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Research paper

Style of Atlassic tectonic deformation and geodynamic evolution of the southern Tethyan margin, Tunisia

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ABSTRACT

The structure of the southern Atlas fold-and-thrust belt of Tunisia was investigated using new geologic mapping, seismic reflection data together with the construction of a balanced cross section. The structural architecture of the Tunisian foreland consists in a mixed tectonic style with deep-seated basement faults, shallower décollements within sedimentary cover and salt diapirism. The restoration of the cross section shows a surface shortening of 8.1 km (~7.3%). Sequential restoration of the balanced cross section has been permitted to decipher the structure and evolution of the southern Tethyan margin of Tunisia. Structural geometry and orientation of the pre-existing Permian (?) to Cretaceous extensional structures controlled subsequent contractional deformation within the sedimentary cover. During the shortening, this inherited tectonic framework controlled the development of ENE-trending thrust-related anticlines such as the Orbata and Chemsi structures, NW-trending lateral ramp such as the Gafsa and Fejej faults and diapir structures as the Beidha anticline. The inversion of the margin can be correlated with the onset of the convergence between Africa and Eurasia. The first phase of the Orbata thrusting growth might occur in late Cretaceous. Continuous inversion of the margin occurred during the Eocene and mainly during the late Miocene to present day. This study underlines the predominant role of inherited basement structures acquired during the evolution of the southern Tethyan margin, and their influence on the geometry of the Atlassic thrust belt. This structural analysis provides new perspectives for future hydrocarbon exploration in this poorly explored region.

1. Introduction

Structural inheritances may control the tectonic styles and kinematics evolution of the fold-and-thrust belts (e.g., McClay and Buchanan, 1992; Coward, 1996; Teixell et al., 2003; Butler et al., 2006; Mora et al., 2006). For example, rift-related structures with extensional faults connected with basement may preferentially accommodate shortening in the outer region of foreland in response to the far-field transmission of orogenic stresses (Coward, 1996; Roure and Colletta, 1996; Lacombe and Mouthereau, 2002; Hilley et al., 2005; Espurt et al., 2012). This outer foreland thick-skinned thrusting may records the early stage of shortening and leads to the formation of isolated structures (McClay, 1989; Hain et al., 2011; Espurt et al., 2012). In addition, the formation of transverse structures may be influenced by the orientation of the inherited normal faults, respectively to the strike of subsequent shortening, and the expulsion of the thick rift sedimentary package (e.g., Marshak and Wilkerson, 1992; Macedo and Marshak, 1999).

In North Africa, the Atlas is a prominent mountain chain, extending for 2000 km in a roughly west-east direction from Morocco to Tunisia. It is bounded by the Algerian basin to the north and by the Saharan platform to the south (Fig. 1a and b). The Atlas is considered as a type-example of intercontinental chain resulting from the collision between Africa and Eurasia since the late Cretaceous (Caire, 1977; Mattauer et al., 1977; Zargouni, 1984; Ziegler et al., 1995; Laville et al., 2004). The complex structural framework of the chain may reflect basement and stratigraphic heterogeneities of North Africa extensional margin inherited from the Paleozoic and Mesozoic times (Guiraud, 1998; Beauchamp et al.,

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1999; Laville et al., 2004; Missenard et al., 2007; Gabtni et al., 2011a; Roure et al., 2012; Frizon de Lamotte et al., 2013). The eastern Tunisian Atlas (Fig. 1c) has particularly recorded the effect of Tethyan rifting as revealed by strong facies and thickness variations within the Mesozoic sequences (Burollet and Byramjee, 1974; Haller, 1983; Zargouni et al., 1985; Ben Ferjani et al., 1990; Burollet, 1991; Bouaziz et al., 2002; Gharbi et al., 2013).

Although the foreland of Tunisian Atlas was widely studied (e.g., Ben Ayed, 1980; Zargouni et al., 1985; Burrollet, 1991; Boukadi, 1994; Zouari et al., 1999), its structural style and the geometry of the structure at depth show controversial interpretations. Based on balanced cross sections modelling, several authors (Outtani et al., 1995; Mercier et al., 1997; Ahmadi et al., 2013) interpret the southern Tunisian Atlas fold-and-thrust belt as governed by a thin-skinned tectonics style involving the Mesozoic–Cenozoic sedimentary cover. In contrast, geophysical data (Hlaiem, 1999; Zouaghi et al., 2011) suggest a dominant thick-skinned tectonics style involving the Paleozoic basement. More recently, Said et al. (2011b) conclude the deformation in southern of Tunisia is characterized by a mixed thick- and thin-skinned tectonics style with lateral variations in regional structural geometry and amounts of shortening controlled by NW–SE oblique ramps and tear faults.

On the basis of new structural and sedimentologic data, new detailed geologic mapping, new interpretation of seismic data together with the construction of a regional ~118 km long balanced and restored cross section, this paper aims to decipher the structural architecture and timing of the deformation of the southern Atlas of Tunisia. The results yield new insights into the role of inherited structures on the general interpretation of the kinematic evolution of the southern Atlas foreland thrust system of Tunisia during the convergence between Africa and Eurasia.

2. Geological setting

This study is focused on the southern Tunisian Atlas fold-and-thrust belt and its relationships with the Saharan platform and the central Atlas hinterland (Fig. 1c). E-to NE-trending folds and thrusts and NW- to WNW-trending strike-slip faults form the southern Tunisian Atlas folds-and-thrusts belt (Figs. 2 and 3) (Ben Ayed et al., 1980; Zargouni, 1984; Zargouni et al., 1985; Ben Ferjani et al., 1990; Burrollet et al., 1991; Boukadi, 1994; Zouari et al., 1999; Haji et al., 2014) and result of the collision between Africa and Eurasia. These structures are generally interpreted to be inherited from Triassic and Jurassic to middle Cretaceous rifting periods related with the opening of the southern Tethyan margin (Guiraud and Maurin, 1992; Kamoun et al., 2001; Piqué et al., 2002; Guiraud et al., 2005; Gharbi et al., 2013). Tethyan extensional structures of the southern Atlas of Tunisia have been reactivated in the late Cretaceous-early Paleocene (Bouaziz et al., 2002; Bracène and Frizon de Lamotte, 2002; Guiraud et al., 2005; Said et al., 2011b; Frizon de Lamotte et al., 2011; Masrouhi and Koyi, 2012; Masrouhi et al., 2013; Gharbi et al., 2013; Van Hinsbergen et al., 2014), middle-late Eocene (Atlassic compression; Bouaziz et al., 2002; Bracène and Frizon de Lamotte, 2002; Frizon de Lamotte et al., 2011; Gharbi et al., 2013; Masrouhi and Koyi, 2012; Masrouhi et al., 2013) and late Miocene to present day (Alpine compression; Zargouni and Termolières, 1981; Dlala, 1992; Chihi, 1992; Bouaziz et al., 2002; Gharbi et al., 2014). The southern Atlas of Tunisia mainly comprises three main tectonic domains: the Metlaoui-Gafsa chain, the Chotts chain and the Saharan platform (Ben Ayed, 1980; Zargouni et al., 1985; Burrollet, 1991; Boukadi, 1994; Zouari et al., 1999; Hlaiem, 1999).

The Metlaoui-Gafsa area is composed of E-to ENE-trending

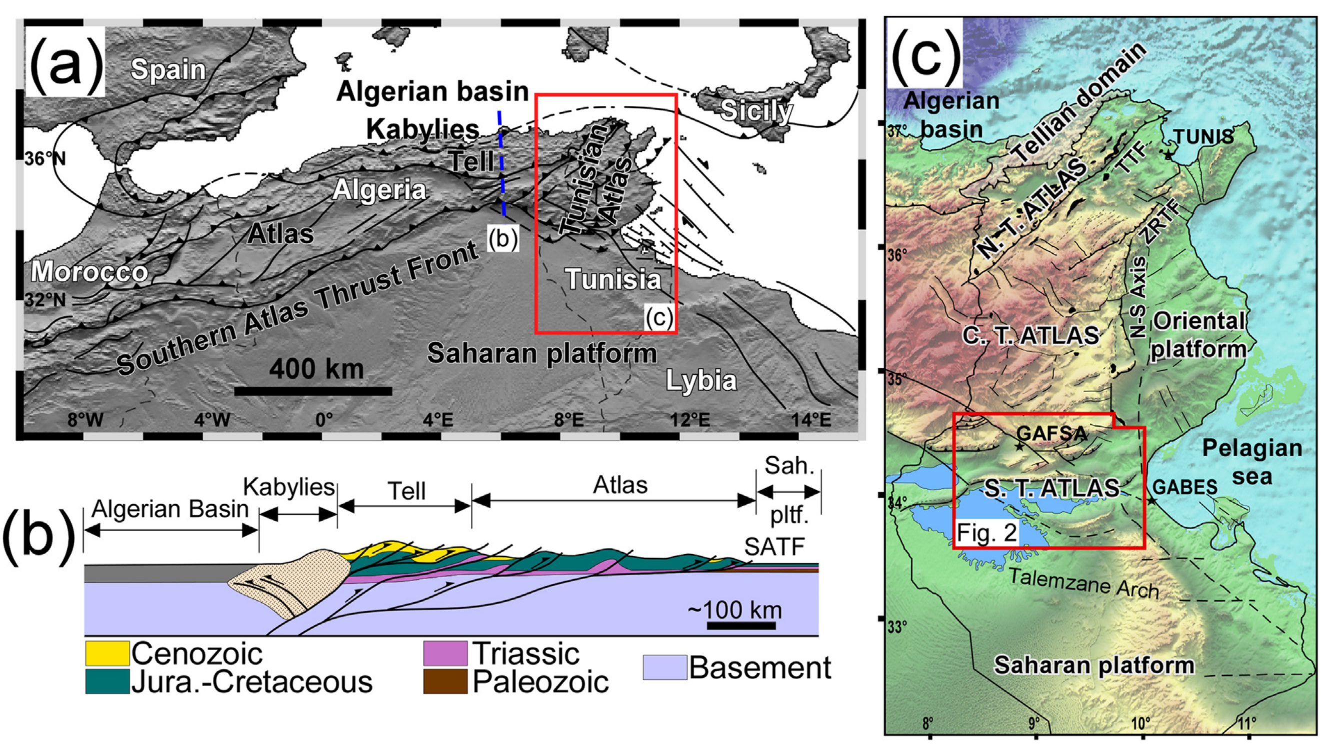

Fig. 1. (a) Structural map of the southern Atlas foreland of Tunisia. (b) Present day cross section across the Algerian basin and the southern Tunisian Atlas foreland modified from Frizon de Lamotte et al. (2011) and Roure et al. (2012). SATF: Southern Atlas thrust front. Sah. pltf: Saharan platform. (c) Structural map of Tunisia See location on (a). The base map is produced using elevation data from NASA (National Aeronautics and Space Administration) 30 m ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) GDEM (Global Digital Elevation Model). North Tunisian Atlas (N. T. ATLAS), Central Tunisian Atlas (C. T. ATLAS), South Tunisian Atlas (S. T. ATLAS), North–South Axis (N–S Axis), TTF: Teboursouk thrust fault, ZRTF: Zaghouan-Ressas thrust fault, SAFTB: Southern Atlas fold-and-thrust belt.