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Neogene extensional deformation and related stress regimes in central Tunisia

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ABSTRACT

A study of brittle fracturing in onshore Tunisia, including field and seismic data, suggests that the conspicuous NW–SE-trending rift system of the Atlasic domain postdates the main compressional event of Tortonian age (Late Miocene). Therefore, the extensional event would be recent, occurring from the latest Miocene to the Quaternary. From fault-slip data set, we demonstrate that the dominant stress regime coeval with the Neogene rifting was purely extensional, with the extensional stress being oriented NE–SW normal to the average trend of the rift faults, excluding any kind of lateral displacements along the rift boundaries. We discuss the integration of the Tunisian rift-system in the context of the eastward crustal thinning in Tunisia and the development of the offshore Sicilian–Tunisian rift system. The upper-crustal stretching within the Pantelleria–Tunisia domain results probably from the migration of the Ionian block towards the Hellenic subduction zone in the NE.

1. Introduction

Since the Triassic, the onshore Tunisian domain has been situated in a continental setting subject to several periods of extension and basinal deposition in relation with the development of the adjacent passive margins. From Late Cretaceous times onward (e.g. Bouaziz et al., 2002; Faccenna et al., 2001, Goes et al., 2004), this domain has formed part of the Africa–Eurasia convergent system (Fig. 1). Apart from possible older compressive events (e.g. Khomsi et al., 2009), the main compressive structures in onshore Tunisia are due to two recent deformational events, which occurred during the Tortonian (Late Miocene) and after the Villafranchian (Early Quaternary) (e.g. Ben Ayed, 1986; Mzali and Zouari, 2006) (Fig. 1).

In Tunisia, a conspicuous structural feature of the Atlasic domain is the presence of a set of NW-trending rifts (Figs. 1 and 2). These rift-zones are recognised not only onshore but also offshore (e.g. Ben Romdhane et al., 2006; Fig. 1). Cartographically, they seem to belong to the same extensional system that developed between Sicily and Tunisia during the Pliocene and Quaternary (e.g. Catalano et al., 2008; Chihi, 1995; Civile et al., 2008). The geometry and distribution of the onshore rifts are not random. Their length varies between 20 and 30 km, with a length/width ratio between 2 and 2.5. These rifts seem to be arranged within two SW–NE trending narrow zones extending from Kasserine in the SW to "Cap Bon" in the NE, displaying in both zones an average spacing (the distance between the centres of two jointed rifts) of 50 ± 3 km (Figs. 1 and 2). Evaporite diapirs crop out frequently at the extremities of the rifts. Available seismic profiles image the presence of an evaporitic level of Triassic age at shallow depth within most of the rifts (e.g. Figs. 3 and 4), suggesting the extrusion and/or sill-like intrusion of evaporites during their genesis. In Tunisia, the crustal thinning gradient towards the NE is sub-orthogonal to the trend of the onshore and offshore rift system, suggesting that these rifts could be the upper-crustal expression of crustal-scale stretching associated with the observed crustal thinning (e.g. Chihi, 1995; Civile et al., 2008) (Fig. 1).

Both the age and origin of this rift system are controversial. Early authors considered that the Late Miocene Tortonian folds were cut by rift-related normal faults (Figs. 1 and 2). Extension was thus considered as postdating the Tortonian, and was therefore assumed to be Plio-Quaternary in age (e.g. Ben Ayed, 1975; Burollet, 1956; Caire, 1977; Jauzein and Perthuisot, 1976). On the contrary, some authors proposed that the rifts formed before the Tortonian compression, during the Lower and Middle Miocene (e.g. Ben Ayed, 1986; Chihi, 1995; Philip et al., 1986), basing their argument on the apparent non-continuity of Atlasic Tortonian folds' hinges, with the notable exception of the Foussana and Siliana rifts (Fig. 2). As additional evidence for the pre-Tortonian age, these authors claimed that the border faults of these rifts experienced significant lateral slip during the Tortonian compressional event. Another explanation for the non-continuity of fold axes has recently been presented by Ben Romdhane et al. (2006), who studied the offshore Jriba rift: they suggested that this rift is Plio-Quaternary in age, and that the border faults acted as lateral ramps during the development of Post-Villafranchian folds.

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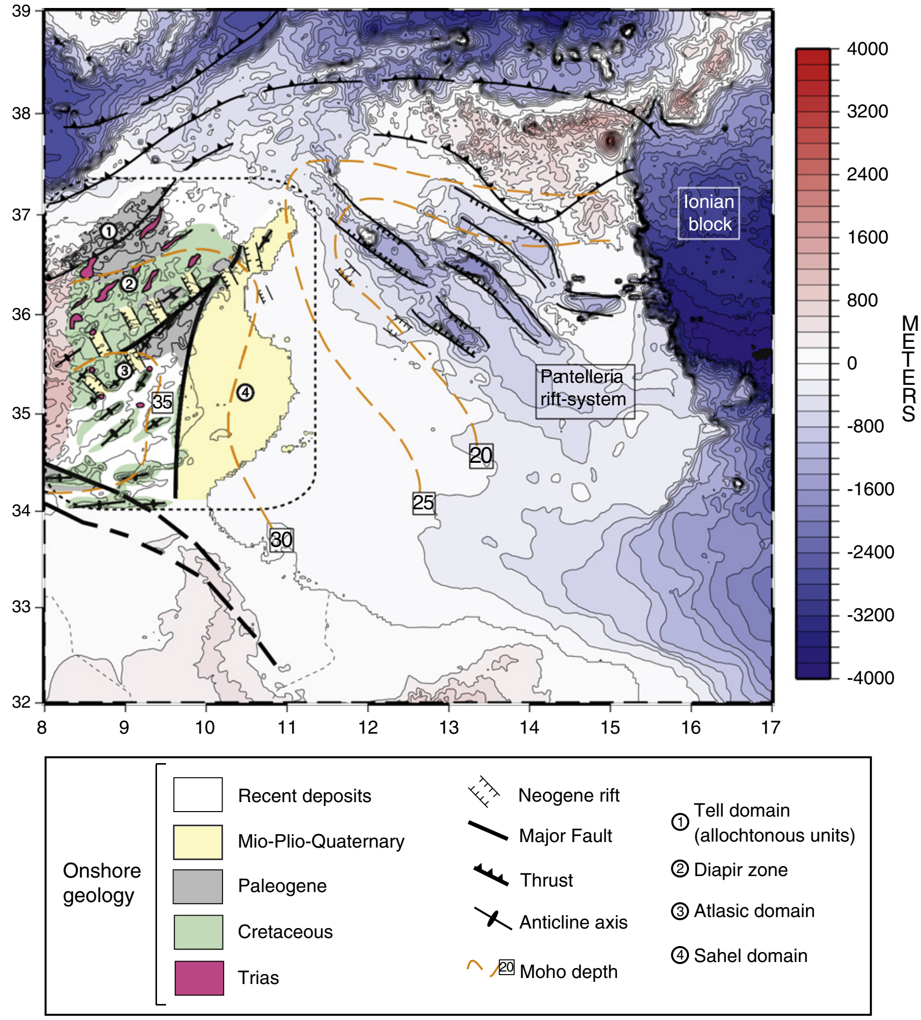

Fig. 1. Topographic and bathymetric maps of the Central Mediterranean showing the main structural features. The figure also indicates Moho isobaths from the European Geotraverse Programme.
Data from Buness, 1992, and Dèzes and Ziegler, 2004.

In the western neighbouring zone of Tunisia, the Atlasic rift system disappears towards Algeria, where the crust thickness is over 30 km (Fig. 1). On the other hand, in the eastern neighbouring zone, the Pantelleria rift system took place during Plio-Quaternary (e.g. Cello, 1987; Dart et al., 1993). This rift zone is constituted by three principal tectonic troughs (Pantelleria, Malta and Linosa graben). Their overall structure is composed of a NW-trending normal faults, which are sometimes linked by E–W and NE–SW-trending faults. It is worth noting that these NW faults had been active since the Late Miocene. Whereas, the E–W and NE–SW faults with an oblique-slip movement were formed more recently (e.g. Boccaletti et al., 1987; Bonson et al., 2007; Cello et al., 1987; Civile et al., 2010; Gardiner et al., 1995).

In the present study, we present new tectonic and observational data from six Atlasic rifts and also from the Sahel domain (Fig. 2), including unpublished seismic profiles, which constrain both the age and origin of the Neogene rift system.

2. Neogene tectonic extension in Tunisia

Field observations within the rifts themselves outline the great difficulty of inferring the age of extension from geological evidence alone. Most studied rifts are filled with very recent Quaternary alluvial sediments that generally display no tectonic structures (Fig. 5A). Fig. 5B and C illustrate some of the few observable structures suggesting that the rifting was active during the deposition of the Messinian–Pliocene (Ségui formation) and Quaternary sediments, respectively. These deposits are characterised by a silicoclastic facies with marked lateral variations in the Tunisian Atlas and in the Sahel domain. In the subsiding Sahel zone, where no distinct rift morphology is recognised in the topography — even though a major buried Plio-Quaternary rift system is thought to exist (Bedir, 1995) — we observe that the Upper-Miocene to Quaternary strata are cross-cut by numerous normal faults (Fig. 6A and B). Some minor reverse faulting is also observed, related to the post-Villafranchian event. Statistical analysis shows that the normal faults strike NW–SE, their planes plunging either to the NE or SW with dips of more than 60° (Fig. 6C). Kinematic markers within the fault planes show that the majority of faults are dip–slip with pitch-angles comprised between 80° and 90° (Fig. 6C). A very small number of normal faults display an orthogonal NE–SW trend; they are characterised by pure dip–slip movement (see Fig. 7).

In outcropping sandstones both in the rift-zone and the Sahel domain, we observe sub-vertical to strongly dipping strain localization bands, a common feature in highly porous materials (Fig. 6D and E) (e.g. Fossen et al. 2007). These bands display no lateral shear and their geometry appears similar to dilatational shear bands with or without a component of dip–slip extensional shear. These bands are well arranged