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Role of tectonic inheritance in the instauration of Tunisian Atlassic fold-and-thrust belt: Case of Bouhedma – Boudouaou structures

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A B S T R A C T

Tectonic inversion in the Bouhedma-Boudouaou Mountains was investigated through recent field work and seismic lines interpretation calibrated with petroleum well data. Located to the Central-Southern Atlas of Tunisia, this area signed shortened intra-continental fold-and-thrust belts. Two dissymmetric anticlines characterize Bouhedma – Boudouaou major fold. These structures show a strong virgation respectively from E-W to NNE-SSW as a response to the interference between both tectonic inversion and tectonic inheritance.

This complex geometry is driven by Mesozoic rifting, which marked an extensional inherited regime. A set of late Triassic-Early Jurassic E-W and NW-SE normal faults dipping respectively to the North and to the East seems to widely affect the overall geodynamic evolution of this domain. They result in major thickness changes across the hanging wall and the footwall blocks in response with the rifting activity.

Tectonic inversion is inferred from convergence between African and European plates since late Cretaceous. During Serravalian - Tortonian event, NW-SE trending paroxysm led to: 1) folding of pre-inversion and syn-inversion strata, 2) reactivation of pre-existing normal faults to reverse ones and 3) orogeny of the main structures with NE-SW and E-W trending.

The compressional feature still remains active during Quaternary event (Post-Villafranchian) with N-S trending compression. Contraction during inversion generates folding and internal deformation as well as Fault-Propagation-Fold and folding related strike.

1. Introduction

Development of positive inversion structures (V. Sciscian, 2009; N. Carrera et al., 2006), involves the reactivation and potential propagation of pre-existing normal faults inherited from previous stage of crustal extension. These normal faults undergo reverse displacements during later contractional deformations (Hayward and Graham, 1989; Coward, 1994; Sibson, 1995).

The fault reactivation (Sibson, 1985, 1995; Etheridge, 1986), fault geometry (Buchanan and McClay, 1991, 1992), previous geometry of basins (Butler, 1989) and tectonic plate setting (Kluth and Coney, 1981; Ziegler et al., 1998; Marshak et al., 2000) are the most important factors which affect the occurrence and style of the structures inversion.

Actual structure of Bouhedma-Boudouaou is the consequence of several deformations inherited from rifting events. It belongs to the Central-Southern Atlas of Tunisia which corresponds to an active foreland fold-and-thrust belt (Zargouni, 1985; Ben Ayed, 1986; Zouari, 1995; Ahmadi, 2006; Ben Salem, 2010; Said, 2011).

The complex structural pattern of the Central-Southern Atlas is mainly a consequence of the polyphased Cenozoic reactivation of inherited Mesozoic normal faults. Thus, during several Mesozoic periods, this domain was marked by a remarkable persistence of an extensional tectonic activity. Normal E-W and NW-SE oriented faults limited a significant system of horsts and grabens and controlled the sedimentation in subsiding basins (Boltenhagen, 1981; Yaich, 1984; Ouali, 1985; Bedir, 1995; Bouaziz et al., 1999, 2002; Soussi and Ben Ismail, 2000; Said et al., 2011; Gharbi et al., 2012).

It is a generally acknowledged that the Maghrabian orogenic

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domain (Fig. 1A), in particular the Central-Southern Atlas of Tunisia, results from the Cenozoic Eurasia-Africa convergence (D.F de Lamotte et al., 2009). Therefore, during compressional events, folds are considered the result of inversion of inherited faults and contraction is accommodated by a reverse displacement along these extensional faults (Haller, 1983; Zargouni, 1985; Ben Ayed, 1986; Bouaziz, 1995; Zouari et al., 1999; Said, 2011). The most important event corresponding to the main shortening tectonic event in the Central-Southern Atlas started in Serravalian-Tortonian and is still active (Said et al., 2011; Ghanmi, 2012).

This paper aims to propose an overview of the tectonic style not yet documented, the Kinematic of the Bouhedma-Boudouaou during the contractional reactivation of previously extensional faults. Furthermore, we will examine the different processes responsible for the asymmetry and the strong virgation of this domain.

2. Geological setting

2.1. Tunisian Atlas

Situated between the Alpine orogeny to the North and Saharian Plateform to the South, the Tunisian Atlas constitutes a field of folds and faults (Fig. 1A). In fact, the structural pattern of Tunisia is the consequence of polyphased Cenozoic reactivation of inherited faults from different phases as well as basement faults, major faults of Paleozoic and Mesozoic basins (Bouaziz et al., 2002). From North to South, particularly in Western part of the Tunisian Atlas, the area reveals the following domains: 1- The Northern Atlas which is made up of thrust faults and folds trending NE-SW. This domain is then marked by NE-SW Triassic outcrops that characterize the saliferious province (Ghanmi, 2003) limited in the South by NE-SW master faults. 2- Central Atlas which characterized by NE-SW trending folds. These are considered the result of inversions of inherited faults since the Cenozoic compressions (Haller, 1983; Zargouni, 1985; Ben Ayed, 1986; Bouaziz, 1995; Zouari et al., 1999; Ben Salem, 2010; Said, 2011). Central Atlas Folds are separated by broad synclines; this domain is marked by several collapse basins trending NW-SE. 3-Southern Atlas which constitutes a natural prolongation of the Central Atlas to the South. It consists of ENE-WSW, NE-SW, WNW-ESE and E-W trending folds that characterized both Gafsa and Chott ranges. This domain is separated from the Saharan Platform by the South Atlas Front which shifts abruptly by 90° and becomes N-S (DF de Lamotte et al., 2009).

The Eastern part of the Tunisian Atlas is characterized by a particular major structure trending N-S which extend from Maknassy-Mezzouna ~ Chott ranges to the South to the Zaghouan Ridge to the North (Bouaziz et al., 2002; Gharbi, 2013). This N-S axis is formed by several tight folds that resulted from the polyphase reactivation of inherited Pan-African or Paleozoic lineament. Separating zones with low and high subsidence rates, this axis acted as a basin boundary since the Mesozoic epochs (Yaich, 1984; Ouali, 1985).

To the East, the Sahel domain and Pelagian block are characterized by several folds buried beneath the late Cenozoic sediments. These domains are affected by NW-SE and E-W trending normal faults (Haller, 1983; Bedir, 1995).

The structural features recorded the different tectonic events that have succeeded and structured this domain and can be summarized as follows: 1-Mesozoic rifting and extensional regime due to the Neo-Tethys ocean widening (Bouaziz et al., 2002; Bumby and Guiraud, 2005; Gharbi et al., 2012), 2- Cenozoic inversion which was characterized by NW-SE Atlassic shortening as a consequence of the Africa-Europe convergence (Bouaziz et al., 2002).

2.2. Bouhedma-Boudouaou structures

Belonging to the Central-Southern Atlas of Tunisia, Bouhedma-Boudouaou mountains are marked by dissymmetric anticlines that show a strong virgation from E-W to NNE-SSW (Fig. 1B). This junction limits the Maknassy basin to the North and Bouhedma plain to the South. It has been affected by both extensional and compressional fault networks since the Mesozoic, Cenozoic and Quaternary times (Boukadi, 1985; Ghanmi, 2012). Thus, this area was affected by two major tectonic directions: the E-W and NNE-SSW to NE-SW trending faults.

The Bouhedma-Boudouaou mega-structures were developed above an important sub E-W trending fault during compressional events (Khessibi, 1978; Boukadi, 1985). This major accident controlled the sedimentation since Mesozoic period. This latter testified an important subsidence rate (Ghanmi, 2012).

3. Data and methods

In order to explain the Bouhedma-Boudouaou structures, we rely on:1- a stratigraphic analysis of all formations outcropping in the sector, 2- a fine cartography of the studied area that shows the structural features and fault framework, 3- seismic interpretation of 2D seismic lines calibrated by petroleum wells and acquired by the “Entreprise Tunisienne d'Activités Pétrolières” (ETAP).

These datasets provide good information that help us to document variations in a structural way, fault development aspects and kinematics of inversion systems explaining the present day architecture of the Bouhedma-Boudouaou junction.

4. Stratigraphic framework

The stratigraphic series outcropping within the study area extend from Jurassic to Quaternary (Figs. 1A and 2). Several hiatus characterize this domain. The major one is marked by Mio-Plio-Quaternary series that unconformably overlie the Cretaceous strata. This unconformity marks the significant tectonic event along the central-Southern Atlas of Tunisia, in particular the Bouhedma-Boudouaou area. The outcropping series in the study area are presented from bottom to top as:

4.1. Nara formation

Recently identified by Bahrouni et al. (2015), this Jurassic carbonate and shaly Formation forms the core of Bouhedma structure.

4.2. Sidi Khalif formation

it consists of marlstone with interbedded carbonate levels, this Formation marks the transition between Jurassic and Cetaceous.

4.3. Meloussi formation

Meloussi Formation well developed in Bouhedma structure, this Formation is Valanginian-Early Hauterivian in age.

4.4. Boudinar formation

Boudinar Formation well distributed in northern flank, this fluvial formation is Hauterivian in age.

4.5. Bouhedma formation

Bouhedma Formation made up of interbedded elements: fine limestone, varicolored clays, laminated dolomite, gypsum,