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The Controlling of Deformation Basing on Strain Partitioning Model: Case Study to Gafsa Basin (Southern Tunisian Atlas)

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Abstract

One of the principal parameters to study the tectonics deformation is the relation between the shortening axis and the direction of preexistent principal fault. It is important to verify this parameter in the belts structures. The aim of this contribution is to check this notion in the Atlassic structures, especially in the southern limit of Tunisian Atlas: Gafsa fault. The strain partitioning model proposed in the interpretation of geodynamics of Gafsa chains suggests the coexistence of thrusting and strike-slip faults during the same tectonics phase. The application of this model requires a particular geometry between the shortening axis and the direction of fault, and indeed the obliquity of preexistent faults by the reported shortening axis interprets us a transpressive context. The slickenside examination shows the coexistence of thrusting and strike-slip faults. The application of model of strain partitioning requires a decollement level which is confirmed in the Gafsa basin by the upper level of Triassic series. These parameters confirm a particular relation thin and thick-skinned and the maximum of deformation is cover, although the basement structures permeate simple passive transport of the deformation along the Triassic decollement level. These problems confirm the assumption of the evolution of the shortening axis during geological events and especially the rotation of Africa and Eurasia.

Keywords

Strain Partitioning, Gafsa Chains, Triassic Decollement Level, Thin and Tick Skinned

1. Introduction

In the North of the African plate, especially in the northern extremity of Atlassic chains, the geological struc-

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tures underwent an intense geodynamic activity and a very complex structural evolution during the tectonic phases (Decourt *et al.*, 1985 [1]; Morelli and Barrier, 2004 [2]; Frizon de Lamotte *et al.*, 2009 [3]). Martinez *et al*. (1990) [4] proposed that the evolution of deformation in the Northern of the African plate was correlated with the intense téthysian activity during the tectonic phases.

In Tunisia, rifting activity at the beginning of Mesozoic is associated with the development of orogenic domains controlled by preexistent faults; the south limit of these deformations is the southern atlasique front of Tunisia (Frizon de Lamotte *et al*., 2000 [5]). The northern African chains especially the Tunisian atlas is the object of several studies. The southern atlas of Tunisia is the limit between two different tectonics domains. This zone is presented by several work (Zargouni *et al*., 1986 [6]; Ben Ayed, 1986 [7]; Boukadi, 1994 [8]; Bouaziz, 1995 [9]), the folds of Gafsa Basin are characterized by NW-SE direction and have a complicated geometry. The genesis of Gafsa folds is particular for Atlassic chains during compressive Atlassic phase and post Villafran chian (Chihi *et al*., 1984 [10]; Zargouni *et al*., 1985 [11]; Boukadi, 1985 [12]). The problem proposed by the major of studies in this zone is the role of tectonics inheritance and reactivation of preexisting faults.

The principal direction of southern Tunisian Atlas is E-W controlled by preexisting faults (Gafsa fault, Bouhedma fault, Orbata fault…), but the particularity of Gafsa folds by the reported major atlassic folds in Tunisia is the NW-SE direction controlled by preexistent faults (**Figure 1**). The condition of development of Gafsa range is problematic because it's parallel to alpine axis of shortening

Many models are proposed to interpret the geometry of folds in the southern Atlassic limits, but they don't resolve yet the implication of the basement in deformation. For the study, we have interest in the relationship between cover and basement, so we propose a model of evolution of structures during the tectonic phases.

2. Geodynamics Setting

Several authors have studied the geometry and kinematic of tectonic structures of the southern central Atlassic of Tunisia based on the evolution of strain during tectonic phases (Zargouni *et al*., 1985 [11], Ahmadi *et al*., 2006 [13]). In the same context, Boukadi (1994) [8] proposed a model of pull-appart basin to explain the evolution of structures in North-South axis and the Gafsa chains (**Figure 2**).

In the North-South axis and southern central of Tunisian Atlas, several models developed the relation between thrusting and strike-slip faults (Perthuisot, 1978 [14]; Zargouni *et al*., 1985 [11], Creuzot *et al*., 1993 [15]; Outtani *et al*., 1995 [16]; Ahmadi *et al*., 2006 [13]; Ouali, 2007 [17]; Bensalem *et al*., 2010 [18]; Zouaghi *et al*., 2011 [19]; Saïd *et al*., 2011 [20], Amamria *et al*., 2011 [21]…). We particularly choose three models to control the evolution of deformation in southern central of Tunisian. The choice of these models is related to the distribution of direction of structures of the principal shortening axis.

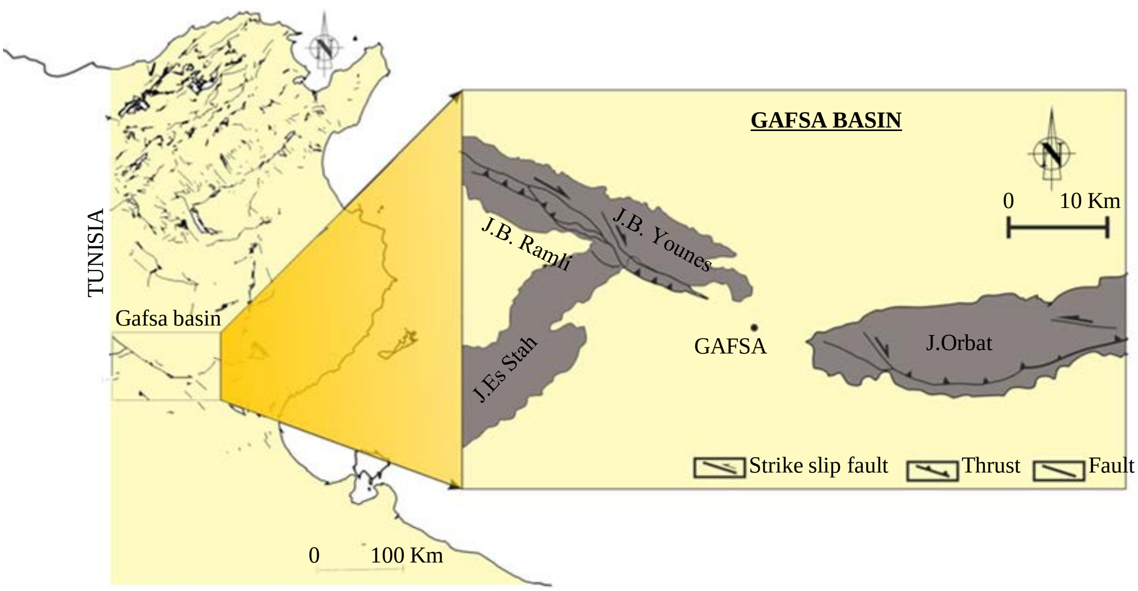

Figure 1. Localization of Gafsa Basin occupied central position of southern-central Tunisian Atlas.

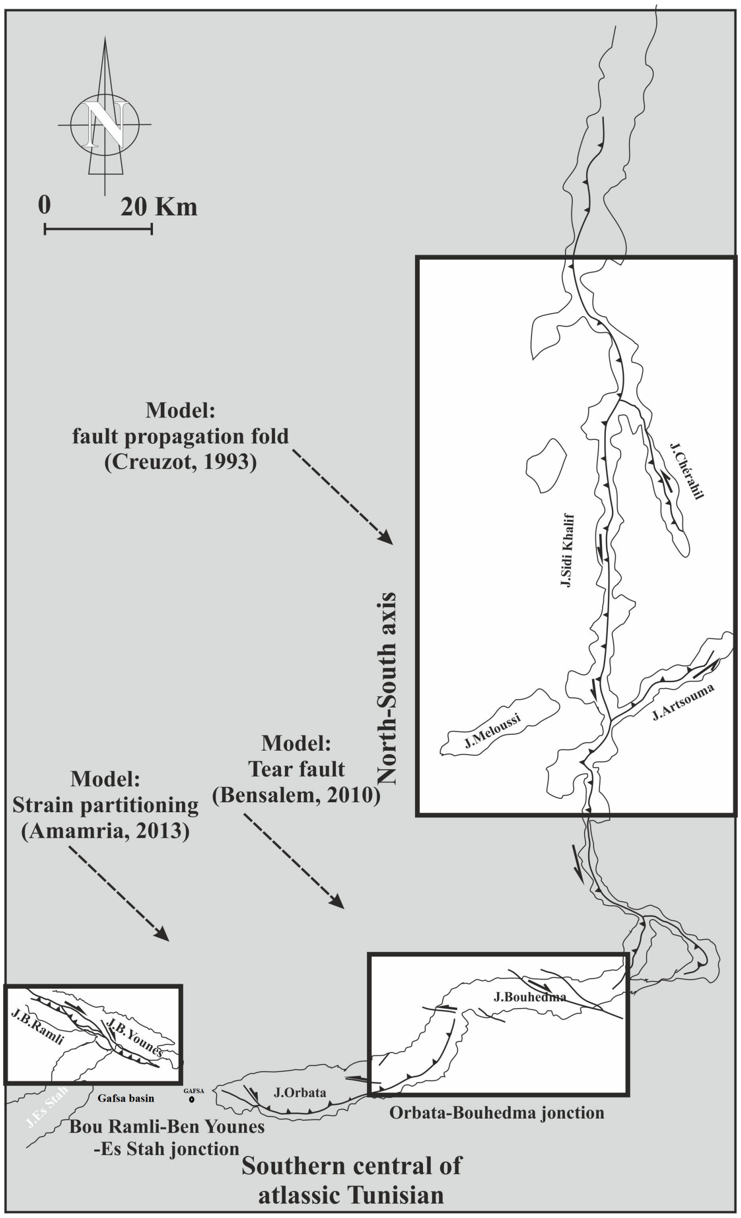

Figure 2. Localization map of different study areas.

Creuzot *et al*. (1993) [15] proposed the model of fault propagation fold which was developed on a ramp with two edge seams in North-South axis.

Bensalem *et al*. (2010) [18], based on the notion of tectonic inheritance, interpreted the role of preexisting faults in the evolution of deformation in Orbata-Bouhedma junction. In this study, the strain was always accentuated proportionally in preexistent faults. The conjugate activity of cover faults was observed by the overlapping of folds in form of duplex structures according to the model of tear faults.

Recently we proposed a model of strain partitioning in Gafsa chains that was verified firstly by the coexistence strike-slip faults to the overlapping and secondly by the obliquity of convergence to preexisting faults. The application of this model required the decollement level delimited basement structures to that of cover.

These various models are related to the obliquity of shortening axis during compressive phases to preexisting faults. This shortening axis is delimited from NNW-SSE to NS direction. This direction of shortening corresponds to the evolution of rotation of Africa to Eurasiatic plates (Aissaoui, 1984 [22]; Gourmelen, 1984 [23], Ouali, 1985 [24]; Zargouni, 1985 [25]; Zouari, 1995 [26]; Bensalem *et al*., 2010 [18]; Amamria *et al*., 2013 [27]…).

The evolution of the geometry of the structures is not only related to the direction of the shortening axis to the preexistent faults but also to the implication of the basement in the deformation. It is important thus to study the relation of cover-basement.

3. Problematic of Implication of the Basement

Several authors supposed that during compressive tectonic phases, the basement faults are inactive (Outtani *et al*., 1995 [16]; Addoum, 1995 [28], Ahmadi *et al*., 2006 [13]). Our study presented the arguments which defended the assumption of the activity of the major faults of the basement that was not retained by these authors, while agreeing with them on the concept of cover deformation or "thin skinned".

In Gafsa Basin, the particularity of Triassic outcrops is their weak thickness, they mark out the preexistent weaknesses. The examination of these weaknesses show the coexistence of the overlapping and the strike-slip faults with a main component is the thrusting (**Figure 3**).

The basement allows only a simple passive transport of the deformation along a Triassic decollement level while the maximum of deformation in the series of covers. Consequently the Triassic series will be mobilized first of all along the preexistent faults during the distensives phases, and the deformation of cover was taken again during compressive phases. The structural study shows a tectonic style in "thin skinned". This style "thin skinned" is materialized by tectonics of cover and its development of model of fault propagation fold is connected on a Triassic decollement level.

4. Relation between Thrusting and Strike-Slip Faults

In basin of Gafsa, the segments of overlapping on the surface recut principal structures with a NW-SE direction. These segments correspond to a great overlapping in subsurface. The transpressive deformation adapted by various structures example of folds and overlapping of variable direction NW-SE to oblique movement example of the faults of FBR 2 and FB 2 and of the major strike-slip faults example of FK 1, FK 2 and FK 3. Whereas, the principal overlapping fault in Gafsa Basin which controls the strain and the genesis of the folds is the result of the passive transport of the movement of the basement. The increase in rate of the deformation is absorbed by the compressive structures, which are oblique compared to the stress field (**Figure 4**).

The overlapping fault partitioned the oblique convergence during the tectonic phases generating the genesis of the strike-slip faults. Thus, the partitioning of the deformation was under control of the oblique ramp in Gafsa Basin with coexistence of the strike-slip faults associated with the overlapping (**Figure 5**).

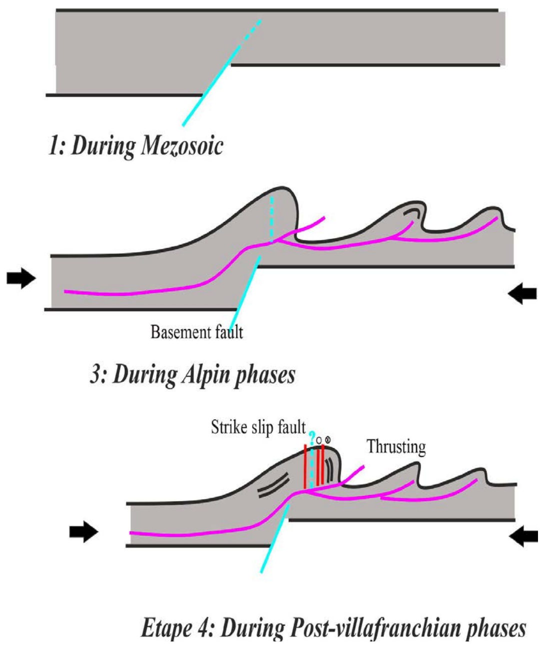

Figure 3. Kinematics of thrusting and strike-slip faults in contact with Triassic decollement level.

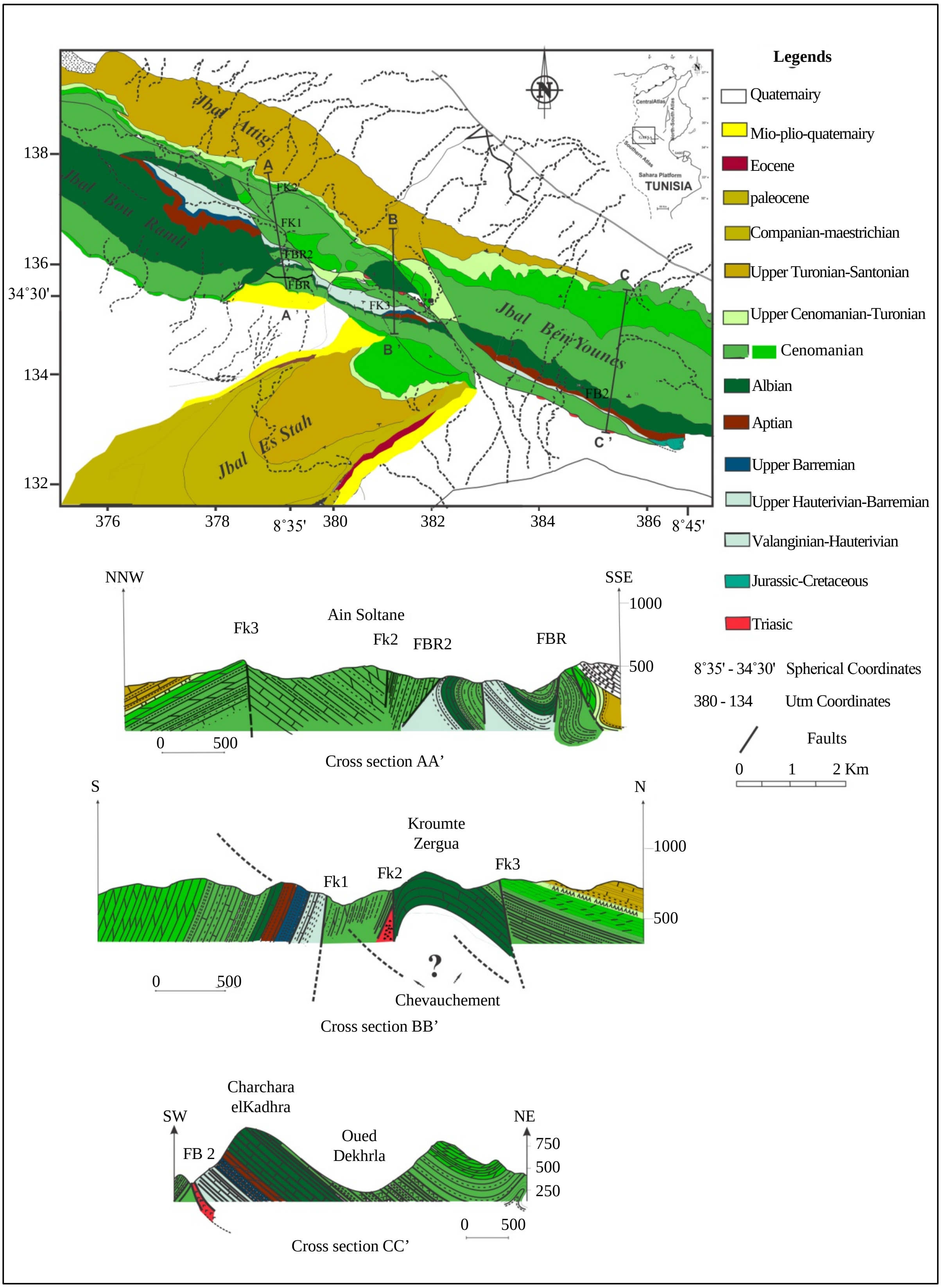

Figure 4. Presentation of the geological cross section which shows the various overlapping faults and strike-slip faults.

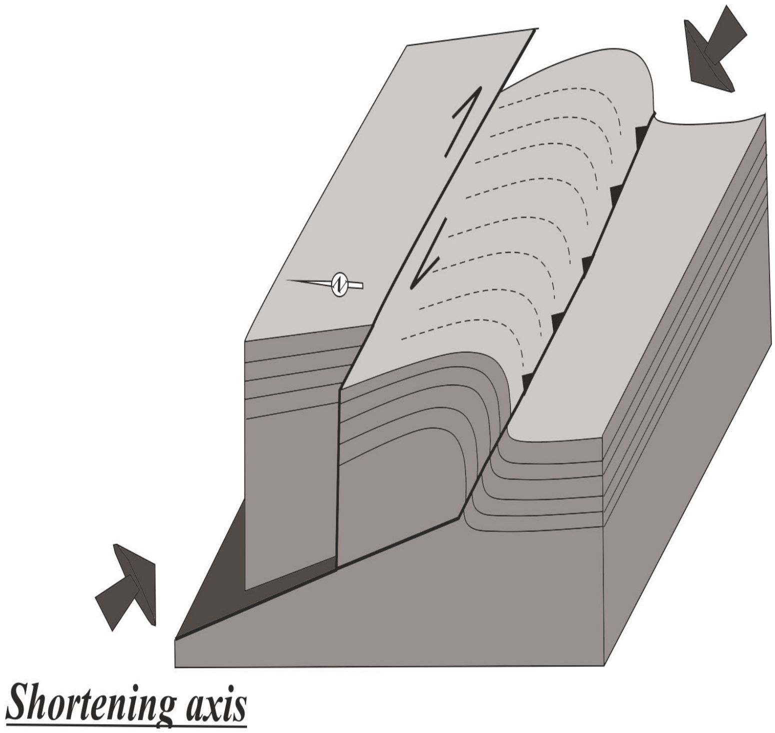

Figure 5. Obliquity of major faults by report of axis of shortening.

5. Deformation in Southern Central of Atlassic of Tunisia

In Bou Ramli-Ben Younes-Es Stah junction (**Figure 2**), the major outcrops limited by faults of NE-SW and NW-SE direction. The activity of these faults in geological time shows the distensional structure and compressional structure. The slickenside of faults allows specifying the geodynamic evolution and the tectono sedimentary relation characterizing every locality.

The structural analysis and kinematics study of faults of N120-130 direction which stake the outcrops of Ben Younes-Bou Ramli-Es Stah shows the direction of stress; indeed σ max suggests the axis of shortening of NNW-SSE and N-S of direction. This direction of axis of shortening can be connected to the state of convergence which affects allocation of North Africa. This regime of constraint is bound to an increase of the rate of convergence.

The oblique convergence between Africa plate and Europe plate is accommodated by the partition of the movement in intracratonic chains. In the southern Atlassic of Tunisia, the strike-slip faults are connected with the thrusting which shows that the axis of shortening is oblique with the major faults of NW-SE direction. The analysis of geomorphologics and kinematics study of these faults allows determining the model of strain of the various outcrops related with the activity of the faults in the subsurface.

These faults contribute to the regional reorganization of the deformation of Triassic to Quaternary and receive the strain partitioning of the oblique convergence between these two plates.

The faults are connected in subsurface and permitted the distribution of the strike-slip faults and the sinusoidal thrusting in some localities in southern Atlassic of Tunisia. Therefore, the structural study and the kinematics of these faults allow reorganization of structures and deformation in southern Atlassic of Tunisia.

6. Discussion

During approaching of two blocs of European and African plates, the deformation can be absorbed along the largest orogenic domain. The distribution of deformation in this domain isn't homogeny. It is accommodated by the orientation of different structures (faults and folds)

The faults transport shortening movement and accommodate party of oblique convergence to limits of system defined by the partitioning of deformation (Martinez *et al*., 2002 [29]).

Related to the importance of obliquity angle of convergence vector to faults trends, the deformation will be accommodated by partitioning, producing a tranpressional deformation example of Alpine, Philippine and Sumatra faults (McCaffrey, 1992 [30]).

The transpressional deformation is also accommodated by the coexistence of strike-slip and thrust fault like the Alpine fault of New Zealand (Walcott, 1979 [31]; Norris *et al*., 1990 [32]). It also permeates the genesis of folds in echelon disposition (Richard and Cobbold, 1990 [33]; Tikoff and Peterson, 1998 [34]) observed in the transition zone of Zagros-Makran in Iran (Regard *et al*., 2005 [35]).

In Tunisia, different models have been proposed based on the position of the major faults and the axis of shortening.

At the North-South axis, the deformation is characterized by the predominance of extensive component on submeridian faults and a slip component on the transverse faults. The model is related to a compressive tectonic determined by extensional inheritance associated with the model of "fault propagation fold" (Creuzot *et al*., 1993 [15]).

The southern central Atlassic of Tunisia is characterized by overlapping structures types of "thick skinned" and by a lateral variation of structural geometry and shortening rates controlled by oblique ramps of NW-SE direction. The main thrust fault affecting Bou Ramli-Ben Younes-Es Stah junction partitions the oblique convergence during the tectonic phases and causes the genesis of major strike-slip faults. So we can propose the model of strain partitioning is under control of oblique ramp in the Gafsa Basin based on the coexistence of strike-slip faults associated with thrusting.

Whereas, in Orbata Bouhedma junction, this important compression allows the activation of these faults in reverse which explains the overlap of anticlines and synclines disappearance resulting the model of tear fault.

7. Conclusions

The originality of this work is the interpretation for the first time in North Africa for a model of partitioning deformation based on the surface data and the comparison among many study areas. This interpretation is related to the reactivation of directional preexisting faults during compressive phases.

Many parameters explain the choice of this model especially the obliquity direction of shortening axis and the convergence of field stress during compressive phase. This kinematics is proven by the coexistence of strike-slip and trust faults and the role of basement structures in displacement of deformation according to decollement level in Triassic series. The maximum of deformation is observed in the forelimb in the cover structures limited by the Gafsa fault.

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