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The Neogene structural evolution of the western margin of the Pelagian Platform, central Tunisia: discussion

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INTRODUCTION

In his paper on the structural evolution of the Central Tunisia Atlas in the Kairouan area, Anderson (1996) proposes a kinematic model that can be characterized by the following features.

(1) The tectonic style is typically thin skinned.

(2) The shortening is very pronounced and the off-sets of some thrust sheets are quite important (up to 20 km for Thrust sheet B in Anderson's fig. 11).

(3) Passive roof-backthrusts have a leading role in the structural geometry.

We completely agree with Anderson on the first point presented in the initial part of his paper and where some of the available published evidence is examined. However, in contrast to Anderson's assertion, this interpretation has already been widely developed in recent studies in a large area around the studied region (Frizon de Lamotte *et al.*, 1990, in press; Creuzot *et al.*, 1992, 1993; Al Saffar, 1993; Mercier *et al.*, 1995; Outtani *et al.*, 1995a,b). Some of these authors underline the congruence between the locations of the anticlines and the basement faults which have a syn-sedimentary signature within Mesozoic and Cenozoic deposits (Axe Nord–Sud *s.s.* Fault, Zaghouan Fault, Gafsa Fault, Fig. 1). But in their interpretation, it is clear that the décollement is localized within the Mesozoic (mostly Triassic) beds and that the basement is not involved in the thrusting.

On the other hand, points (2) and (3), in Anderson's model, are more a matter of debate and require discussion in the light of both the regional context and a large amount of data already published from the studied area, not referred to by Anderson. The purpose of this Comment is to discuss the thrust model proposed by Anderson and to examine a much more 'autochthonistic' alternative model.

In the studied area (Fig. 1), three major NE–SW-trending ridges correspond to major anticlines. These ridges are, from the foreland (SE) towards the hinterland (NW): the Jebel Cherichira, the Jebel Ousselat–Bou Dabouss and the Jebel Serdj–Kessera (Fig. 1). In the following we will discuss the structural evolution and geometry of these three main anticlines. Finally, we will propose a new schematic cross-section through this frontal area of the Tunisia Atlas (Fig. 2) which differs considerably from the model proposed by Anderson (his figs 11 and 12).

THE JEBEL CHERICHIRA

In the easternmost anticline, Triassic rocks crop out in a large area. In some places these beds are truncated and overthrust by Cretaceous and Tertiary thrust sheets. This relationship (younger rocks thrust over older rocks) is interpreted by Anderson as consistent with an 'out-of-sequence' thrust. In this model the Ousselat anticline, occurring 15 km to the west, appears as a better candidate for the upper thrust sheet homeland. Consequently, the shortening accommodated in this structure would be in the order of the distance (or greater) between these areas.

The Jebel Cherichira is on a line with some halokinetic structures (Jebel K. El Halfa, Jebel Troza, Fig. 1). Salt diapirs are very common in the northwestern Tunisia Atlas ('Diapirs area', Fig. 1). They also occur in the southeastern Atlas, and particularly in areas where the structural grain abruptly changes its orientation (for example Jebel En Nejilet and Jebel Rhéouis, Fig. 1). The emplacement of the Atlas diapirs mainly took place during the Cretaceous (Aptian and upper Cretaceous).

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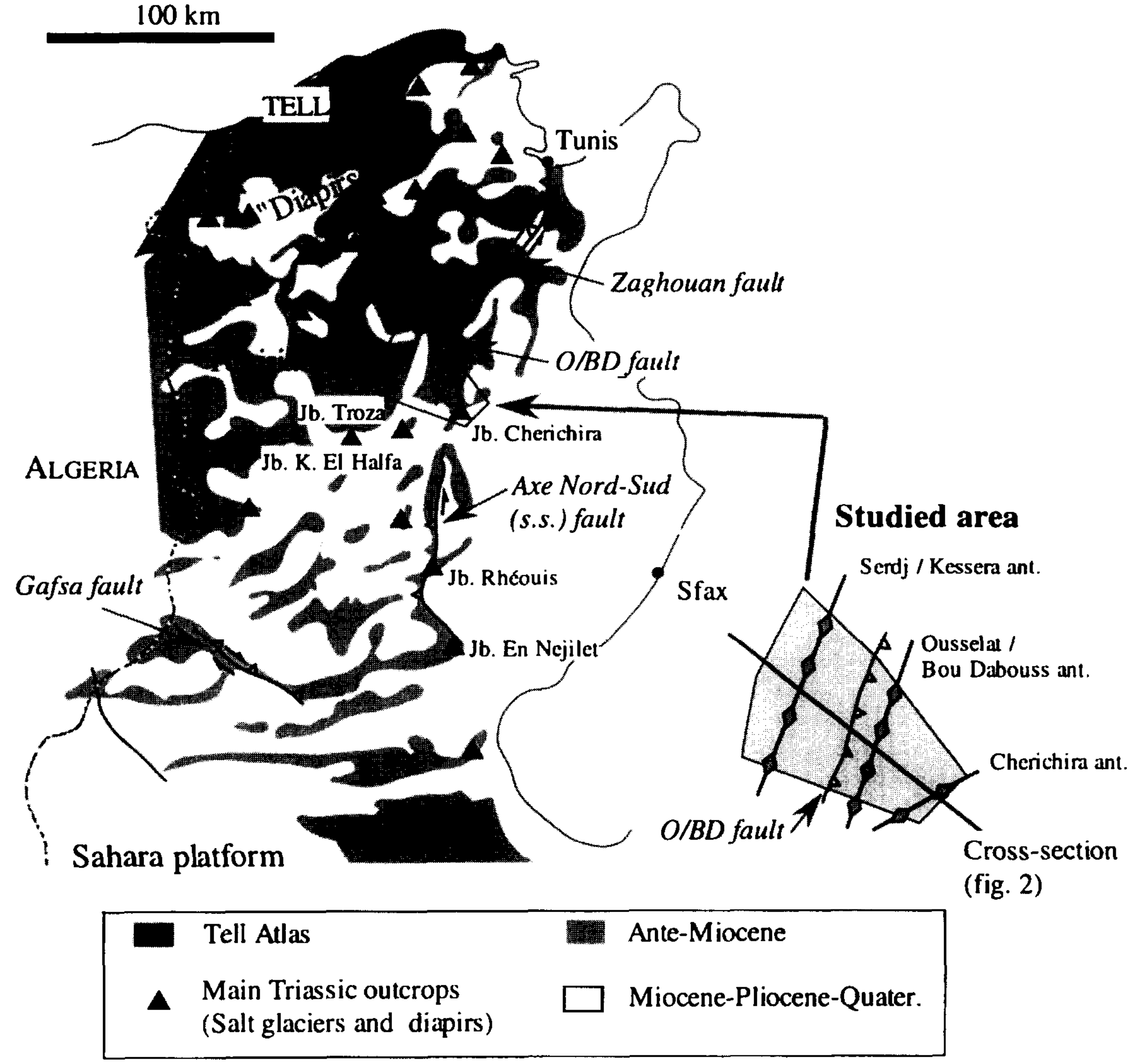

Fig. 1. Location of the region in a schematic geological map of northern Tunisia. O/BD fault = Ousselat–Bou Dabouss fault; Jb = Jebel. The insert is a structural sketch of the studied area (ant. = anticline).

Locally, the diapirs reached the surface, overflowed, and generated salt glaciers that are interbedded within the Cretaceous sediments (Vila, 1985). In some well-studied anticlines these masses of evaporites and their associated rocks were mobilized by later compressive events, and evaporites were injected along the thrusts forming sheets where both the hangingwall and the floor are in contact with younger strata.

This feature and the chaotic pattern of the Jebel Cherichira Triassic rocks enable us to consider, in accordance with all of the previous studies in the area (references and a detailed map given in Abbes and Boukadi, 1988), that the emplacement of Triassic rock are related to the diapiric process. Consequently: (1) an out-of-sequence thrust interpretation is not required to explain Triassic sediments interlayered with Cretaceous and Tertiary rocks; and (2) the shortening accommodated by this structure could be much smaller that inferred in Anderson's fig. 11 (see Fig. 2).

THE JEBELS OUSSELAT–BOU DABOUSS

According to Anderson (1996), a major backthrust is exposed in the Ousselat–Bou Dabouss anticline. However, SE-directed thrusts do not outcrop in the area. Anderson examined two hypotheses: (1) the anticline is an ESE-verging tip-line or a 'hybrid' fold; and (2) the anticline geometry can be interpreted as a 'passive roof' duplex. He validates the second hypothesis by a balanced cross-section (Anderson's fig. 12). These conclusions appear not to be acceptable for two reasons detailed below: (1) the cross-section-balancing standard tools are not applicable in this case; and (2) the backthrust is more likely to be directly branched from the deep Triassic décollement.

(1) At about 12 km south-southwest of point J in Anderson's fig. 4, Abbes *et al.* (1981) provided evidence that the hangingwall of the main backthrust is younger

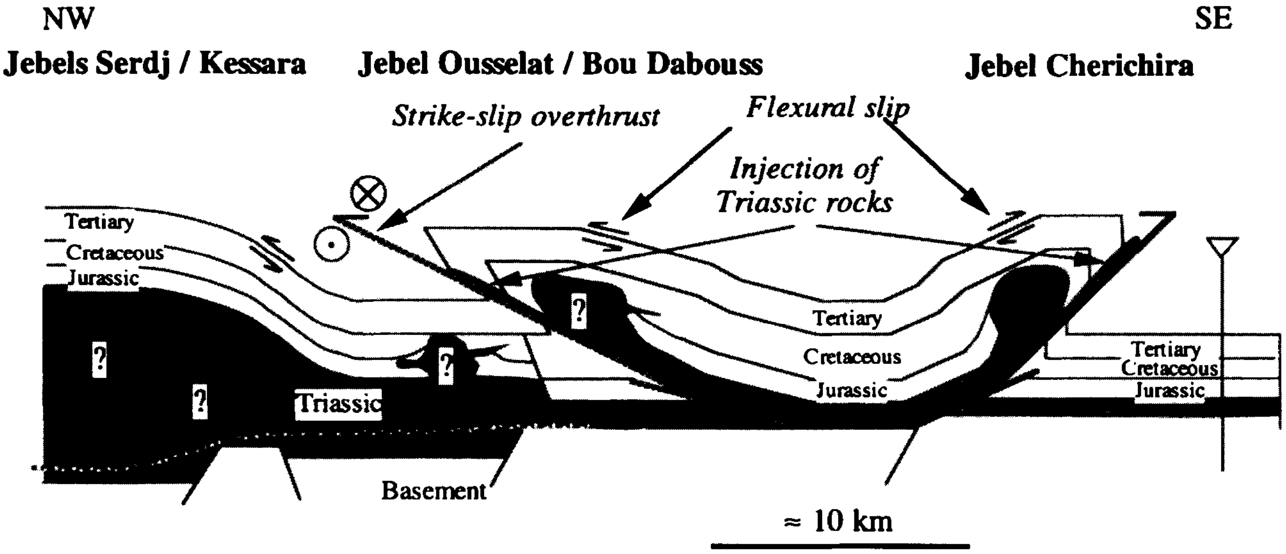

Fig. 2. Schematic cross-section of the area. It is redrawn from figs 11 and 12(b) of Anderson (1996) and reinterpreted in light of the discussion in the text. The eastern folds are interpreted, in this sketch, as fault-related folds (see complete discussion in the text) and the western fold as a detachment fold. Note: (1) the strong thickness variations within the cover; (2) the inferred complex pattern of the basement; (3) the very limited shortening in the plane of the cross-section; and (4) the occurrence of a major oblique slip backthrust.

(Metlaoui Formation; upper Eocene) than the footwall (El Haria Formation; Maastrichian–Paleocene). Note that these two formations are not distinguished in Anderson's fig. 4. This very paradoxical relationship enables us to suggest that the Ousselat–Bou Dabouss fault represents a backthrust with an important sinistral strike-slip component. This kind of oblique thrust, with a important sinistral strike-slip component, is well documented in the Tunisia Atlas (Figs 1 & 2). Numerous kinematic analyses of striated fault populations (Gourmelen, 1984; Yaïch, 1984; Ouali, 1985; Creuzot and Ouali, 1989; Soyer and Tricart, 1989) show that the Central Tunisia Atlas, and the adjacent area in Algeria, were deformed by two non-coaxial contractional events. The first 'Miocene event' is responsible for folding. Its timing is poorly constrained but considered to be of Tortonian age in Tunisia. The second one, known as the 'Quaternary event', is dated as Villafranchian. This event is responsible for the development of new E–W-trending new folds, mainly in the Southern Tunisia Atlas; and also for a second stage of deformation superimposed on previous folds. This deformation includes, particularly in the frontal area, the occurrence of sub-meridian trending thrust faults with an important sinistral strike-slip component such as the 'Axe Nord–Sud' and the Zaghouan strike-slip overthrusts. These structures are in perfect alignment with the Ousselat–Bou Dabouss fault (Fig. 1). The regional pattern thus also suggests that the Ousselat–Bou Dabouss backthrust has an important sinistral strike-slip component. In this case, and in accordance with the foundation of the method, the use of cross-section-balancing standard tools appears not to be reasonable.

(2) In the case of passive roof duplexes, the roof backthrust follows a particular stratigraphic level for the entire fold. The Triassic rocks outcropping in the footwall of the Ousselat–Bou Dabouss fault (locality K in Anderson's fig. 4 and shown in the detailed map in Abbes *et al.*, 1981) demonstrate, as previously shown (Jebel Cherichera), that this backthrust is necessarily branched from the deep Triassic décollement under the anticline itself. For the studied fault, we suggest that the roof thrust hypothesis no longer is tenable.

In consequence, we need to investigate another structural hypothesis (Fig. 2) that agrees with the field data. We suggest that the Ousselat–Bou Dabouss anticline has resulted from: (1) a NE transport of Mesozoic and Tertiary sediments in the hangingwall of a thin-skinned backthrust during the Tertiary event; and (2) from breakthrough, with a sinistral strike-slip component, of the pre-existing anticline during the Quaternary tectonic event. The evaporites and their associated rocks that were injected along the thrust surface were mobilized by the late compressive event.

In our Fig. 2 we propose a schematic cross-section of this anticline but, in light of the previous discussion, a simple fault-related fold model is probably unrealistic to describe this complex anticline that, furthermore, changes its geometry considerably along strike. We must also draw attention to the very strong variations of thickness and facies on both sides of the Ousselat–Bou Dabouss backthrust (for example, the Senonian Abiod Formation varies from 50 to 400 m; Turki *et al.*, 1988). The initial geometry was quite different from the layer-cake pattern that is usually used in fault-related models. Consequently, we suggest that the anticline could be, in part, an inverted syn-sedimentary graben.

THE JEBELS SERDJ–KESSERA

Concerning the western anticline, Anderson (1996) proposed a structural hypothesis referred to as a 'passive roof' duplex. However, as noted also by us, the inferred major NW-verging backthrusts are not exposed. On the other hand, in the western area the Triassic evaporites become progressively thicker and the fold hinge does not have a kink-like style. Consequently, we suggest that these anticlines are better explained by detachment-related folding processes as illustrated in Fig. 2.

CONCLUSION

From a regional point of view, and in accordance with most studies in the area since 1990, our structural interpretation refers to thin-skinned tectonics. In contrast to the suggestion by Anderson (1996), our structural scenario is more 'autochthonistic'. Our structural evolution model described briefly here contradicts Anderson's model for the following reasons.

(1) If we take account of the diapiric and halokinetic processes, no evidence of major shortening is available.

(2) If we examine the field data, no evidence for passive roof duplexes are available; the major backthrust branches from the deep Triassic décollement and the minor intraformational thrusts reported by Anderson (1996) in some incompetent levels are most probably explained by flexural slip related to folding.

(3) We believe, for both local and regional reasons as argued above, that the major backthrusts have important sinistral strike-slip components.

We conclude by bringing attention to the polyphase deformation, the occurrence of diapirs and the very strong variations in thicknesses and facies within a small area, which make the use of cross-section-balancing standard tools problematic, and probably not justified in this area (Creuzot *et al.*, 1993; Mercier *et al.*, 1995).

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