upper:

- grey to black marly series with *Ticinella breggiensis*, *Rotalipora subticinesis*, *P. praebuxtorfi* microfauna characterizing the early Upper Albian;
- platy limestone with *P. buxtorfi* dating the Upper Albian;
- Cenomanian marls dated with *Rotalipora appennica*;
- Turonian limestone dated with *Helvetoglobotruncana helvetica*;

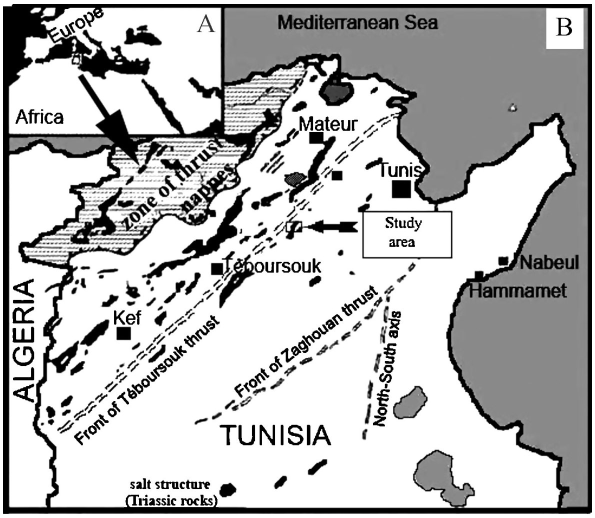

Fig. 1. A. General situation of the northern Tunisia domain, B. Simplified geo-tectonic map of the northern Tunisia showing the location of Medjez-El-Bab structure.

A. Localisation générale de la Tunisie du Nord, schéma tectonique simplifié de la Tunisie du Nord, avec emplacement de la structure de Medjez-El-Bab.

- the Coniacian–Santonian marl of the Aleg Formation dated with *Globotruncana coronata* and *Dicarinella concavata* at its base and with *Pseudolinneiana* sp., *Dicarinella asymetrica* et *D. concavata* at its top.

These series are conformably covered, in the J. Bou Mouss as well as in the Sidi Med Akermi periclinal anticlinal closure of the MEB, by the Companian-Maastrichtian limestone dated with *Globotruncana*

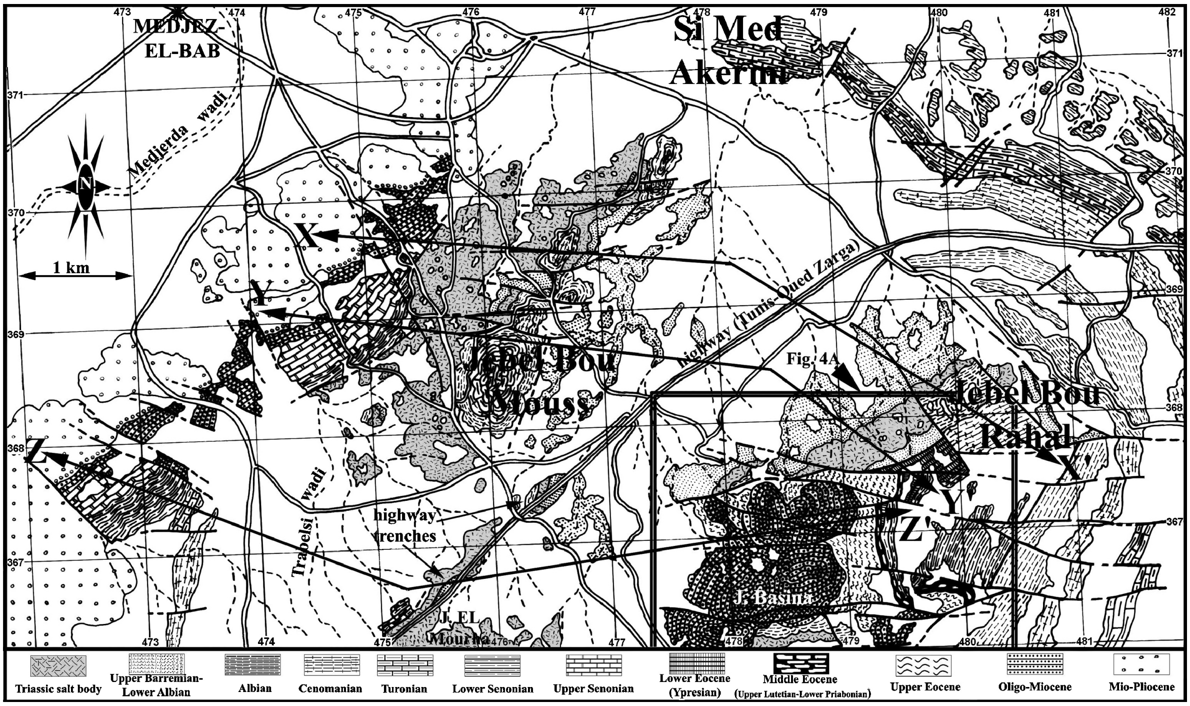

Fig. 2. Simplified geological map of the de Medjez-el-Bab structure, white: Quaternary, litho-stratigraphic symbols: see legend on figure and cross-sections of Fig. 3, thin lines: stratigraphic contact, thin and dashed lines: hydrography, bold lines: faults.

Carte géologique simplifiée de Medjez-El-Bab, blanc : Quaternaire, légende litho-stratigraphique (carte et Fig. 3), traits fins : limites stratigraphiques, traits moyens tiretés ; réseau hydrographique, traits forts : fractures (tirets si supposées).

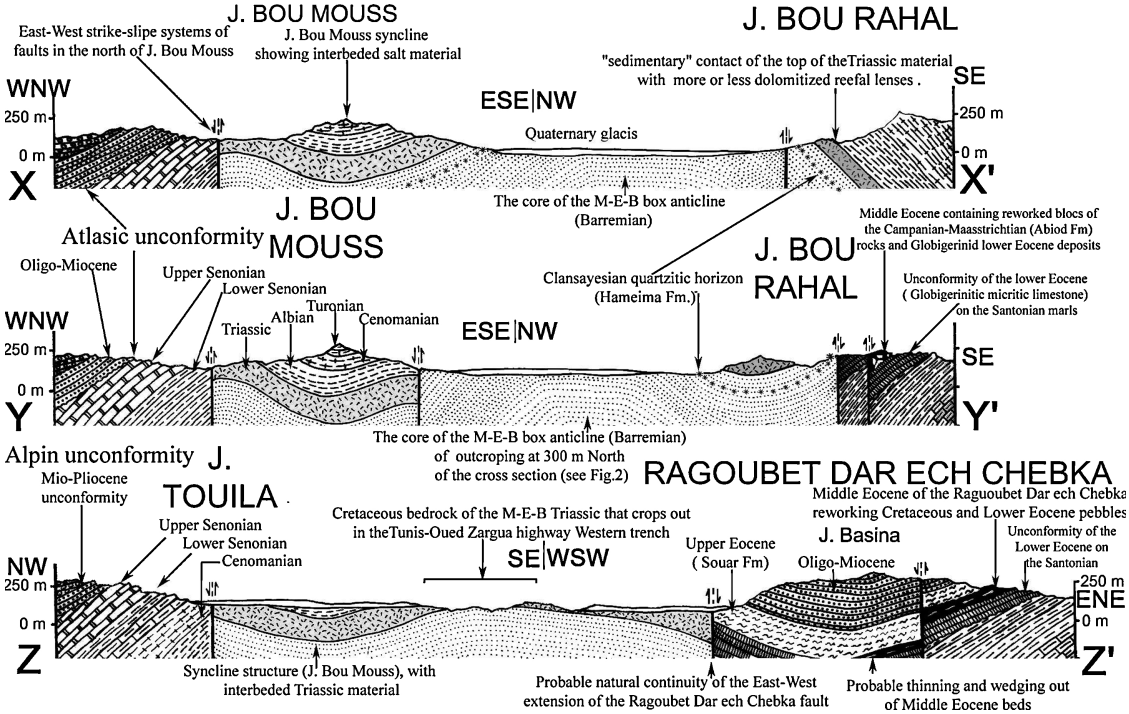

Fig. 3. Interpretative cross-section of the Medjez-el-Bab structure (location on Fig. 2).
Coupes interprétatives de la structure de Medjez-El-Bab (localisées Fig.2).

ventricosa at its bottom, *G. calcarata* at its middle and *G. falsostuarti* at its top. On the contrary, on the southern limb of the MEB structure (J. Bou Rahal), this Late Senonian beds are absent (Fig. 3).

2.2. *Tertiary series*

It has been established that the limestone layers hat crop out south of the J. Bou Rahal are Ypresian in age. They are transgressive and lie unconformably on the Cretaceous bedrock and exhibit spectacular changes in their thickness and facies within short distances [18–20]. These sedimentary alterations were explained by an active pre- and/or syn-Ypresian diapirism. However, in this study, the review of the MEB structure permits to define in the Tertiary pre-Miocene series four units which are, from the late to the upper:

- a siliceous yellowish limestone layer (Fig. 4B1), slightly laminated and globigerinid-rich (defined in the literature as globigerinid facies). This layer, which is transgressive on the Santonian marl [18–20], shows at this base a thin biodetritic and glauconitic layer, which does not show any reworked Triassic clast (Fig. 4A). Close to its top, this layer shows rare small and broken nummulites. Thus, this limestone layer is as indicated in the literature [18,19] of Ypresian age. The Ypresian-Santonian unconformity, records a slight uplift of the area, likely from a tectonic origin. The diapiric origin, as previously mentioned [18–20], is excluded due to the absence of Triassic reworking elements. On the other hand, contrarily to previous geological maps, we note that, south of J. Bou Rahal, this Ypresian layer is not in contact with Triassic materials but is bounded by vertical faults on the Lower Cretaceous series (Fig. 3, $x = 479.5$, $y = 367.5$), which themselves dip under the Triassic materials;
- a massive and lithoclastic limestone lying unconformably on the older layers and under which the first unit pinches out in the eastern piedmont of the Ragoubet Dar ech Chebka (Figs. 2 and 3 YY′). This phosphate-rich second unit is characterized by the presence of big nummulites (*Nummulites* sp.) and *Discocyclina* dating the Upper Lutetian-Lower Priabonian. In addition to micropaleontological difference with respect to the first unit, this unit shows a different lithology and is obviously distinguishable (Fig. 4B2). In fact, this unit has reworked different elements (Fig. 4C) i.e. biomicrite Globotruncanidae-rich Campanian and Maastrichtian cobbles and pebbles, gritty Triassic cobbles, typical

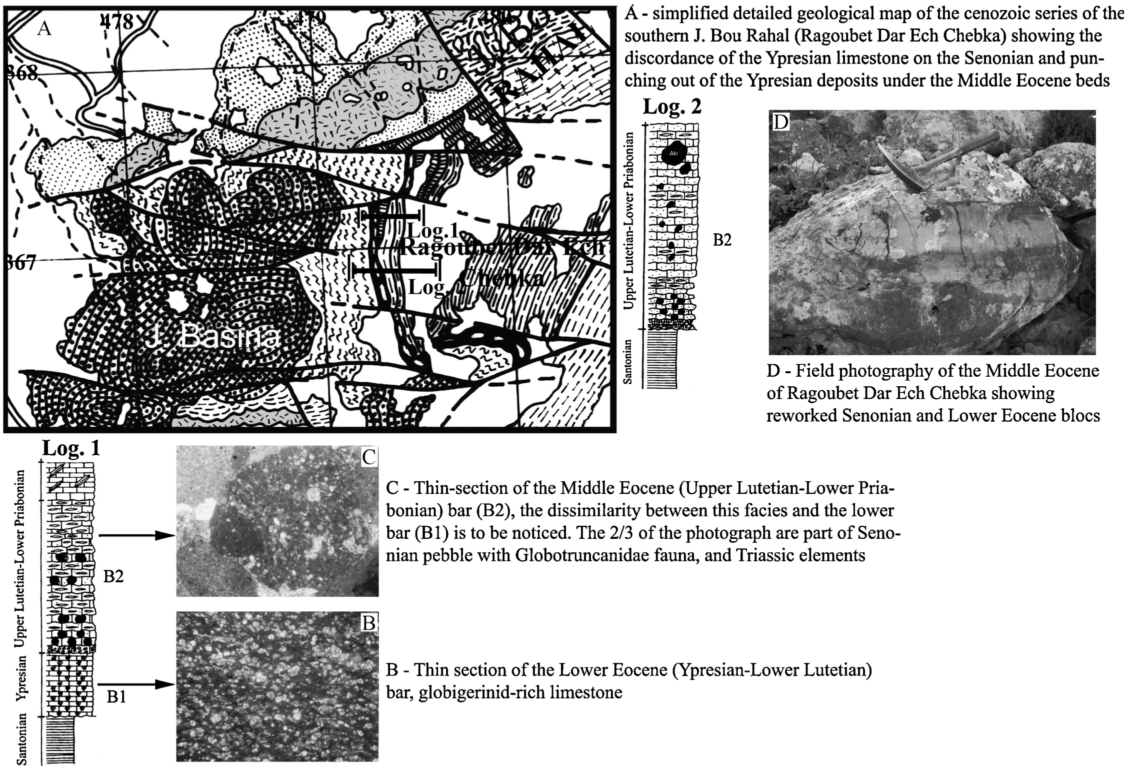

Fig. 4. Simplified detailed map of southern Jebel Bou Rahal, synthetic logs of the Eocene series, facies and microfacies photos.
Carte simplifiée et détaillée du Sud de Jebel Bou Rahal, logs synthétiques de l'Éocène et photos de faciès et de microfaciès.

bi-pyramidal Triassic quartz (Fig. 4B) as well as centimetric to decimetric Ypresian cobbles of the first unit. Consequently, we cannot maintain the hypothesis of lateral facies changes [18–20] from the first to the second unit as previously considered. These conglomerates, from which the Campano-Maastrichtian ones were carried out from at least 4 km (from the northern limb of the MEB structure), record a contemporaneous compressive tectonic event, which folded moderately the bedrock;

- the plastic clays with ostreids coquinoid intercalations of the Late Eocene Souar Formation [10]. These transgressive clays repose on different deposits showing a 20° angular unconformity. This unconformity, together with evidence from the above mentioned two units, constitutes an argument in favour of a Middle-to-Upper Eocene shortening tectonic event;
- siliceous grainstone characterizing the Oligocene Fortuna Formation [10]. This formation is itself transgressive, lies on the different deposits of the underling series with again a 20° angular unconformity (Fig. 3). It reposes, in particular, on the Senonian deposits of the north flank of the MEB structure (J. Bou Mouss, Fig. 3XX′ and YY′). The latter observation gives another evidence to support the hypothesis of an Eocene compression phase because of the lack of the Souar Formation (post-compression) in the northern flank of the MEB (Fig. 3XX′ and YY′), which is already suggested as the source zone of reworking Senonian boulders existing in the Eocene deposits of the J. Bou Rahal (southern flank). Besides, in the south flank the Fortuna Formation lies directly on the Late Albian layer in the J. Basina (Fig. 4) confirming that the environment was deeper in the southern flank during the Eocene.

3. Interpretation

The new tectono-stratigraphic data of the MEB structure, presented here above, shows there are two tectono-sedimentary cycles.

3.1. Upper Barremian-Lower Senonian cycle

A first Upper Barremian-Lower Senonian cycle corresponding to series of deep-sea basin facies constituted by marly and marly-calcareous deposits.

These deposits have registered during the ''Clansyesian'' period the sedimentation of detrital slump-balls layer reflecting the existence of sub-marine slopes on which a ''salt glacier'' developed. The alimentation zone of this ''salt glacier'' is likely one of the important faults looking presently as strike-slip faults. These faults, vertical at the surface, become oblique at the depth as indicated by the mining boreholes [34] and the seismic profiles [40]. On this ''salt glacier'', the sedimentation re-installed firstly by some reefal bodies [31,32] and then by deep-sea basin facies deposits reflecting the deepening of the basin. The Upper Albian-Lower Senonian series, overlying the salt body, shows [18,20] considerable variations with thicknesses ranging between some ten meters in the J. Bou Mouss and several hundreds of meters in the Si Med Akermi anticline closure (Fig. 2). These thickness variations are not accompanied by facies changes; the series are, however, of pelagic to hemi-pelagic facies [31,32]. Besides this numerous sedimentary features occur that support sea-floor instabilities that can be related to active extensional tectonics.

As a summary of this first cycle, the above mentioned data fit with the North Tunisia local geodynamic framework [4,7,15,29,42,43,53] as well as with the North-African margin geodynamic framework [13,24] in which it has been established that the South-Tethyan margin was an extensive margin with tilted block.

3.2. Second post-Senonian cycle

A second post-Senonian cycle characterized by a compressive tectonic episode intercalated with periods of relative tectonic quiescence. Incipiency of this cycle is proposed to account for the local unconformity of the Ypresian deposits on the Lower Santonian marl. Thus, it is possible to localize the positive tectonic inversion between the Lower Santonian and the Ypresian. However, if we consider the results of several studies carried in Algeria [8,13,24,48] and Morocco [1], we can propose the transition Lower Senonian-Upper Senonian as the age of the beginning of the positive tectonics inversion of the North-African margin. This result is in agreement with the global geodynamic framework in which it has been established that the convergence between Africa and Europe began in the Late Cretaceous [14,30].

Another important result highlighted in the MEB structure is the occurrence of an Eocene tectonic compressive phase (during the Middle Eocene or the Early Upper Eocene) well recorded, in the study area, by reworked pebbles and cobbles sourced from older series within the Middle Eocene deposits as well as by the angular unconformity of the Late Eocene layers.

The present configuration of this paleo-margin is the result of at least two other tectonic events i.e. the Tortonian and the Quaternary events. The first one corresponding to the ''Alpine'' event (the so-called Atlasic phase in Tunisia) is a paroxysmal event according to the regional geological studies [2,10,11,25,38,45,52]. These studies have established that this Alpine event is responsible for the formation of the Tunisia Atlasic range and the emplacement of the North Tunisian thrust nappes [37,41]. In the study area, this tectonic event is underlined by the angular unconformity of the Mio-Pliocene deposits (Figs. 2 and 3). The second phase corresponds to the neotectonics Quaternary event (Lower Pleistocene). It is also well documented in Tunisia [2,5], especially in the North where the compression has reactivated the preexistent faults [22].

4. Conclusion

The new data exposed above support the positive Mesozoic tectonic inversion possibly started as soon as the Lower Senonian-Upper Senonian transition. Our results are in favour of widespread compressional Eocene phase displayed by recent publications in the surrounding areas (in Lansarine plateau [33], in the Tunisian Sahel [26] and the north-eastern Tunisia [36]). Thus, the tectonic calendar we propose is, however, similar to that of the eastern Algeria [8,12,13,23,24,47,49] as well as in Morocco [13,35].

As a conclusion, our results support the hypothesis of a generalized compressional Eocene tectonic event along the North-African paleo-margin. Nevertheless, the effects of such an Eocene phase appear to be more tenuous in Tunisia (only 20° for the angular unconformity) than with respect to those registered in the rest of the Maghreb domain.

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