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Tunisian Transtensive Basins in Tethyan Geodynamic Context and Their Post-Tortonian Inversion

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1. Introduction

Generally, the geological and structural context of Tunisia can be described, from the North to the South, in terms of the structural domains illustrated on Fig. 1:

1. The Alpine zone, composed of the Tellian Atlas, characterized by the stacking of allochthonous units (Jauzein et al., 1965; Biely et al., 1974; Rouvier, 1977; Ben Ferjani et al., 2006; Ould Bagga et al., 2006) and a series of imbricate thrust slices, whose front corresponds to the major Teboursouk overthrust (Zargouni, 1975; Perthuisot, 1978).
2. The diapir zone (DZ), represented by the N050-trending Triassic outcrops of northern Tunisia (Perthuisot, 1978).
3. The Atlasic zone includes the Northern Atlas, the central Atlas, the southernmost Atlas and the "North-South Axis". The central Atlas and the Northern Atlas are characterized by a bundle of N040-050 anticlinal folds that are cut orthogonally by a graben system. The southernmost Atlas is made up of E-W folds, inflected towards N060 at their terminations and bounded by the major faults of Gafsa and Négrine-Tozeur striking N120-130 (Zargouni, 1985). The "North-South Axis" comprises a folded and faulted zone delimiting the central Atlas (*sensu lato*) and the Eastern Atlas. It corresponds to a zone of major heterogeneity giving rise to N-S trending faults (Burollet, 1956; Turki, 1984, 1985, Gourmelen, 1984; Abbès, 2004).
4. The Eastern platform is characterized by a weakly folded thick Neogene succession that extends eastward to the Malta scarp.
5. The Saharan platform is characterized by folded Paleozoic rocks of the African craton, and makes up the foreland of the Atlasic chains (Fig. 1).

The present architecture of the Saharan Atlas in Tunisia is defined by two principal models: The first one (Fig. 1) emphasizes a general SW-NE geological structure in successive and parallel bands represented by the tellian zone and the diapirs zone in the North, the central Atlas then the southernmost Atlas with oblique orientation and installed within a NW-SE corridor. These fields are bordered in the East by the "North-South Axis" (Castany, 1951; Burollet, 1956, 1991; Rouvier, 1977; Zargouni, 1984, 1985).

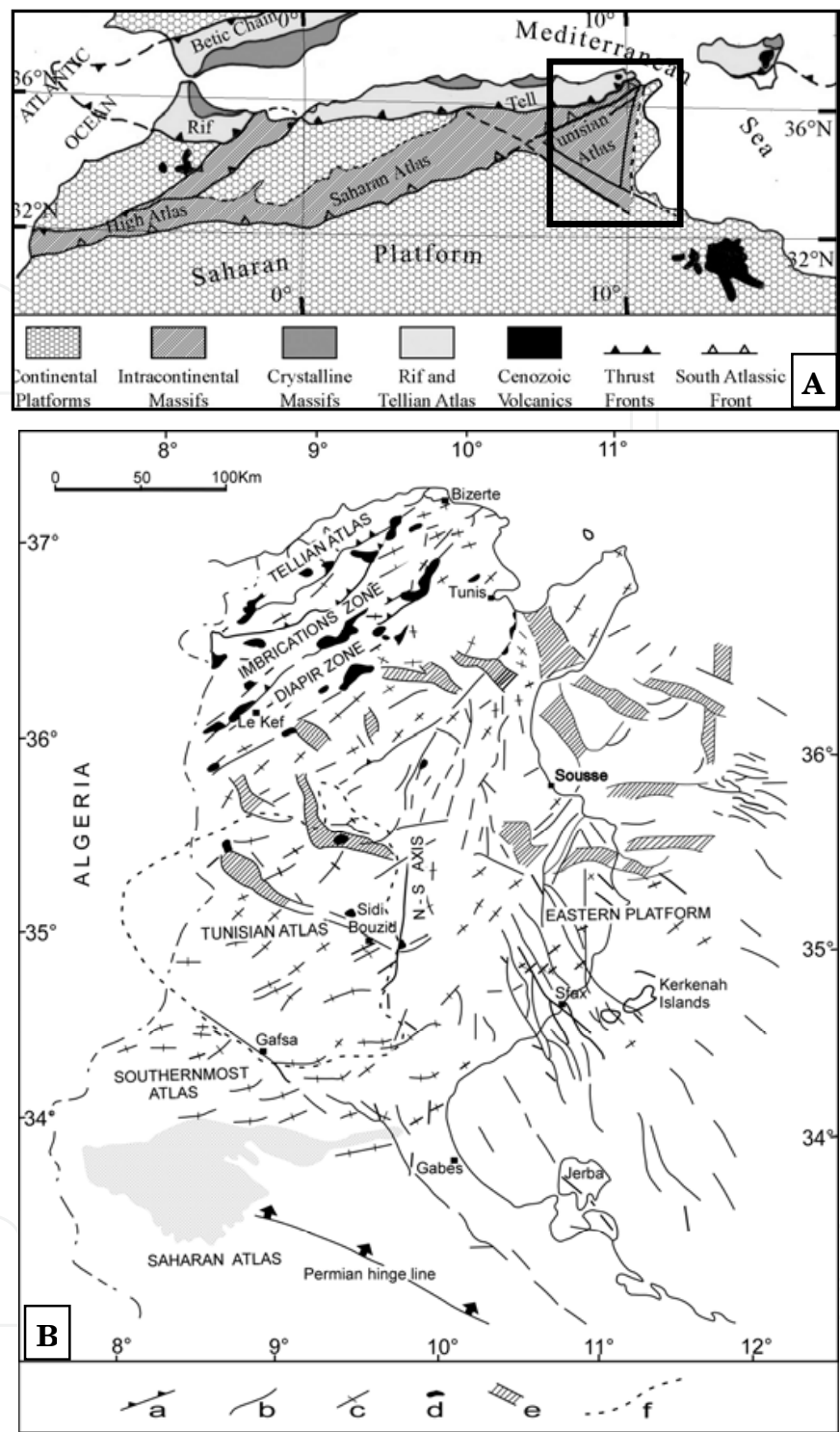


Fig. 1. Location of Tunisia in the eastern Maghreb: A- general context; B- schematic tectonic map of Tunisia. In B: a- major thrust, b- major faults, c- major anticlines, d- Trias, e- grben, f- limit of Kasserine Island

The second model (Fig. 2) frames atlasic Tunisia in a big E-W strike-slip corridor which controls at first the facies distribution during the Meso-Cenozoic sedimentation and generates later long echelon folds in the sedimentary cover by dextral shear zone (Ben Ayed 1980; Ben Ayed and Viguier, 1981; Ben Ayed, 1986; El Ghali et al., 2003).

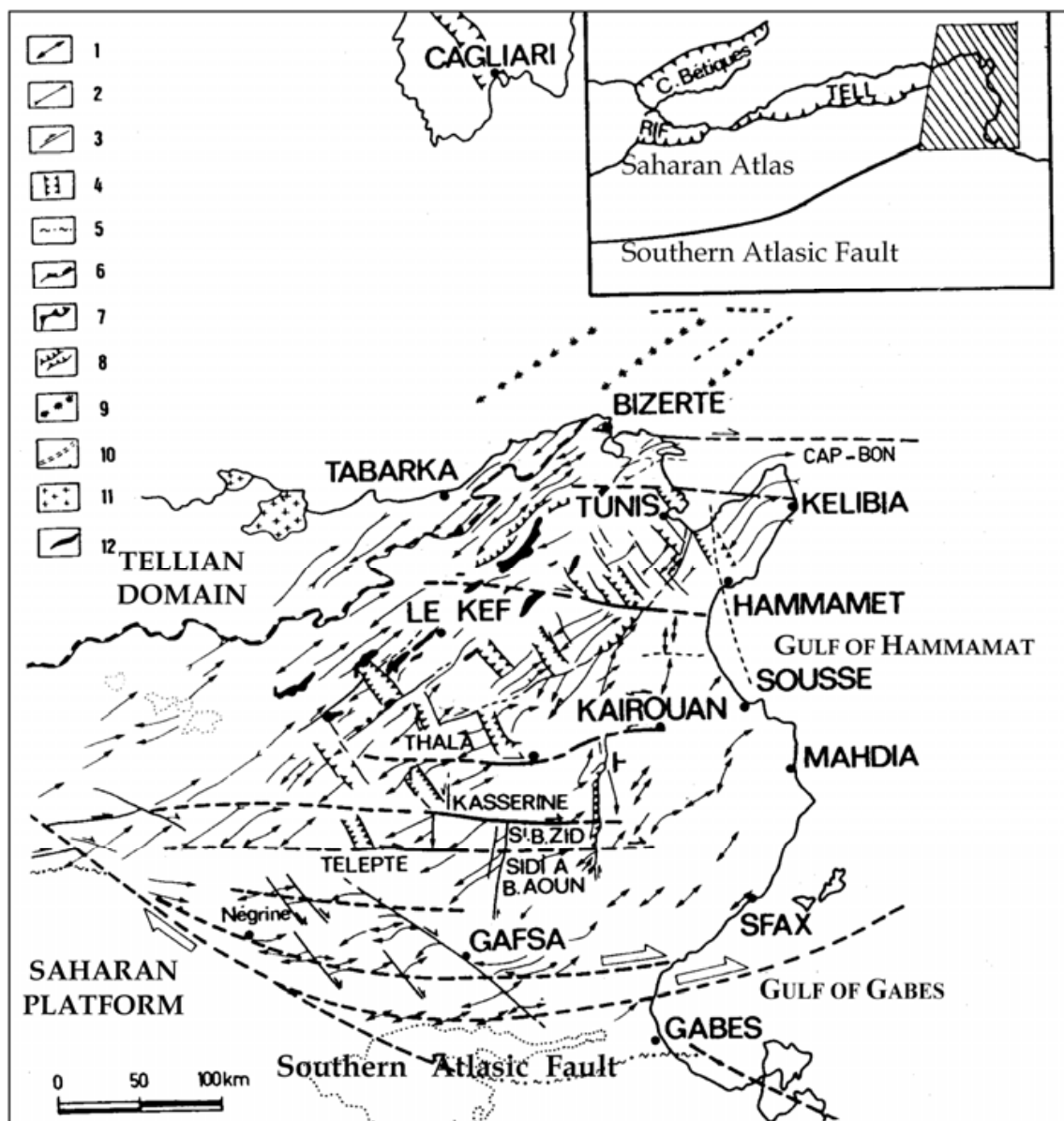


Fig. 2. Simplified tectonic map of Tunisian Atlasic domain (Ben Ayed and Viguiier, 1981).

1: anticline; 2: syncline; 3: strike-slip fault; 4: rift; 5: flexure; 6: slipping thrust front; 7: thrust; 8: imbrications; 9: anticlinal alignment; 10: eastern extension of this alignment from the bathymetrical data; 11: pre-alpine; 12: Triassic outcrops

2. Present-day architecture of Tunisian Atlas

Independently of these two historical models, the present Tunisian Atlas appears as a megabloc that we call “Tunisian Block (TB)”. These feature is bordered by three major faults belonging to the Northern Saharan “reghmatic” network (Fig.3): (1) the eastern boundary appears as a complex faulted and folded corridor (NSC), defined by Rigane and Gourmelen (submitted paper) delimiting the folded zone of the Central and the Northern Atlas in the West and the Sahel subsident zone in the East: it corresponds to the “North-South Axis (sensu stricto)” described in the literature (Burollet, 1956; Gourmelen, 1984; Gourmelen and Tricart, 1985; Khessibi, 1978; Rigane, 1991, Piqué et al., 1998; Abbès, 2004; Rigane and

Gourmelen, submitted). (2) The Southern boundary also corresponds to a faulted domain, known as the Gafsa-Negrine-Tozeur (GNTC) (Zargouni, 1986; Zouaghi et al., 2005). The GNTC interrupts the extension of the NSC towards the south in the Gabès area, and corresponds to the Southern Saharan Atlas limited by the Gafsa fault in the North and the Negrine-Tozeur fault in the South (Zargouni, 1985; Boukadi, 1998; Zouari, 1999). (3) The Northern boundary is characterized by a SW-NE orientation. This zone appears rather as a sheaf of reverse faults, facing South-East or South (with oblique convergence), whose major structural feature corresponds to the El Alia-Teboursouk fault (Jauzein, 1967; Martinez and Truillet, 1987). This tectonic bundle, which also coincides with the “diapir zone (DZ)” corresponds to the Southernmost limit of the TB in Algeria. This Northern boundary cuts across and limits the NSC in the North, so this feature is bounded at both extremities. Finally, within the TB corresponds to a mosaic of second-order blocks (Gourmelen et al., 2000; Zouaghi et al., 2005; Rigane and Gourmelen, submitted). In this domain, we observe widely spaced SW-NE anticlinal folds separated by vast plains very often occupied by sebkhas. The paleogeographic and structural evolution of the studied area shows that the TB became individualized very early in Mesozoic and Paleogene times and characterized, thus, by an extensive (and/ or transtensive) tectonic regime.

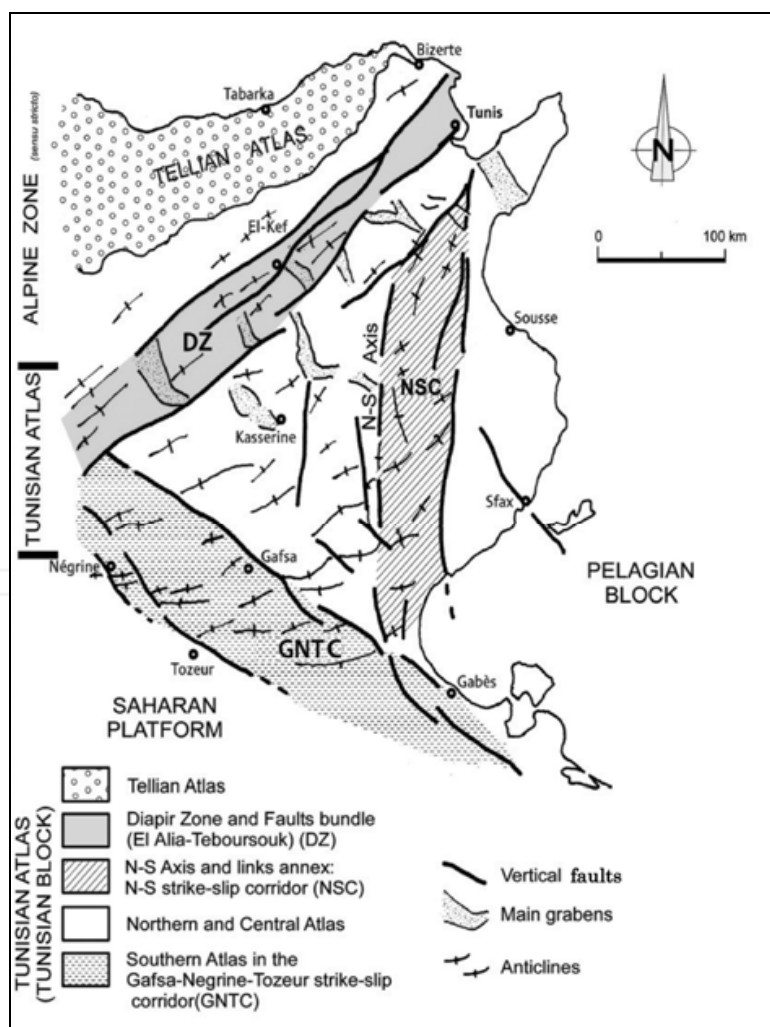


Fig. 3. The present-day architecture of Tunisian Atlas: the faulted block and its components

3. Pre-orogenic history of the “Tunisian Block”

3.1 Paleogeographic and structural evolution of the basin

The studied area, as illustrated in Fig. 4, shows that this TB became individualized very early in Mesozoic times along with its determined limits.

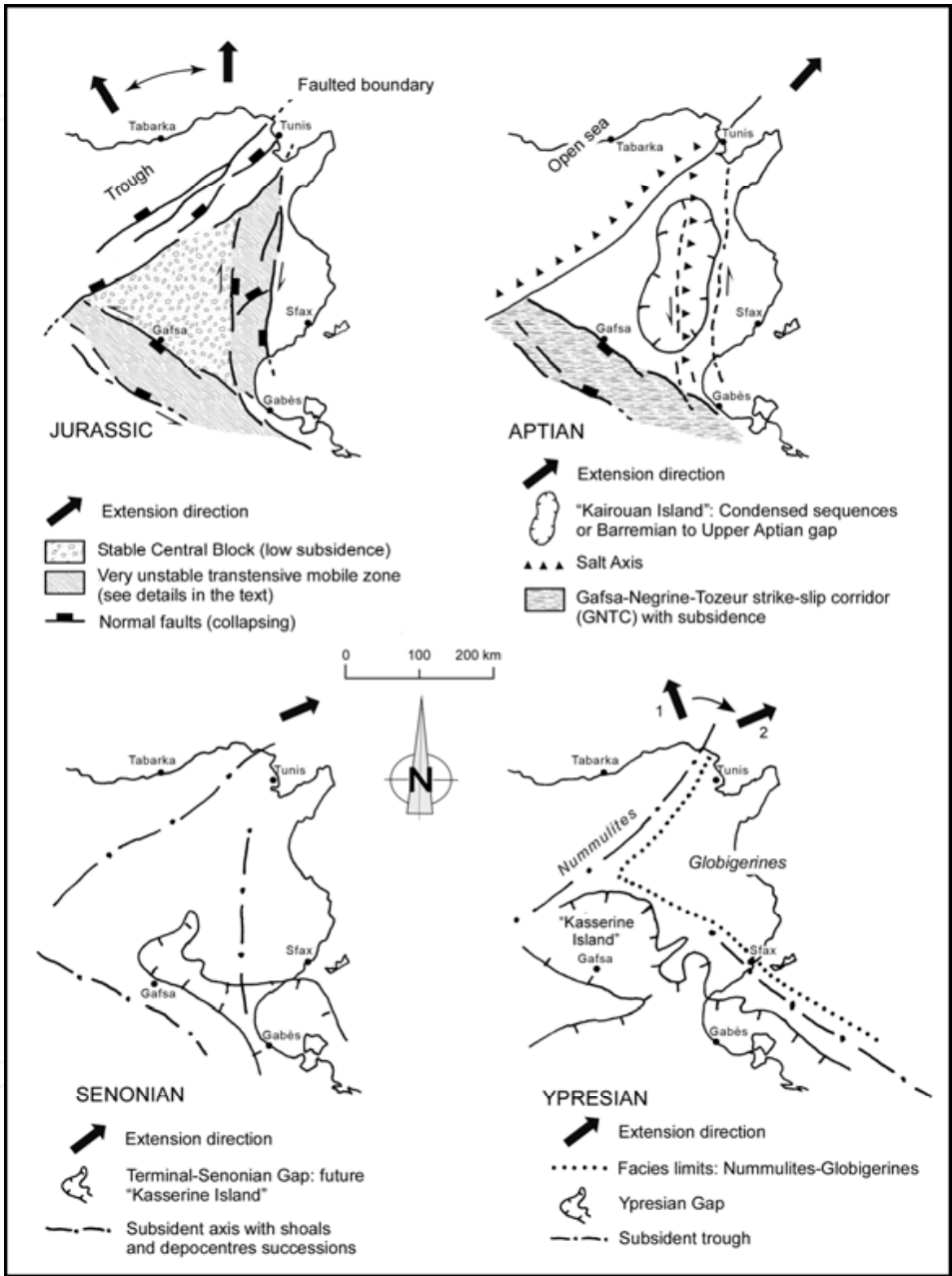


Fig. 4. Tunisian Basin and continuously mobile boundaries

Whereas the Saharan Atlas in Algeria is composed of a folded and faulted chain elongated in the SW-NE direction, it forms an almost isosceles triangle in Tunisia. This latter terrain corresponds to a true continental block, whose origin is precisely linked to its paleogeographic history, which is dominated by its three boundaries, undergoing continuous tectonic remobilization, controlling the geometry, morphology and filling of the basin (Fig.4).

More precisely, these boundaries correspond to mobile zones from the early Mesozoic onwards, with the formation of sedimentary wedges, gaps and unconformities (Buroillet, 1956, 1991 and Buroillet et al., 2000; Rouvier, 1977; Hlaïem, 1999; Jauzein, 1967; Soyer and Tricart, 1987). In this way, the Tunisian Atlas appears to inherit its present morphology from the early and continual compartmentalization of the basin, which is tectonically inverted from Tortonian times onward to form the folded Atlas chain.

3.1.1 During the Jurassic

The three boundaries of the block form mobile zones of variable width associated at depth with vertical faults of the pre-Triassic basement (Midassi, 1982; Morelli and Nicolih, 1990; European Geotraverse, 1992; Piqué et al., 2002; Gabtni et al., 2005).

- The southern boundary, which, moreover, is prolonged in the extreme south-east of Tunisia, corresponds to a coastal depositional environment, sometimes of evaporitic type but in a subsident zone, (Kamoun et al., 1999; Soussi, 2002), with a series of depocentres and tectonic highs succeeding each other from NW to SE: the Chotts basin, the Tébaga high, the Tatatouine basin and the Néfouza highs in Libya (Aissaoui, 1984; Bouaziz, 1995). All these morphostructural features result from transtensive movements of the GNTC in an overall N-S extensional regime (en echelon E-W normal faults). At this epoch, sedimentation was occurring in a typical intracratonic basin.
- The northern boundary corresponds to the faulted edge of the "deep trough" (Buroillet, 1956) i.e. an open marine basin. This basin contains pelagic deposits displaying a margin-type character with SW-NE-trending active faults (El Alia-Téboursouk, Boujabeur-Lorbeus-Gafour, for the principal ones). These faults are probably inherited from the basement, and are picked out by diapirs. They could be integrated into a transform margin on a much larger scale associated with a sinistral strike-slip fault zone in relation to the Açores-Gibraltar-Sicily system (Dercourt et al., 1985; Dewey et al., 1989).
- The Eastern boundary is generally expressed as a N-S-trending axis of dome-type diapiric highs with condensed series, gaps, wedges and discordances (Gourmelen et al., 1989), intersected by local depocentres associated with grabens or hemi-graben structures linked to the regional extension and arranged according to transverse faults following the axial trend.

Finally, in the Jurassic, in spite of the scarcity of outcrops and subsurface data, a synthesis of sedimentological and paleogeographic studies (Kamoun et al., 1999; Soussi, 2002) combined with the existing tectonics allows us to propose a simple geometrical model of the Tunisian basin at that time: three unstable zones are arranged around a resistant central block with little or no subsidence, and are subject to the remobilization of pre-Triassic basement fractures. As a result, this basin displays clearly intracontinental characteristics. Subsequently, these three unstable zones exert a more or less important influence on the geometry and development of the basin at different times.

3.1.2 During Early Cretaceous

A positive zone appears corresponding to the "Kairouan Island" (M'Rabet, 1981), clearly delimited in the East by the CNS and the GNTC in the South undergoing more subsidence. The tectonic regime is thus extensional with a maximum lengthening towards the NE (Rigane et al., 2010). At this time, the Eastern boundary becomes increasingly positive,

while, throughout the region, we observe the development of condensed series, gaps and wedges of Aptian age called the Gafsa group by M' Rabet (1981); sometimes, the entire Gafsa group is even reduced to a metre-thick quartz-bearing dolomitic level named the Bouzer dolomite by Gourmelen (1984). Among other factors, this mobile and positive zone is the result of diapiric phenomena which probably begins at the end of the Triassic and which ceases, at least temporarily, at the end of the Aptian, since, along the entire length of this boundary, the Cenomanian is discordant on various units ranging from the Triassic to the Aptian.

At the end of the Aptian, the tectonic regime is shown to consist of a SW-NE extension (Bismuth et al., 1982; Boltenhagen, 1985; Soyer and Tricart, 1987; Feki et al., 2005; Rigane et al., 2010), with a strong strike-slip component (transtension) on the megablock boundaries.

3.1.3 During Cenomanian

The Tunisian block temporarily loses its individual character as a consequence of the generalized transgression expressed in Tunisia by the Zebbag formation *sensu lato* (Burolet, 1956; Lüming et al., 2004). In detail, however, the N, S and E boundaries remain mobile with highs zones in the East, a deep basin towards the NW (formation Bahloul) and a subsident southern corridor. During the Cenomanian, the tectonic regime is predominantly extensional (Bouaziz et al., 2002).

3.1.4 At End-Senonian

The distribution of depocentres is inverted along the three boundaries of the block. The CNS becomes subsident, with the development of a succession of depocentres and highs, frequently of halokinetic origin. The Western extremity of the block shows a tendency towards emergence reflecting the appearance of the "Kasserine Island".

We may conclude that, since the Jurassic period, the eastern part of Tunisia, mainly to the east of the CNS, remains a subsident zone, with, however, the existence of some more marked basins (Ellouz, 1984).

3.1.5 The Paleogene

Throughout this era, some major changes occur in the basin geometry:

3.1.5.1 Ypresian

The "Kasserine Island" is superposed on the southernmost part of the Tunisian block. Indeed, isopach and facies maps (Bishop, 1975; Rigane, 1991; Rigane et al., 1994; Zaier et al., 1998; Ben Ferjani et al., 2006) clearly show the presence of shallow basins, in the NW and the SW (nummulitic and phosphatic facies), which become deeper in the East (troughs of the Gulfs of Tunis and Gabes). During this epoch, a NW-SE extensive and/ or transtensive tectonic regime controls the sedimentation (thickness and facies) in the Ypresian basin (Rigane et al., 1994).

3.1.5.2 Lutetian-Priabonian

The deposits are arranged in isofacial bands almost parallel to the CNGT trend. The "Kasserine Island" gradually loses its individual character to become connected finally to the Saharan continent. The predominant tectonic regime is also transtensive, but we observe a change in orientation towards a SW-NE trend (Gourmelen et al., 2000). This radical change

in basin cartography is probably linked to the modification of Africa/ Europe kinematics at this time (Dewey et al., 1989).

3.1.5.3 Oligocene

Although the area of emerged land tends to migrate northwards, the shoreline is always constrained by the NW-SE trend. The tectonic regime is characterized by a SW-NE extension (Blondel, 1991; Yaïch, 1997).

3.2 Major crises

Since the Jurassic to the Oligocene period, a succession of basins and shoals is observed and controlled by continuous mobility of the three faulted corridors (DZ, NSC, GNTC) delimiting the TB associated to diapiric movements. The corridors mobility attains his paroxysm during three major tectonic crises: at the end of the Aptian, the Ypresian and the Oligocene. Each crisis is marked by a momentary stopping (Aptian, Ypresian) or definitive (Oligocene) of halocinetic ascension.

3.2.1 The Aptian crisis

At that time, Tunisia can be regarded as an intracontinental basin at the northern margin of the African craton, characterized by depocentres directly related to the activity (reactivation) of pre-existing faults. In this case, mobility is concentrated within an N–S trending tectonic bundle in a transtensive regime. For example, the structural and tectono-sedimentary study of Jebel El Hamra to the West of Kasserine (central Tunisia) underlines the predominant role of paleostructures acquired during the evolution of the South-Tethyan basin, and their influence of the present-day geometry of the fold belt. Indeed, the existing pattern of folding and faulting results directly from tectonic blocks formed during the Aptian. Hence, the depocentres appear as two pull-apart basins bounded by a lower-shaped structure (Fig. 5). shown by small arrows. Black arrows: direction of Extension (Rigane et al., 2010).

Lastly, the existence of tectonic nodes supports the hypothesis that diapirism can induce local tectonic extension. The tilted blocks of Jebel El Hamra can be, consequently, the final result of this transtensive tectonics, locally associated to halocinetic vertical movements of Triassic salt. At a large scale, in the African geodynamic context of this period (Guiraud and Maurin, 1991; Guiraud and Maurin, 1992; Guiraud et al., 2005; Basile et al., 2005), this late Aptian phase, very exactly dated in the studied area to the end of Clansaysian age, is integrated in the rifting phase shown by Guiraud and Maurin (1991) in all the intracontinental basins of the Northern part of the African craton, in particular in Libya (gulf of Syrte). In addition, as noticed by these authors (Guiraud and Maurin, 1991, 1992), we conclude also that the opening was done on a mobile zone of the crust in Tunisia, more precisely on a submeridian fault, inherited from the African craton. Finally, the SW–NE detected extension originates from the rifting and oceanic activity in Northern basin (tethyan western branch) and the Eastern basin (Tethyan southernmost branch: Mesogea) (Dercourt et al., 1985; Martinez and Truillet, 1987; Ricou, 1994; Stampfli et al., 2002; Schettino and Scotese, 2002).

In this context, the northern margin behaves like a strike-slip margin (Gibraltar-Messine transform fault) from the upper Liassic onwards, while the Eastern margin represents a

classical passive margin that takes over from or develops alongside the transcurrent shear zone from the Early/ Late Cretaceous boundary (Fig. 6).

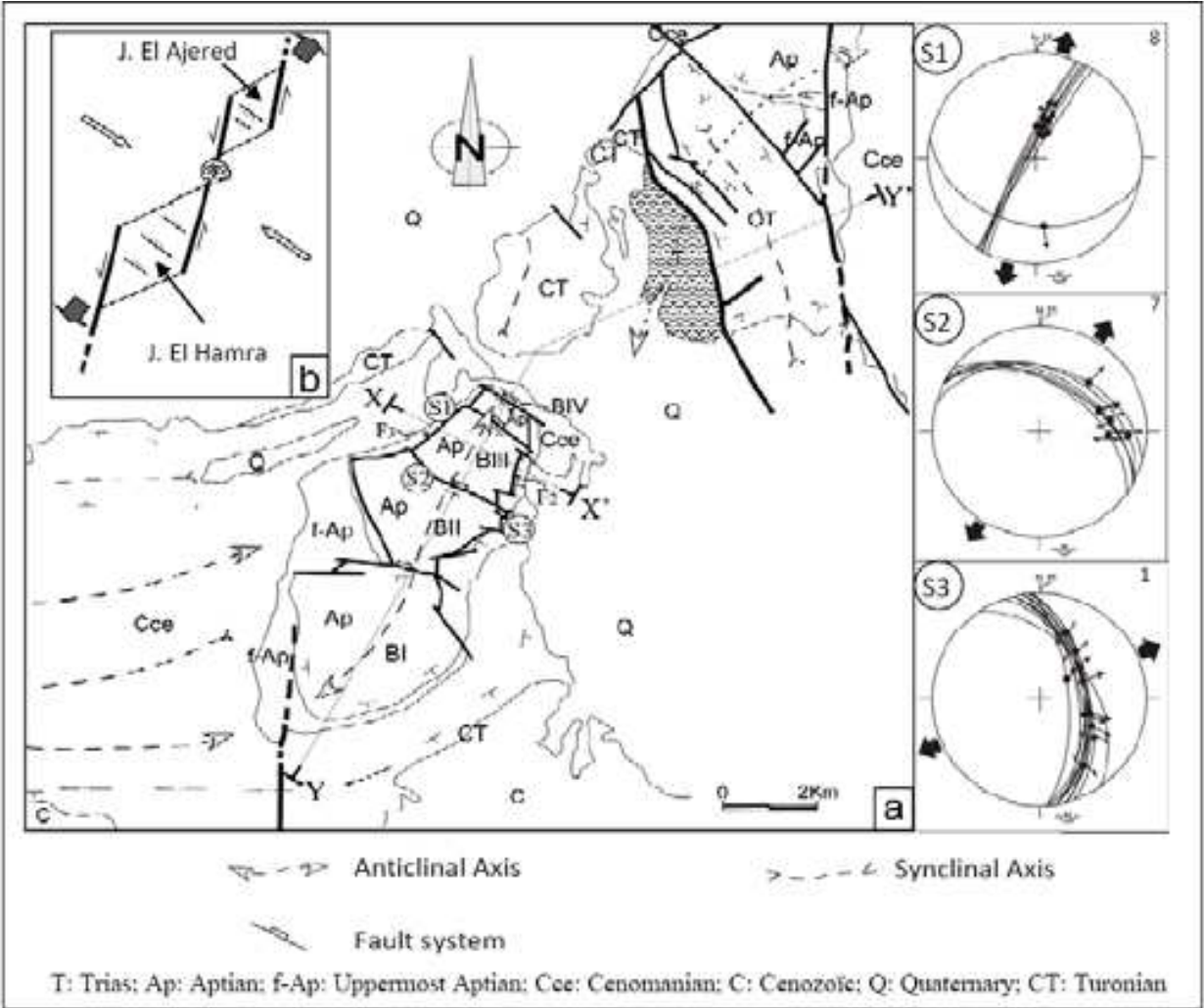


Fig. 5. a) Simplified geological and structural map of El Hamra-El Ajered area and stereographic plots of faults (equal-area, lower hemisphere). Slickenside lineations are shown by small arrows. Black arrows: direction of Extension (Rigane et al., 2010). b) Interpretation of the study area: two negative lozenge-shaped depocentre bounded by a N-S shear zone (Rigane et al., 2010).

3.2.2 The Ypresian crisis

The Ypresian limestones, in Central area or Tunisia, are cut up by normal dip-slip and strike-slip faults of late Ypresian age. All these fractures are arranged mainly in submeridian N060, E-W and N140 directional systems. The first, the commonest and the most pronounced associates locally according to sectors with the other systems to form Riedel-type, pull-apart or horst and graben structures. The detailed structural analysis of these Ypresian limestones clearly shows that this period is characterized by normal fault and extensive strike-slip fault movements. The normal and/ or strike fault throw vary from a few centimeters to a few meters and evolve laterally into a flexure.

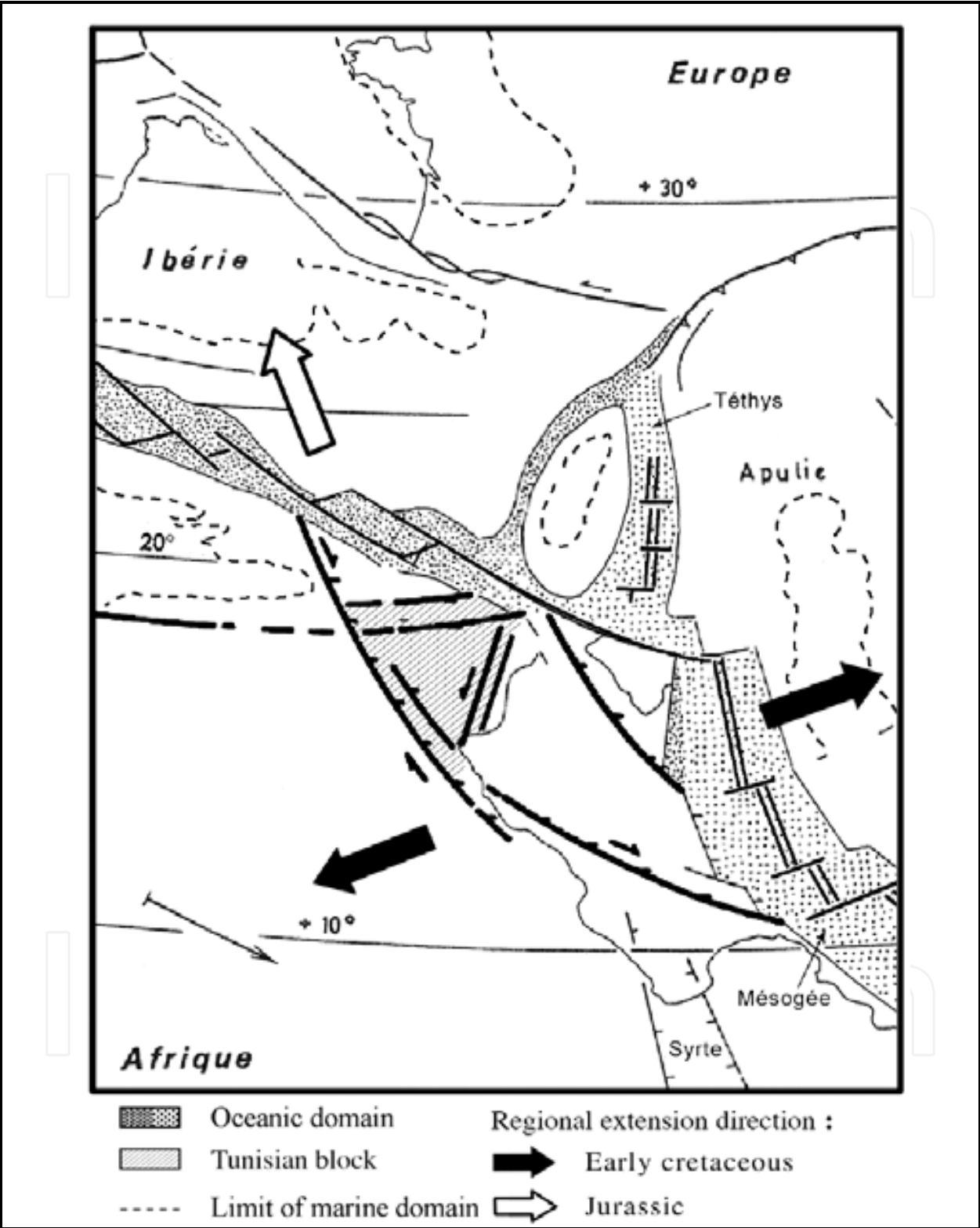


Fig. 6. Geodynamic context of Tunisian Basin from Jurassic to the end of Lower Cretaceous (after Martinez et al. 1991, modified)

The results obtained from the different measures carried out for each system and their processing show that the finite Ypresian faulting event is the result of two successive

episodes, very close in time (Fig. 7). They are characterized first by a NW-SE extension (episode 1) followed by a SW-NE extension (episode 2).

The geometric and kinematic study of this area clearly indicates that, during late Ypresian, there was a remobilization of ancient fractures, mainly submeridian and NW-SE, in an extensive strike-slip context.

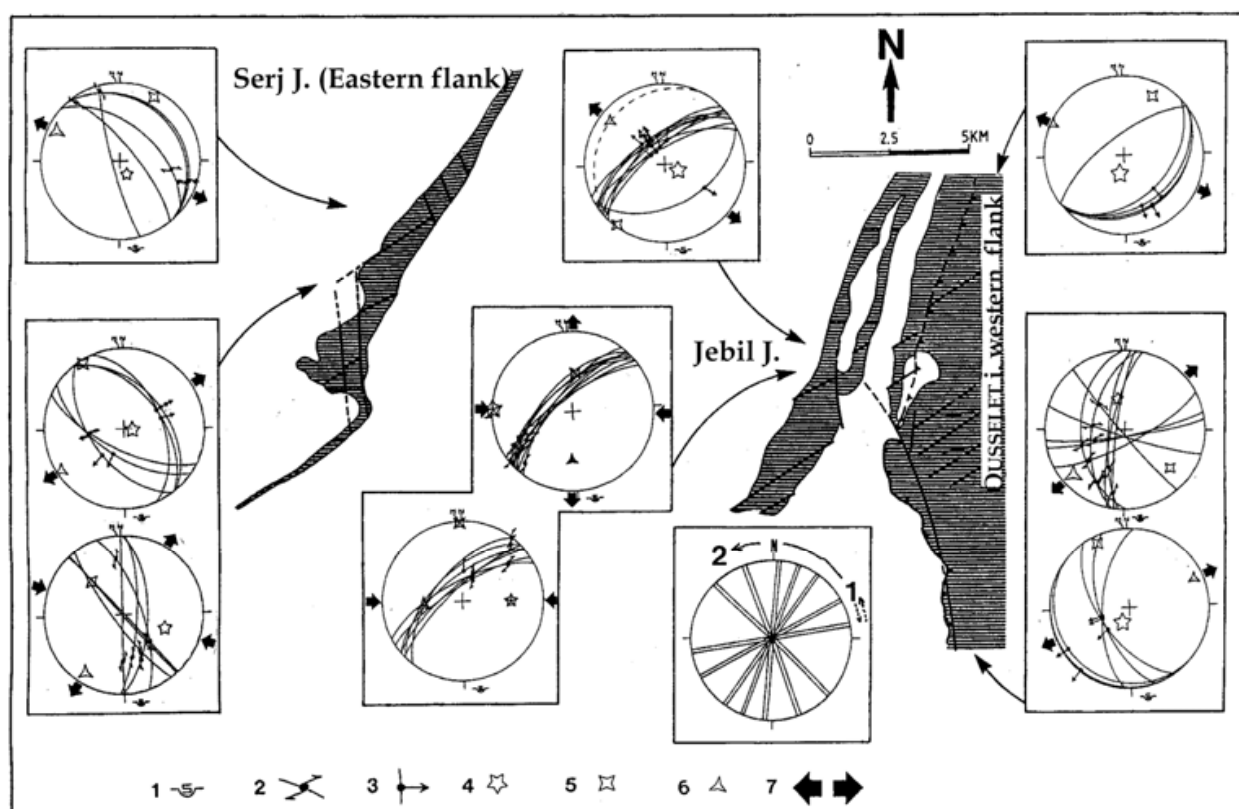


Fig. 7. Quantitative analysis of terminal Ypresian striated slickensides revealing the two strain sequences and their directions of extension in Central Tunisia. 1) Schmidt pattern, lower hemisphere; 2) strike-slip fault; 3) normal fault; 4, 5, 6) major axes of the stress tensor; 7) direction of extension

Extensive structures (normal faults, normal strike-slip-faults and flexures) appeared and evolved in this context within the Oussetia block (Fig. 8) which, therefore, presented, at that time, a mainly-vertical mobility the origin of which stays in the basement. This mobility results in extensive structures in the basin. The corresponding extension is manifested in the sedimentary pile by horizontal shearing in the ductile level and notably in the evaporites of the Trias. The strong rotation of the stress field observed in this block corresponds exactly to the period when important variation in the drifting of Africa and Europe is recorded.

In fact, according to Dewey et al. (1989), after a noticeable slowing down and “erratic movements” of the two converging plates during Paleocene, Africa move again towards the NE precisely during late Ypresian around 51 Ma (anomaly 21). We are tempted to believe that this brutal change of behavior of the African plate was recorded in the late Ypresian faulting episode in this part of the Saharan Platform and corresponds to the rotation of the detected stress fields.

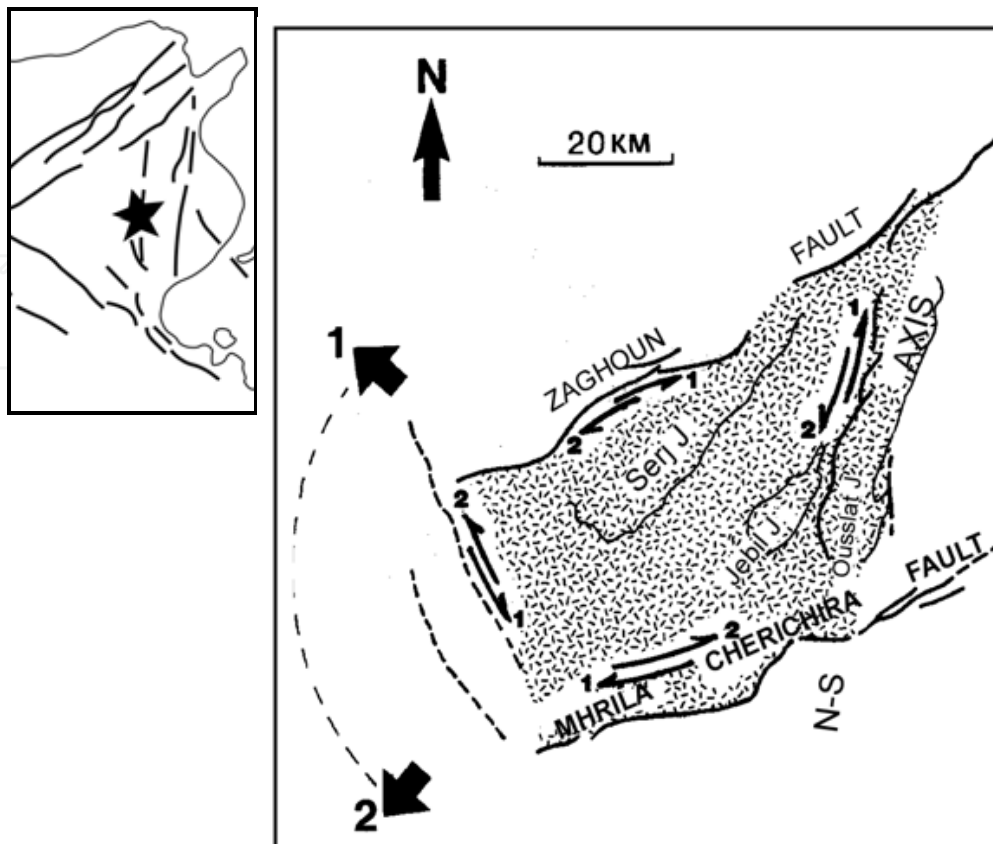


Fig. 8. Terminal Ypresian movements on the borders of the Ousseltia Block associated with NW-SE then NE-SW transtension (1-2: successive extension direction at the end of Ypresian)

At the end of the Ypresian, the Tunisian platform looked like a jigsaw puzzle made up of huge blocks limited by ancient fractures. The Ousseltia block is an example of this blocks. The remobilization of the block boundaries occurred in an extensive context. The stress field developed a strain within the blocks themselves that corresponds to the stress pattern. In this context, the material affected during lithification, reacted in an original way by developing a ductile/ fragile strain according to the rheological characteristic of the levels.

This intra-block deformation appears superficial and space limited compared to the one that can be seen on the block boundaries. It is immediately registered and memorized in the deposits and then sealed by successive sedimentation periods.

The later stress fields which strained these blocks again caused a remobilization at the boundaries, more and less masking the earlier movements, and provoked new intra-block deformation which, on the contrary, will be fossilized. Thus, that is how a great number of palaeo-structures have been yielded to us nearly intact for observation since Jurassic. The example of the Ousseltia block evolution at late Ypresian may represent a model of the tectonic behavior of the Africa plate in Tunisia during its pre-Alpine history.

Finally, this geological structure (blocks) could correspond to a similar geodynamic context observed during Aptian crisis: northern tethyan transtensive and eastern mesogean margins (Fig. 9).

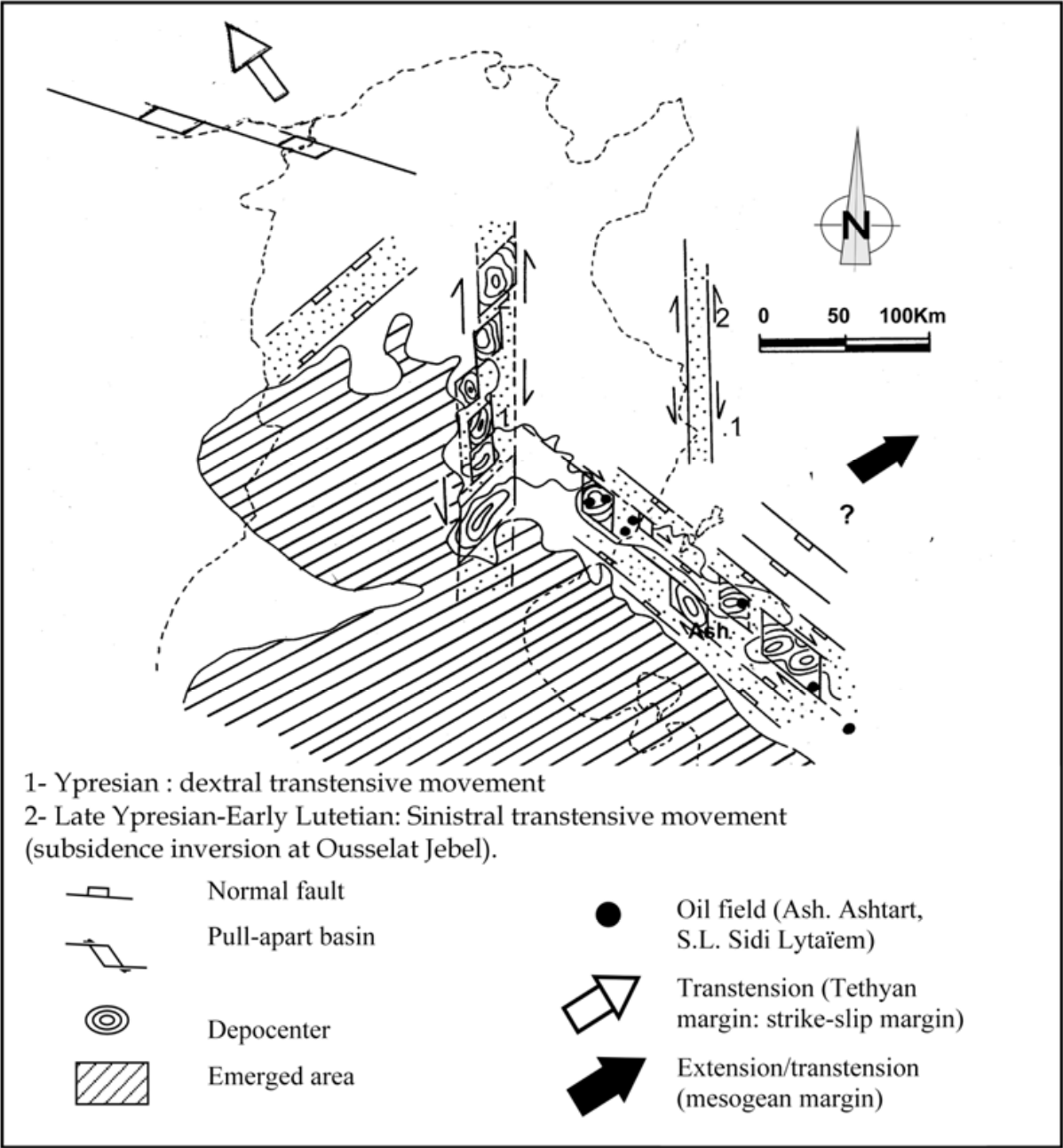


Fig. 9. Geodynamic context of Ypresian Basin in Tunisia

3.2.3 Pre-Burdigalian crisis

This crisis is identified in Central Tunisia by Yaïch (1984, 1997) and confirmed by Blondel (1991). It is characterized by extension related to the Western Mediterranean, Red Sea and Suez Gulf opening and Western Europe Rifts genesis.

4. Structural inversion and its consequences

4.1 Compressive phases in Tunisia

For a long time, the scientific community (Castany, 1951; Richert, 1971; Rouvier, 1977) accepted that the Alpine chain in Tunisia was built up by two major compressive phases: the

first is dated as middle Miocene (Tortonian) and the other as Quaternary (post-Villafranchian). However, recent work has revealed the existence of an early tectonic event known as the "Atlasic phase" of Middle Eocene age (Khomsi et al., 2006; Frizon de Lamotte et al., 2006). These authors base their argument on the presence of angular unconformities located on the flanks of anticlines observed on seismic sections (Fig. 10). In agreement with the present study, other authors (Brahim and Mercier, 2007) have shown that these discordances are actually located on the flanks of diapiric domes and result from a slow and progressive diapirism. Zouaghi et al. (2005) also propose a compressive phase during the Late Cretaceous and even at the end of the Aptian (Ben Ayed, 1986; Rabhi and Ben Ayed, 1990; Ben Ayed et al., 1997; Bouaziz et al., 2002). In these two latter cases, we consider that the discordances observed by these authors are either of the same type as previously described (on diapir flanks) or relate to disharmonic structures within the Miocene and Quaternary folds or are located on top of drape fold zones (Gourmelen et al., 2000; Rigane et al., 2010).

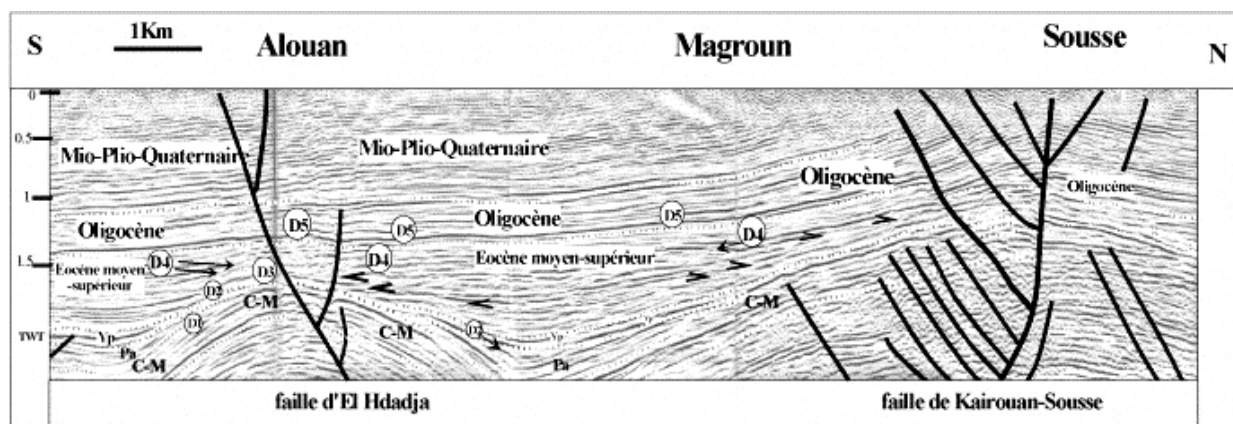


Fig. 10. Interpreted seismic line L1, showing the angular unconformities D1 to D5, the compressional Eocene tectonics and the extensional tectonic affecting the Oligocene (Khomsi et al., 2006). CM: Late Cretaceous, Pa: Palaeocene, Yp: Ypresian

However, we should stress that these discordances are always local and/or linear. Moreover, at these times, typical compressive structures (folds, reverse faults, etc.) are not observed or described in the Tunisian Atlas. On the contrary, as discussed above, the geometrical, kinematic and dynamic characteristics of these structures indicate that the studied area corresponds to an extensional (or transtensive) setting.

4.2 Inherited structures, deformation style and compressive tectonics

The deformation style resulting from these two major tectonic phases (i.e. Tortonian and Villafranchian) are different from one region to another (Fig. 11).

We find a geographical distribution of deformation that is similar to the pattern that prevailed during the basin history: central block and mobile borders. In addition, the variety of structural styles draws its origin from the structures gradually acquired since the Jurassic and accumulated until the Oligocene. The compressive deformation phases appear strongly controlled by the pre-existing geometries: folds, faults and strike-slip faults are directly induced by the paleostructures orientation of the TB.

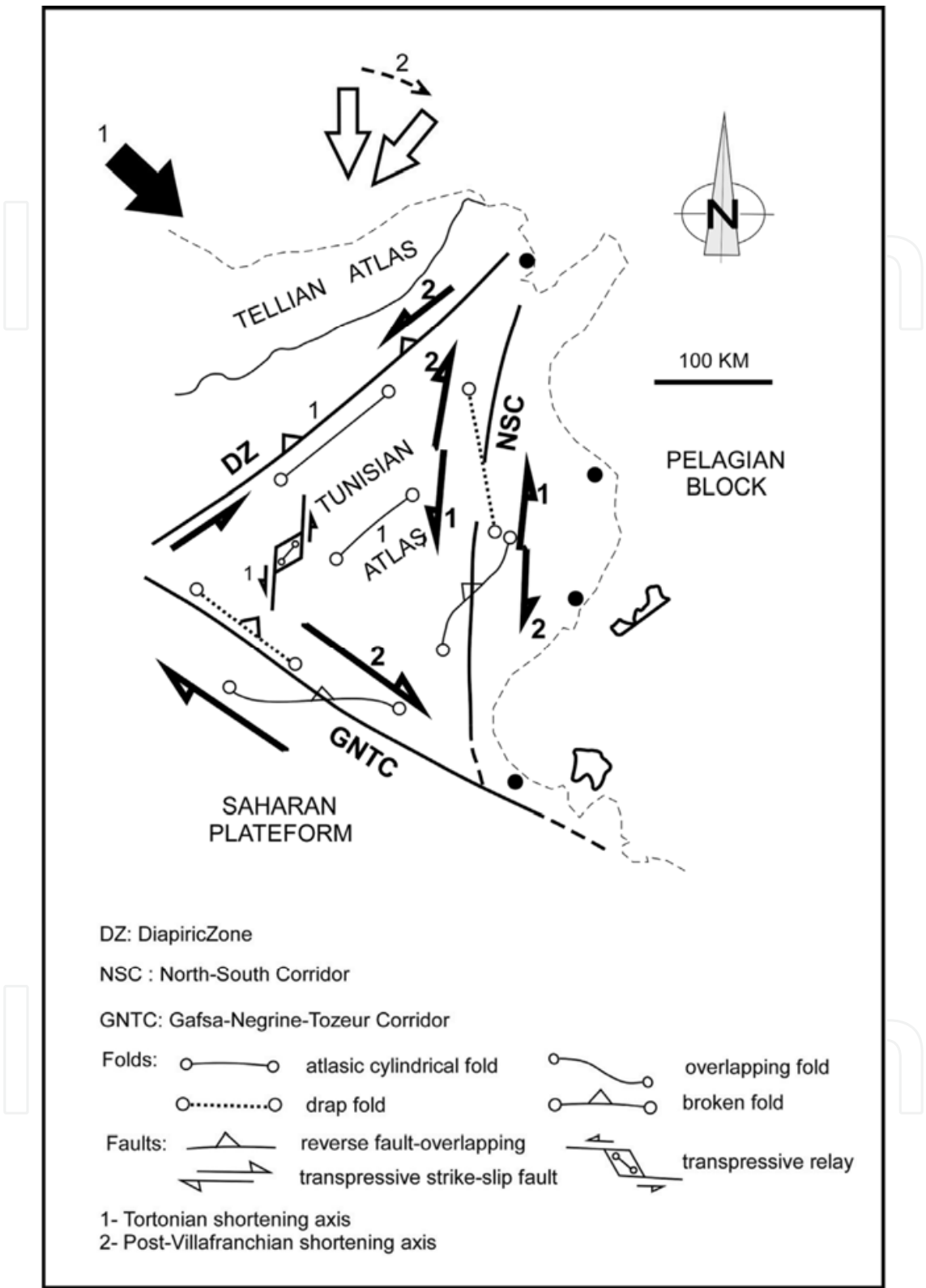


Fig. 11. Tectonic control of compressive structures by inherited structure

On the boundaries, the tectonic reactivation affects essentially vertical accidents (localized at the block limit) inducing with ancient sedimentary wedges a very superficial overthrust (Fig. 12).

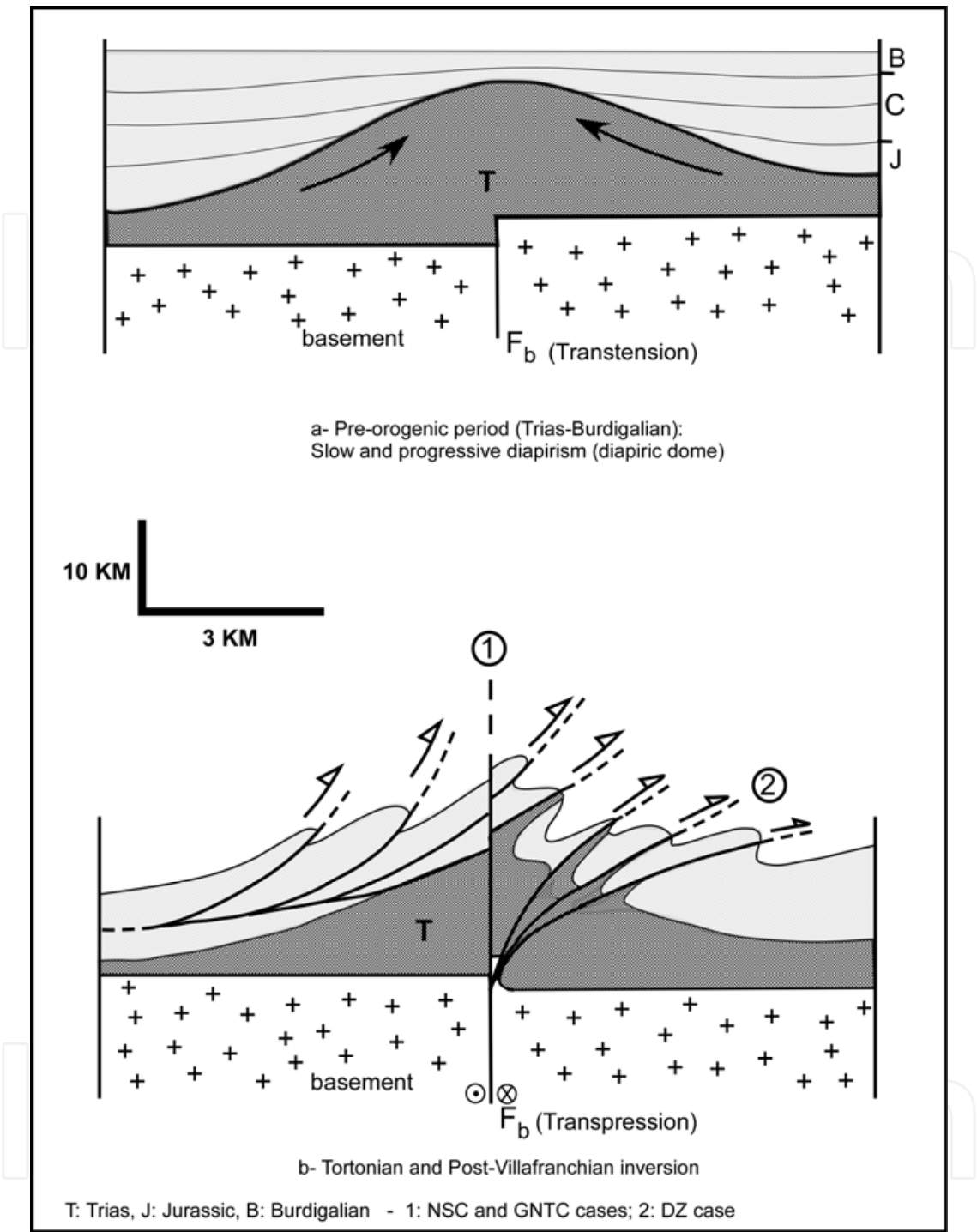


Fig. 12. Basement fault, diapiric dome, sedimentary wedges and superficial structures associated to structural inversion

Within the TB, the folds or broken-fold are, still, the superficial expressions of deep and vertical faults observed in tow major direction:

- The atlasic direction (SW-NE) corresponding to major folds very spaced with vast plain characterized by tabular structure;
- The N-S direction associated to a transpressive relay corresponding to ancient depocenters.

5. Conclusions

From the Triassic to the Middle Miocene, the Tunisian basin represents a typical intracontinental basin for the reason that there is no detectable evidence of ocean-floor accretion or a classical passive margin setting. Throughout its history, this basin shows a structure composed of blocks, all of which are incorporated into a main block (the Tunisian block: BT) of triangular form and bounded by continuously mobile shear corridors which thus result from polyphase deformation. The mobility of these corridors corresponds to the reactivation of inherited faults in an extensive or transtensive setting.

The changes in stress regime (or rotations), and hence the extension directions, are related to the existence of two sedimentary basins: the first in the North corresponds to a strike-slip margin (Western Tethys with numerous pull-apart basins), while the second, in the East, corresponds to the present-day Tunisian basin, which is developed in an oceanic setting on a passive-type margin (Mesogea), with predominance of the activity of one or the other of the basins at different times. Three major crises can be recognized, the first at the end of Jurassic, the second at the end of the Aptian (Soyer and Tricart, 1987; Rigane et al., 2010) and the last at the end of the Ypresian (Rigane et al., 1994; Gourmelen et al., 2000). This vertical tectonics is often characterized by abundant drape folds giving rise to extensional-fault related folding and strike-slip/ dip-slip fault geometry, creating frequent discordances that are always localized and linear.

The salt tectonic phenomena related to the Triassic are linear (diapir zone axis) or localized (tectonic node), form high zones during the basin evolution that accentuate the vertical tectonics associated with the extension and/ or transtension of blocks. The diapiric movements are slow and progressive, taking place from the Late Triassic until the Langhian, and inducing the formation of many sedimentary wedges on the dome flanks.

The folded chain resulting from the structural inversion of the Tunisian paleoblock and its boundaries show mainly SW-NE-trending folds since the Tortonian, in accord with the NW-SE major shortening direction. However, other folds are characterized by oblique axes compared to this shortening direction, which appear completely aberrant in relation to the two main folding phases: Tortonian (NW-SE) and post-Villafranchian (N-S). These axial trends can be interpreted in the context of an intracontinental chain where the inherited major vertical faults can only develop at the surface as drape folds in a transpressive regime. Finally, the Tunisian block has an eastern front that has been subsiding since Middle Miocene times, with SSW-NNE oriented depocentres on the edge of the NSC, but which follow an almost orthogonal NW-SE trend close to the Malta scarp. A renewed vertical inversion of wide extent thus affects the Tunisian block, in contrast to the Pelagian block, as a result of the present-day N-S compression.

6. References

- Abbès, Ch. (2004). Structurations et évolutions tectono-sédimentaires mésozoïques et cénozoïques, associés aux accidents reghmatiques, à la jonction des marges téthysienne et Nord-africaine (chaîne Nord-Sud, Tunisie centrale). Thèse Doctorat ès-Sciences. Univ. Tunis El Manar, 437p.
- Aissaoui, D. (1984). Les structures liées à l'accident sud-atlasique entre Biskra et le Jebel Manndra, Algérie, évolution géométrique et cinématique. Thèse 3^{ème} cycle, Univ. L. Pasteur, Strasbourg, 145p.

- Ben Ayed, N. (1980). Le rôle des décrochements E-W dans l'évolution structurale de l'Atlas tunisien. *C. R. somm. Soc. Géol. France*, Vol.1, pp.29-32
- Ben Ayed, N. (1986). Evolution tectonique de l'avant-pays de la chaîne alpine de Tunisie du début du Mésozoïque à l'Actuel. Thèse Doct. Ès-Sciences Naturelles, Univ. Paris Sud-Orsay, 286p.
- Ben Ayed, N.; Chekhma, H. & Gueddiche, M. (1997). La zonation des structures compressives et distensives de la Tunisie centrale et ses relations avec les décrochements. *C. R. Acad. Sci. Paris*, Vol.324, pp.485-490.
- Ben Ayed, N. & Viguier, C. (1981). Interprétation structurale de la Tunisie atlasique. *C. R. Acad. Sc.*, Paris, Vol.292, pp.1445-1448.
- Ben Ferjani A.; Burollet P.F. & Mejri F. (2006). Petroleum Geology of Tunisia. A Renewed Synthesis. *Entreprise Tunisienne d'Activités Pétrolières*, Mém. N°22.
- Biely, A.; Burollet, P.F. & Lajmi, T. (1974). Etude géodynamique de la Tunisie et des secteurs voisins de la méditerranée. *Notes Serv. Géol. Tunisie*, Vol.41, pp.23-38.
- Bishop, W.F. (1975). Geology of Tunisia and adjacent parts of Algeria and Libya. *AAPG Bulletin*, Vol.59, pp.413-450.
- Bismuth, H.; Boltenhagen, C.; Donze, P.; Le Fevre, J. & Saint-Marc, P. (1982). Etude sédimentologique et biostratigraphique du Crétacé moyen et supérieur du Jebel Semmama (Tunisie Centre Nord). *Cretaceous Research*, Vol.3, pp.171-185.
- Blondel, T.J.A. (1991). Les séries à tendance transgressive marine du Miocène inférieur à moyen de Tunisie centrale. Thèse Univ. Genève, n° 2469, Swiss, 409p.
- Boltenhagen, C. (1985). Paléogéographie du Crétacé moyen de la Tunisie centrale. *Proceedings of 1er Congrès Nat. Sc. Terre*, Tunis, 1981, 1, 97-114.
- Bouaziz, S. (1995). Etude de la tectonique cassante dans la plate-forme et l'Atlas sahariens (Tunisie méridionale) : évolution des pléochamps de contraintes et implications géodynamiques. Thèse Doc. Etat, Univ. Tunis II, 485p.
- Bouaziz, S.; Barrier, E.; Soussi M.; Turki, M.M. & Zouari, H. (2002). Tectonic evolution of the northern African margin in Tunisia from paleostress data sedimentary record. *Tectonophysics*, Vol.357, pp. 227-253.
- Boukadi, N.; Bédir, M. & Zargouni, F. (1998). Geometric and kinematic analyses of pull-apart basins produced by en echelon strike-slip of Gafsa fault systems (Southern Tunisia). *African Geoscience Review*, Vol.5, pp. 327-338.
- Brahim, N. & Mercier, E., (2007). Commentaire à la note intitulée « Mise en évidence en subsurface d'événements compressifs Eocène moyen-supérieur en Tunisie orientale (sahel) : généralité de la phase atlasique en Afrique du Nord de Sami Khomsi, Mourad Bédir, Mohamed Soussi, Mohamed Ghazi Ben Jemia et Kmar Ben Ismail-Lattrache [C. R. Geoscience 338 (2006) 41-49]. *C. R. Geoscience*, Vol.338, pp. 41-49.
- Burollet, P.F. (1956). Contribution à l'étude stratigraphique de la Tunisie centrale. *Ann. Mines Géol. Tunis*, 18, 350p.
- Burollet, P.F. (1991). Structures and tectonics of Tunisia. *Tectonophysics*, Vol.195, pp. 359-369.
- Burollet, P.F.; Mejri, F. & Ben Kilani, H. (2000). What about the deep structure of Tunisia? *Proceedings of 7th Tunisian Petroleum Exploration and Production Conference*, Tunis, April, 167-178.
- Castany, G. (1951). Etude géologique de l'Atlas tunisien oriental. *Ann. Min. et Géol.*, Tunisie, 8. Thèse Doct. Ès-Sc., Paris

- Dercourt, J.; Zonenshain, L.P. & Ricou, L.E. (1985). Présentation de 9 cartes paléogéographiques au 1/ 20 000 000 s'étendant de l'Atlantique au Pamir pour la période du Lias à l'Actuel. *Bull. Soc. Géol. France*, Vol.8, pp. 635-652.
- Dewey, J.F.; Helman, M.L.; Turko, E.; Hutton, D.H.W. & Knott, S.D. (1989). Kinematics of the western Mediterranean. *Geol. Soc. Spec. Publ.*, Vol.45, pp.265-83.
- El Ghali, A.; Bobier, C. & Ben Ayed, N. (2003). Rôle du système de failles E-W dans l'évolution géodynamique de l'avant-pays de la chaîne alpine de Tunisie. Exemple de l'accident de Sbiba-Chérichira en Tunisie centrale. *Bull. Soc. Géol. France*, Vol.174, pp.373-381.
- European Geotraverse, (1992). The EGT'85 seismic experiment: a reconnaissance of the deep structure. *Tectonophysics*, Vol.207, pp. 245-267.
- Feki, M.; Rigane, A. & Gourmelen, C. (2005). Tectonique distensive fini-aptienne au Jebel El Hamra de Kasserine (Tunisie centro-occidentale). *Notes Serv. Géol. Tunisie*, Vol.73, pp.77-89.
- Frizon de Lamotte, D.; Michard, A. & Saddiqi, O. (2006). Quelques développements récents sur la géodynamique du Maghreb. *C. R. Geoscience*, Vol.336, pp.1-10.
- Gabtni, H.; Jallouli, C.; Mickus, K.; Zouari, H. & Turki, M.M. (2005). Geophysical constraints on the location and nature of the North Saharan Flexure in Southern Tunisia. *Pure appl. Geophys.* Vol.162, pp.2051-2069.
- Gourmelen, C. (1984). Serrage polyphasé de paléostructures distensives dans l'Axe Nord-Sud tunisien : le segment Bou Zer-Rhéouis. Thèse 3^{ème} cycle, Grenoble, 216p.
- Gourmelen, C. & Tricart, P. (1985). Nouvelle interprétation de l'Axe Nord-Sud en Tunisie centrale : le chaînon du Bou Zer. *Terra Cognita*, EUG, Strasbourg, Vol.5, pp.258-259.
- Gourmelen, C.; Ouali, J. & Tricart, P. (1989). Les blocs basculés mésozoïques dans l'Axe nord-sud de Tunisie centrale: importance et signification. *Bull. Soc. Géol. France*, Vol.8, pp.117-122.
- Gourmelen, C.; Rigane, A.; Broquet, P.; Truillet, R. & Aïte, M.R. (2000). Caractères structuraux et dynamiques d'un bassin en transtension : la plate-forme tunisienne à l'Yprésien terminal. *Bull. Soc. Géol. France*, Vol.171, pp.559-568.
- Guiraud, R. & Maurin, J.C. (1991). Le rifting au Crétacé inférieur: synthèse structurale, mise en évidence de deux étapes dans la genèse des bassins, relations avec les couvertures océaniques péri-africaines. *Bull. Soc. Géol. France*, Vol.162, pp.811– 823.
- Guiraud, R. and Maurin, J.C. (1992). Early Cretaceous rifts of western and central Africa: an overview. *Tectonophysics*, Vol.213, pp.153–168.
- Guiraud, R.; Bosworth, W.; Thierry, J. & Delplanque, A. (2005). Phanerozoic geological evolution of Northern and Central Africa: an overview. *J African Earth Sci.* Vol.43, pp.83–143.
- Hlaiem, A., (1999). Halokinesis and structural evolution of the major features in eastern and southern Atlas. *Tectonophysics*, Vol.306, pp79-95.
- Jauzein, A. & Rouvier, H. (1965). Sur les formations allochtones de Kroumirie (Tunisie septentrionale). *C. R. somm. Soc. Géol.*, Vol.2, pp.36-38.
- Jauzein, A. (1967). Contribution à l'étude géologique des confins de la bordure tunisienne (Tunisie septentrionale). *Ann. Mines et géol.*, Tunisie, Vol.22, 475p.
- Kamoun, F.; Peybernès, B. & Fauré P., (1999). Evolution paléogéographique de la Tunisie saharienne et atlasique au cours du Jurassique. *C. R. Acad. Sciences, Paris*, Vol.328, pp.547-552.

- Khessibi, M., 1978. Etude géologique du secteur Maknassy-Mezzouna et du Jebel Kebar (Tunisie centrale). - Thèse Univ. Claude Bernard, Lyon, 175p.
- Khomsi, S.; Bedir, M.; Soussi, M.; Ben Jemia, M.G. & Ben Ismail-Lattrache, K. (2006). Mise en évidence en subsurface d'événements compressifs Eocène moyen-supérieur en Tunisie orientale (Sahel) : généralités de la phase atlasique en Afrique du Nord. *C. R. Géoscience*, Vol.338, pp. 41-49.
- Lüning, S.; Kolonic, S.; Belhaj, E.M.; Belhaj, Z.; Cota, L.; Baric, G. & Wagner, T. (2004). Integrated depositional model for the Cenomanian-Turonian organic-rich strata in North Africa. *Earth-Science Reviews*, Vol.64, pp.51-117.
- Martinez, C., & Truillet, R. (1987). Evolution paléogéographique et structurale de la Tunisie.- *Mém. Soc. Géol. It.*, Vol.38, pp.35-45.
- Midassi, M., (1982). Regional gravity of Tunisia. Masters Thesis, Univ. South Carolina. USA, 125p.
- Morelli, C. & Nicolih, R. (1990). A cross section of the lithosphere along the European Geotraverse Southern Segment (from the Alps to Tunisia). *Tectonophysics*, Vol.176, pp.229-243.
- M'Rabet, A. (1981). Stratigraphie, sédimentation et diagenèse carbonatée des séries du Crétacé inférieur de Tunisie centrale. Thèse Doct. Ès Sciences, Univ. Paris Sud Orsay, 540p.
- Ould Bagga, M.A.; Saadi, A. & Mercier, E. (2006). La "zone des nappes" de Tunisie: une marge méso-cénozoïque en blocs basculés modérément inversé (région de Tabarka/ Jendouba ; Tunisie nord-occidentale). *Bull. Soc. Géol. France*, Vol.177, pp.145-154.
- Perthuisot, V. (1978). Dynamique et pétrogenèse des extrusions triasiques en Tunisie septentrionale. Thèse Doct. Ès-Sc. Nat., Ecole Norm. Sup., Paris, 312p.
- Pervinquière, L. (1903). Etude géologique de la Tunisie centrale. In: F.R. DE Rudeval. (Ed.), Thèse doct. es-sciences, Paris. 360p.
- Piqué, A.; Ait Brahim, L.; Ait Ouali, R.; Amrhar, M.; Charroud, F.; Gourmelen, C.; Laville, E.; Rekhiss, F. & Tricart, P. (1998). Evolution structurale des domaines atlasiques du Maghreb au Méso-Cénozoïque ; le rôle des structures héritées dans la déformation du domaine atlasique de l'Afrique du Nord. *Bull. Soc. Géol. France*, Vol.169, pp.797-810.
- Piqué, A.; Tricart, P.; Guiraud, R.; Laville, E.; Bouaziz, S.; Amrhar, M. & Ait Ouali, R. (2002). The Mesozoic-Cenozoic Atlas belt (North Africa): an overview. *Geodinamica Acta*, Vol.15, pp.185-208.
- Rabhi, M. & Ben Ayed, N. (1990). Mise en évidence d'une tectonique compressive d'âge Aptien supérieur en Tunisie centrale. *Notes Serv. Géol. Tunisie*, Vol.56, pp.91-98.
- Richert, J.P. (1971). Mise en évidence de quatre phases tectoniques successives en Tunisie. *Notes Serv. Géol. Tunisie*, Vol.34, pp.115-125.
- Ricou, L.E. (1994). Tethys reconstructed: plates Continental fragments and their boundaries since 260 Ma from Central America to South-Eastern Asia. *Geodinamica Acta*, Vol.7, pp.160-218.
- Rigane, A. (1991). Les calcaires de l'Yprésien en Tunisie centro-septentrionale : cartographie, cinématique et dynamique des structures. Thèse d'Univ. Franche-Comté, 236, 214p.

- Rigane, A.; Gourmelen, C.; Broquet, P. & Truillet, R., (1994). Originalité des phénomènes tectoniques synsédimentaires fini-yprésiens en Tunisie centro-septentrionale (région de Kairouan). *Bull. Soc. Géol. France*, Vol.156, pp.27-35.
- Rigane, A.; Feki, M.; Gourmelen, C. & Montacer, M. (2010). The « Aptian Crisis » of the South-Tethyan margin: New tectonic data in Tunisia. *Journal of African Earth Sciences*, Vol.57, pp.360-366.
- Rigane, A. & Gourmelen, C. (submitted, to *Journal of African Earth Sciences*, under revision). Inverted intracontinental Basin and Vertical Tectonics: The Saharan Atlas in Tunisia.
- Rouvier, H. (1977). Géologie de l'extrême nord tunisien : tectoniques et paléogéographie superposées à l'extrémité orientale de la chaîne nord maghrébine. Thèse d'Etat, Université Paris-VI, 898 p.
- Schettino, A. & Scotese, C. (2002). Global kinematic constraints to the tectonic history of the Mediterranean region and surrounding areas during the Jurassic and Cretaceous. In: In: Rosenbaum, G. and Lister, G. S. 2002. Reconstruction of the evolution of the Alpine-Himalayan Orogen. *Journal Virtual Explorer*, Vol.8, pp.148-168
- Soussi, M. (2002). Le Jurassique de la Tunisie atlasique : stratigraphie, dynamique sédimentaire, paléogéographie et intérêt pétrolier. Ed. Villeurbanne : Univ. Claude Bernard-UFR des Sciences de la Terre, 363p.
- Soyer C. & Tricart, P. (1987). La crise aptienne en Tunisie centrale : approche paléostructurale aux confins de l'Atlas et de l' « axe Nord – Sud », C. R. Acad. Sc., Paris, Vol.305, pp.301-305.
- Stampfli, G.M.; Borel, G.; R., Marchant, R. & Mosar J (2002). Western Alps geological constraints on western Tethyan reconstructions. In: Rosenbaum, G. and Lister, G. S. 2002. Reconstruction of the evolution of the Alpine-Himalayan Orogen. *Journal Virtual Explorer*, Vol.8, pp.77-106.
- Turki, M.M. (1984). L'Ousselat-Boudabbous : un exemple de bassin subsident sénonien supérieur-éocène inférieur. Implication sur la notion d' « axe Nord-Sud » (Atlas tunisien). 10^{ème} RAST Bordeaux, p. 529.
- Turki, M.M. (1985). Polycinématique et contrôle sédimentaire associé sur la cicatrice Zaghuan-Nebhana. Thèse ès-Sc., Univ. Tunis, Revue Sc. Terre, édit. INRST, Tunis, 1988, 262p.
- Yaich, C. (1984). Etude géologique des chaînons du Chérahil et du Khechem El Artsouma (Tunisie centrale). Liaison avec les structures profondes des plaines adjacentes. Thèse 3^{ème} cycle. Univ. Franche-Comté. Besançon, 165p.
- Yaich, C. (1997). Dynamique sédimentaire, eustatisme et tectonique Durant l'Oligo-Miocène en Tunisie centro-septentrionale. Thèse d'Etat, Univ. de Tunis, 479p.
- Zaier, A.; Béji-Sassi, A. & Moody, R.T.J (1998). Basin evolution and deposition during the early Paleogene in Tunisia. *Geological Society*, London, Special Publication, Vol.132, pp.375-393.
- Zargouni, F. (1975). Etude géologique de la chaîne de Lansarine (région de Tébourba, Atlas tunisien). Thèse de 3^{ème} cycle. Univ. Pierre et Marie-Curie (Paris 6).
- Zargouni, F. (1985). Tectonique de l'Atlas méridional de Tunisie, évolution géométrique et cinématique des structures en zone de cisaillement. Thèse Doct. ès-Sc., Univ. Louis Pasteur (Strasbourg). Ed. Rev. Sc. Terre, INRST, Tunisie.

- Zargouni, F. (1986). Style tectonique de l'Atlas méridional de Tunisie. Evolution géométrique et cinématique des structures en zone de cisaillement. Thèse es Sciences, Univ. Louis Pasteur Strasbourg. Revue Sciences Terre. Ed. Centre Sciences, Institut National Recherches Scientifiques Techniques, Tunisie (1985), 304p.
- Zouaghi, T.; Bedir, M. & Inoubli, M.H. (2005). 2D Seismic interpretation of strike-slip faulting, salt tectonics, and Cretaceous unconformities, Atlas Mountains, central Tunisia. *Journal of African Earth Sciences*, Vol.43, pp.464-486.
- Zouari, H.; Turki, M.M.; Delteil, J & Stephan, JF. (1999). Tectonique transtensive de la paléomarge tunisienne au cours de l'Aptien-Campanien. *Bull. Soc. Géol. France*, Vol.170, pp.295-301.

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Ocean closure involves a variety of converging tectonic processes that reshape shrinking basins, their adjacent margins and the entire earth underneath. Following continental breakup, margin formation and sediment accumulation, tectonics normally relaxes and the margins become passive for millions of years. However, when final convergence is at the gate, the passive days of any ocean and its margins are over or soon will be. The fate of the Mediterranean and Persian Gulf is seemingly known beforehand, as they are nestled in the midst of Africa-Arabia plate convergence with Eurasia. Over millions of years through the Cenozoic era they progressively shriveled, leaving only a glimpse of the Tethys Ocean. Eventually, the basins will adhere to the Alpine-Himalaya orogen and dissipate. This book focuses on a unique stage in the ocean closure process, when significant convergence already induced major deformations, yet the inter-plate basins and margins still record the geological history.

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