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The Albian tectonic "crisis" in Central Tunisia: Nature and chronology of the deformations

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A B S T R A C T

The Mid-Cretaceous tectonic "crisis" is a classical feature of the tectono-sedimentary evolution of Tunisia. A reappraisal of synsedimentary deformation observed in the Tajerouine and Kasserine areas shows that deformation began in the earliest Albian, increased during the Early Albian, and culminated in the Middle Albian. Late Albian deposits overly, locally with a strong angular unconformity, Aptian to Early Albian sediments. In the southern part of the studied area, fault tectonics and tilted blocks dominate, whereas in the northern area, the occurrence of slumps and olistoliths suggests deformation related to incipient salt movements at depth. These new chronological constraints suggest that this tectonic event is most probably related to the final opening of the Atlantic Ocean at equatorial latitudes.

1. Introduction

The Mid-Cretaceous tectonic phase is a classical feature of the geological evolution of Central Tunisia and Eastern Algeria, where it was often ascribed to the Aptian ("Aptian crisis" of Soyer and Tricart, 1987; Rigane et al., 2010; Zouaghi et al., 2011). It is usually interpreted as an extensional tectonic phase related, either to the rifting of the Equatorial Atlantic Ocean, or to the rifting of the Eastern Mediterranean ("Mesogean") Ocean (Burollet, 1956; Soyer and Tricart, 1987; Martinez et al., 1991; Barrier et al., 1993; Piqué et al., 1998; Bouaziz et al., 2002; Guiraud et al., 2005; Ouali, 2007). It provoked the end of the Aptian carbonate shelf sedimentation, the emergence of Central Tunisia, and the regional unconformity of Late Albian beds upon Jurassic to Early Albian deposits.

However, few studies document the nature, distribution and accurate chronology of this deformation phase, which are important for the regional interpretation of this tectonic event. The aim of this contribution is to present accurately dated and well documented examples of synsedimentary deformation, in order to make their regional or geodynamic interpretation more reliable. For this purpose, we shall discuss some synsedimentary deformation observed in well dated Late Aptian–Albian deposits, between 35° and 36° lat. N. in western Central Tunisia, in the light of new stratigraphic data obtained recently (Chihaoui et al., 2010; Latil, 2011).

2. Geological setting

Tunisia is part of the southern Tethyan margin, which is marked by Late Triassic to Middle Jurassic rifting, a middle Cretaceous extensional tectonic event, and by compressional tectonic events from the Late Cretaceous onwards, which culminated with Mid-Late Eocene and Plio-Pleistocene compressional phases, related to the Alpine orogeny (Burollet, 1956; Bishop, 1975; Masse et al., 1995; Souquet et al., 1997; Frizon de Lamotte et al., 2000, 2011).

In the Cretaceous, the passive margin of Tunisia is classically divided into three main paleogeographic domains (Fournié and Pacaud, 1973; Zghal and Arnaud-Vanneau, 2005; Fig. 1).

- To the South, the stable Saharan epicratonic platform is covered by thin, mainly clastic, continental to shallow marine deposits, which are virtually undeformed.
- The Central Tunisian platform is marked by shallow marine, first siliciclastic, then calcareous deposits. The Central Tunisian platform is bounded to the north by the present-day NE–SW

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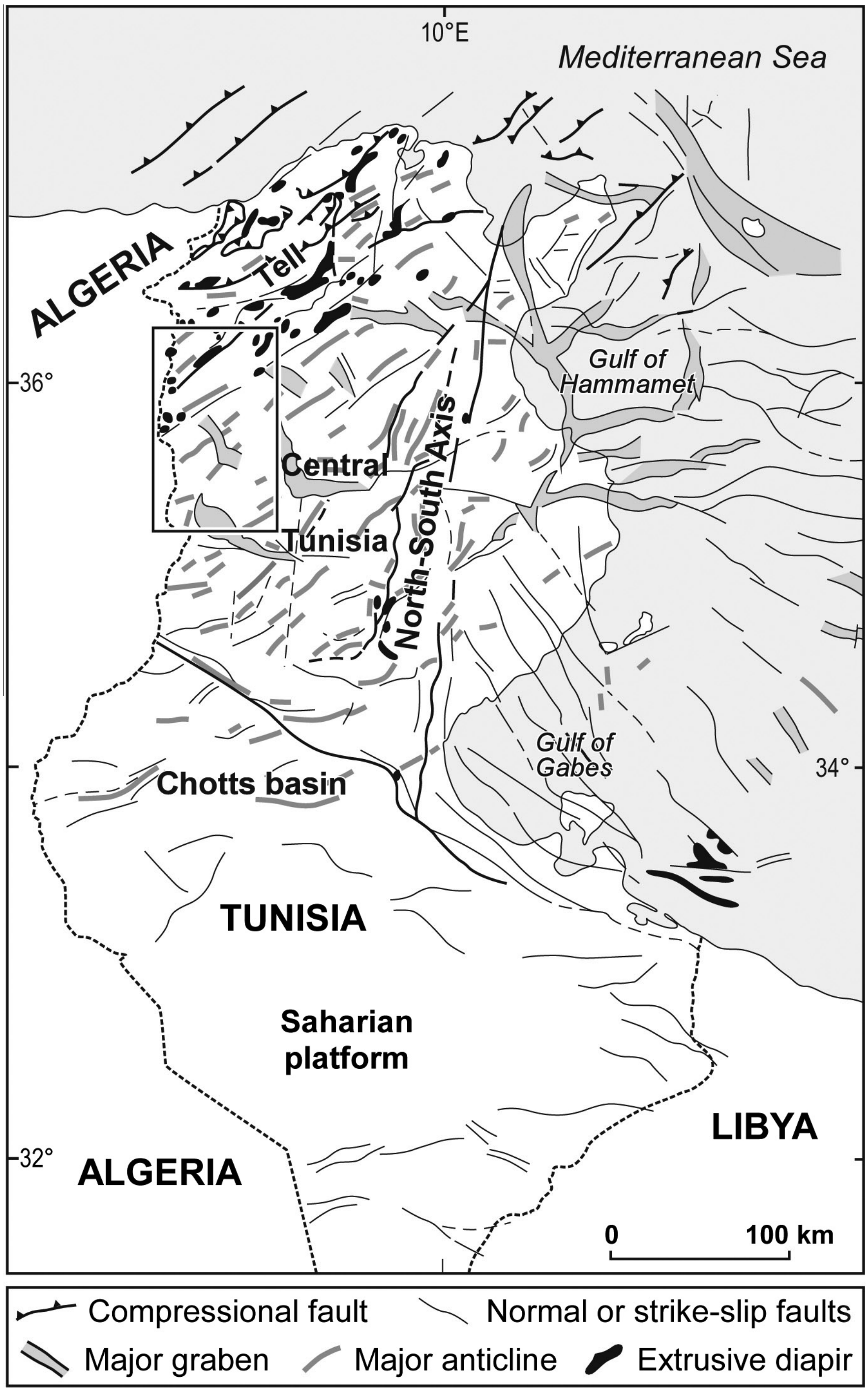

Fig. 1. Structural sketch of Tunisia (after Klett, 2001), and location of Fig. 2.

trending thrust and fold belt that corresponds to the Tell chain, and includes the southern Chott depression that separates the Saharan and Central Tunisian platforms. It is presently marked by NW-trending folds and by SW-trending grabens, both of Neogene age.
- The North Tunisian basin received thick marly deposits during most of the Cretaceous, and is presently folded to form the Tunisian Tell, marked by numerous thrusts and diapirs (Fig. 1).

The study area is comprised between Jebel Harraba to the Northwest, Jebel Jerissa and Bou el Haneche to the East, and Jebel El Hamra to the South. It comprises Jebel Harraba, Guern Halfaya, Henchir el Goussa, and Jebel Hameima, Slata, Jerissa, Bou el Haneche, Ajered and El Hamra (Fig. 2).

3. Stratigraphy

The Aptian–Albian stratigraphy of Central Tunisia has been first established by Burollet (1956) (see also Dubourdieu, 1956) and then refined by Bismuth (1973), Bismuth et al. (1981, 1982), M'rabet (1981) and M'rabet et al. (1995). According to more recent works (Zghal, 1994; Zghal et al., 1997; Jaillard et al., 2005; Robaszynski et al., 2008; Chihaoui et al., 2010; Latil, 2011), the following nomenclature will be adopted.

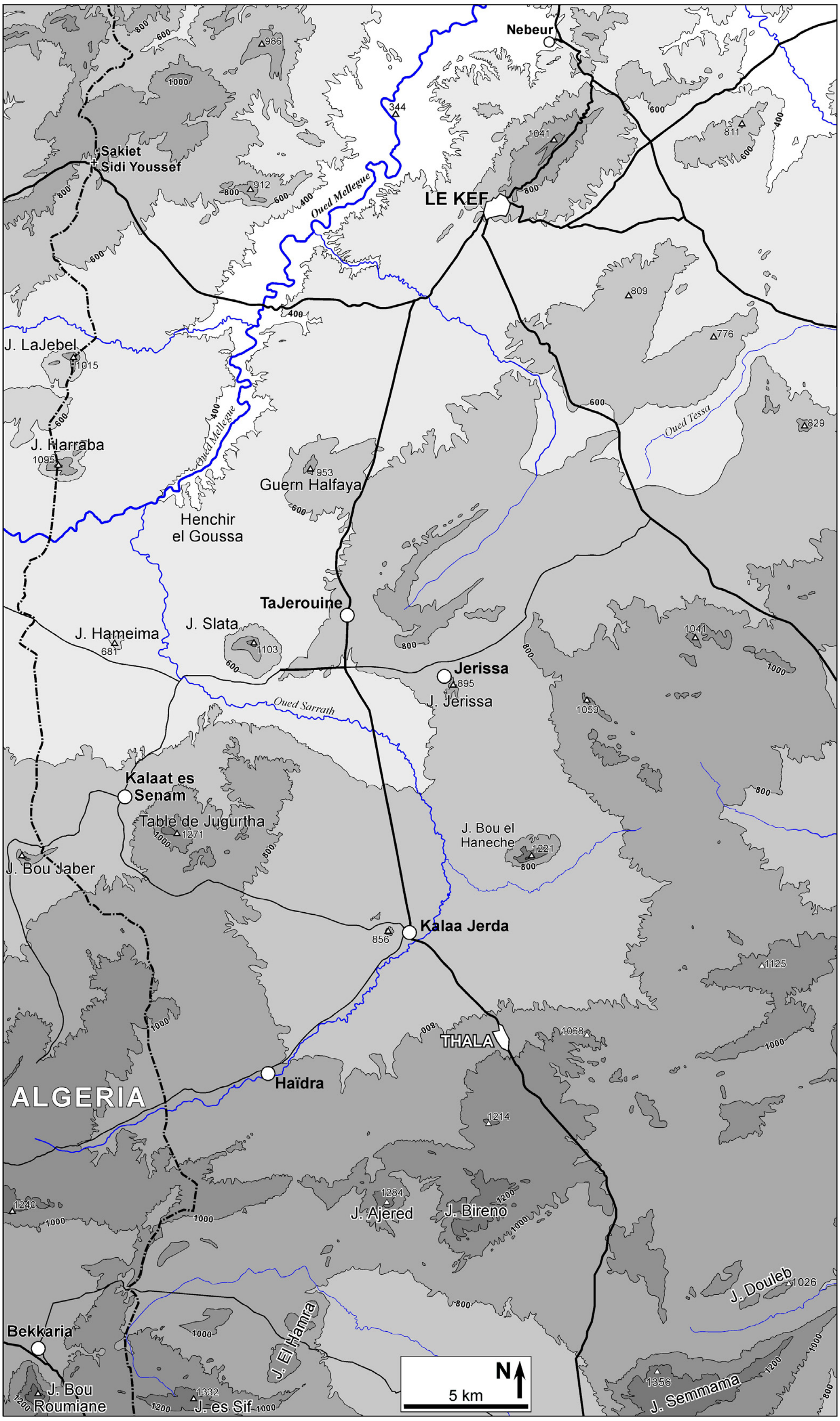

Fig. 2. Location map of the main study areas (location on Fig. 1).

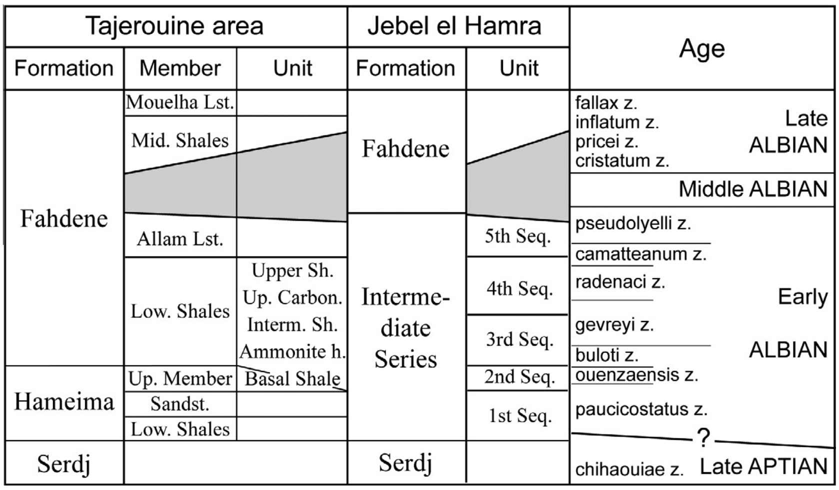

Fig. 3. Stratigraphy of the Tajerouine area and Jebel El Hamra (according to Chihaoui, 2009; Chihaoui et al., 2010; Latil, 2011).

The Late Aptian Serdj Formation is composed of massive limestones and dolostones, which form steep reliefs. To the North and Northwest, these Aptian rocks form reliefs that dominate the surrounding plains, mostly made of Albian to Late Cretaceous marls and covered by recent deposits, whereas to the South and Southeast, they are surrounded by Cenomanian and Turonian limestone cliffs.

Where present, the Hameima Formation overlies the Serdj Formation, usually in conformable contact. It is composed of marls, limestone and sandstone beds, and can be divided into three members. The Lower Member is mostly composed of marls and limestones, locally dolomitised. The Middle Member is made of sandstones alternating with sandy to silty marls. The Upper Member is mostly calcareous, and wedges out toward the Northwest (Hameima, El Goussa), where shales of the Fahdene Formation directly overly the Middle Member of the Hameima Formation. The ammonite fauna indicates an earliest Albian age for the Hameima Formation (L. tardefurcata zone; Chihaoui et al., 2010; Latil, 2011).

The Fahdene Formation is mostly made of shaly marls. Burollet (1956) divided it, from base to top, into the Lower Shales, the Allam Limestones, the Middle Shales, the Mouelha Limestones, and the Upper Shales (Fig. 3). We will deal only with the Lower Shales, the Allam Limestones and the base of the Middle Shales.

According to Chihaoui et al. (2010), the Lower Shales are dominated by shales and marls, and comprise several units, which will not be described here. The base of the Lower Shales ("Basal Shales") is still of earliest Albian age (L. tardefurcata zone), while most of the unit is of Early Albian age (D. mammillatum superzone *p.p.*) (Fig. 3).

The "Allam limestones" are made of alternating dark shales and marly laminated limestones. Their lower part is of late Early Albian age (D. mammillatum superzone), while the upper half part is of late Early Albian age (L. pseudolyelli zone, Chihaoui et al., 2010).

The base of the Middle Shales, of Late Albian age, is diachronous, its age being between the D. cristatum zone to the North (Hameima) and the M. pricei or even the M. inflatum zone to the South (e.g. El Hamra). Therefore, the Allam Limestones and the Middle Shales are separated by a long-lasting hiatus that spans the Middle Albian and locally a significant part of the Late Albian (Fig. 3).

Farther South, in Jebel El Hamra, this lithostratigraphic nomenclature cannot be used. Overlying the Late Aptian Serdj Formation, El Euchi (1993) defined an "intermediate series", which is overlain by the Fahdene Formation. The "intermediate series" can be divided into 5 sedimentary sequences (Chihaoui, 2009; Fig. 3).

The 1st sequence (a few metres) is made of pale grey marls capped by a massive dolomite bed, karstified at the top. The 2nd sequence (3–10 m) is composed of green shales overlain by an orange-coloured dolomitic bed, also karstified. For both sequences, scarce ammonites suggest an earliest Albian age (L. tardefurcata zone).

The 3rd sequence (8–15 m) comprises black shales marked by a conspicuous yellow marly bed, and capped by an orbitolinid-rich massive limestone bed, karstified at the top. Several ammonites indicate an Early Albian age (L. tardefurcata zone or D. mammillatum superzone). The 4th sequence (0.5–25 m) is made of fossiliferous marls with limestone beds. The ammonite fauna indicates an Early Albian age (upper part of D. mammillatum superzone). Finally, the 5th sequence (15–35 m) is lithologically comparable to the 4th one. The occurrence of various specimens of *Lyelliceras pseudolyelli* indicates a late Early Albian age (L. pseudolyelli zone).

The Fahdene Formation begins with a sandy, glauconitic and phosphatic condensed layer, which contains clasts, and ammonites of both Middle and Late Albian age. According to the locality, the age of the overlying marls of the basal Fahdene Formation are of early (not earliest) to middle Late Albian age (M. pricei to M. inflatum zone).

4. The Late Aptian–Albian synsedimentary deformations in Central Tunisia

Based on the establishment of a detailed regional stratigraphic chart (Chihaoui et al., 2010; Latil, 2011), most of the observed synsedimentary deformations can be precisely dated, and will be described in a stratigraphic order.

4.1. Around the Aptian–Albian boundary

Scarce tectonic deformations has been observed between the Late Aptian Serdj and the Early Albian Hameima Formations.

Southeast of Jebel Harraba (Sidi Embarka section, Dubourdieu, 1956), the thin, uppermost reefal limestone bed of the Serdj Formation is unconformably overlain by the Hameima Formation (Fig. 4). This pattern suggests that the northeastern part of the Late Aptian Serdj limestone had been slightly uplifted before the earliest Albian, possibly because of deep motions of Triassic evaporites that presently crop out as a diapir East of the area (Dubourdieu, 1956; Fig. 4). The eastern tip of the uppermost limestone bed of the Serdj Formation is affected by small scale normal faults indicating a lowering of the southwestern compartments (Fig. 4), consis-

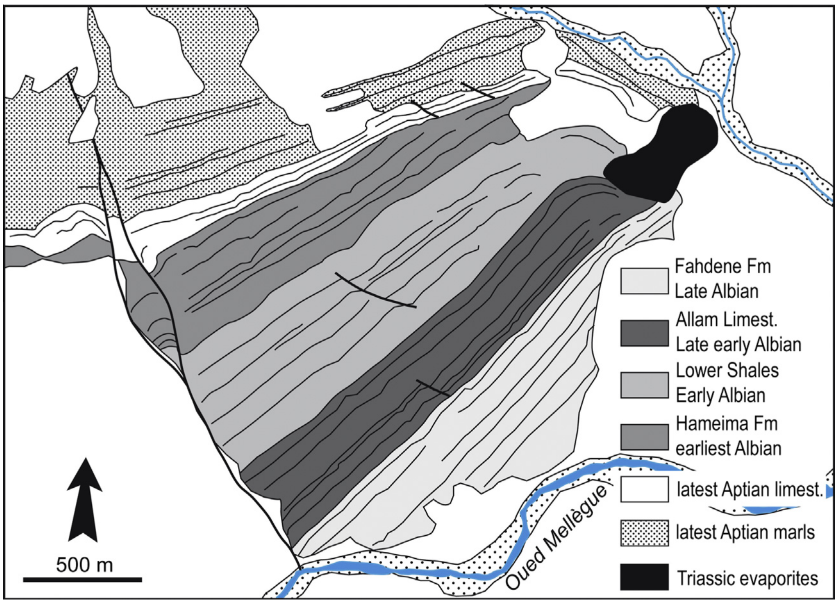

Fig. 4. Geological map of the Sidi Embarka outcrop, SW of Jebel Harraba (modified from Dubourdieu, 1956). Note the onlap of the base of the earliest Albian Hameima Fm onto the Late Aptian Serdj Fm.

tent with uplift of eastern areas. Therefore, this slight unconformity is more likely due to an incipient halokinetic activity, rather than to the progradation of the marly deposits of the Hameima Formation.

At Jebel Jerissa, a deep paleovalley incises the uppermost bed of the Serdj Formation (Chihaoui, 2009). Although this kind of structure is commonly observed in emergent sequence boundaries, it may have been enhanced by a slight local tectonic uplift.

4.2. Lower Hameima Formation (L. tardefurcata zone p.p.)

The lower part of the Hameima Formation exhibits few indications of smooth tectonic movements.

Thin beds of quartz-rich sandstones are locally observed near the base of the Hameima Formation (Jebel Hameima and Jerissa), which suggests that erosion affected, either remote areas floored by crystalline basement, or mesozoic clastic rocks.

At Jebel Bou El Haneche, the first minor sequence of the Hameima Formation is represented by only 0–0.5 m of dark, orbitolinid-rich limestones, while the overlying sequence overlaps westwards onto the top of the Serdj Formation, and thins out in the same direction (Fig. 5). This disposition indicates that the western part of this massif underwent a slight uplift around the Aptian–Albian boundary.

In Jebel Slata, Jerissa and Bou El Haneche, karstic cracks and caves that mark the top of the upper depositional sequence of the Lower Hameima Formation are clearly driven by small-scale normal faults, the offset of which does not exceed 1 m.

Finally, small-scale, fan shaped, synsedimentary angular unconformities are observed in the Lower Hameima Formation of the northwestern part of Jebel Slata, which suggest a slight uplift of the northwestern part of the area (Fig. 6). Since neither breccias nor coeval faulting are observed in the neighbourhood, this feature is interpreted as resulting from a progressive tilt movement.

4.3. Upper Hameima Formation (L. tardefurcata zone p.p.)

Most authors agree that the source of the Hameima sandstones ("Clansayes Sandstones" of Vila et al., 2001) was located Southwest of Central Tunisia, probably in southern Algeria (Burollet, 1956; Dubourdieu, 1956; Masse and Thieuloy, 1979; Vila, 1980). Therefore, this detrital influx does not provide information on the tectonic behaviour of the study area.

At a regional scale, the area located Northwest of Tajerouine (El Goussa, Hameima, Slata, Fig. 2) exhibits a reduced upper Hameima Formation (0–8 m), while the southeastern sections (Jerissa, Bou El Haneche), present a thicker sequence (15–20 m). This suggests that the Tajerouine region was more subsident to the Southeast at that

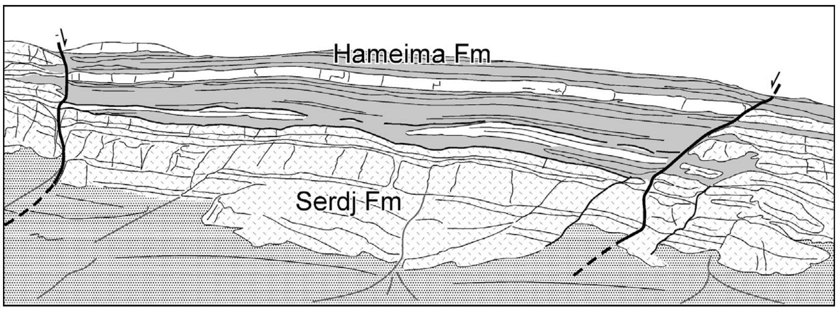

Fig. 5. Pos Albian graben preserving the Hameima Formation in Jebel Boulhaneche. The lowermost beds of the Hameima Formation onlap the top of the Serdj Formation to the West (left).

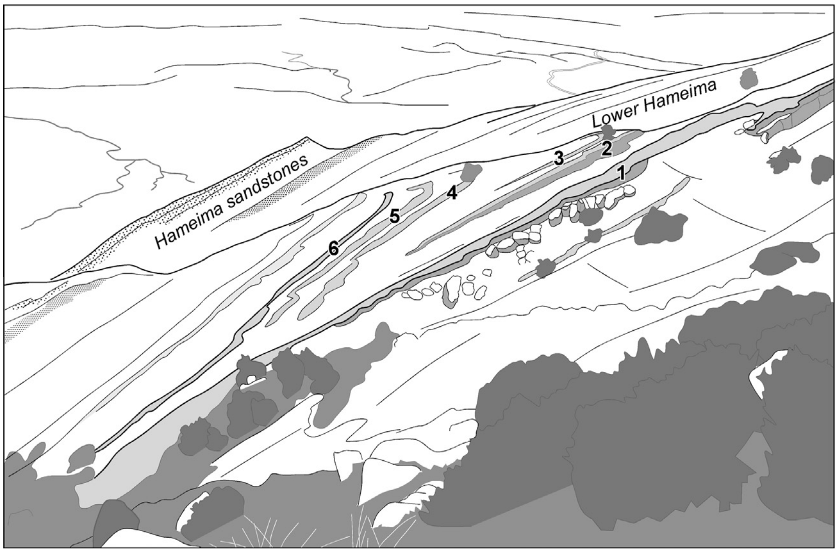

Fig. 6. Synsedimentary progressive unconformity (beds 1–6) in the Lower Hameima Formation (earliest Albian), observed in the northwestern part of Jebel Slata. Thickness between beds 1 and 6 evolves from about 10 m to the right, to about 2 m to the left; beds 1 and 2 deep 30–35° to the NW, whereas beds 5 and 6 deep 40–45° to the NW.

time, and therefore, the area was relatively uplifted to the Northwest. At a smaller scale, Chihaoui (2009) described an incised valley at the base of the Upper Hameima Formation in Jebel Slata. Deposits that infill this paleovalley were subsequently deeply karstified. This observation is consistent with the interpretation of an uplifted area located west of Tajerouine.

On the other hand, small scale synsedimentary normal faults, with offsets of about 1 m, have been observed near the top of the Hameima Formation in Jebel Jerissa and Bou El Haneche. The play of these faults is associated with soft-sediment deformation, which indicates that deformation took place before lithification was completed. In Jebel Jerissa, these faults provoked a slight angular unconformity beneath the last minor sequence of the Hameima Formation, the base of which is marked by reworked limestone clasts.

In summary, synsedimentary deformation of earliest Albian age is rather smooth, and mainly consists in extensional structures, possibly associated with incipient diapir movements in the Tajerouine area.

4.4. Fahdene Formation: Lower Shales (*D. mammillatum superzone*)

In Henchir El Goussa, the lowermost part of the Fahdene Formation is marked by large scale slumps, that caused slight angular unconformities and thickness variations. Note that, a few kilometres from El Goussa, southwest of Guern Halfaya, Vila et al. (1998) proposed that a "salt glacier" was emplaced during the Albian. Although we did not find this "salt glacier" the observed deformations at El Goussa are consistent with the creation of slopes related to incipient, large scale halokinetic movements.

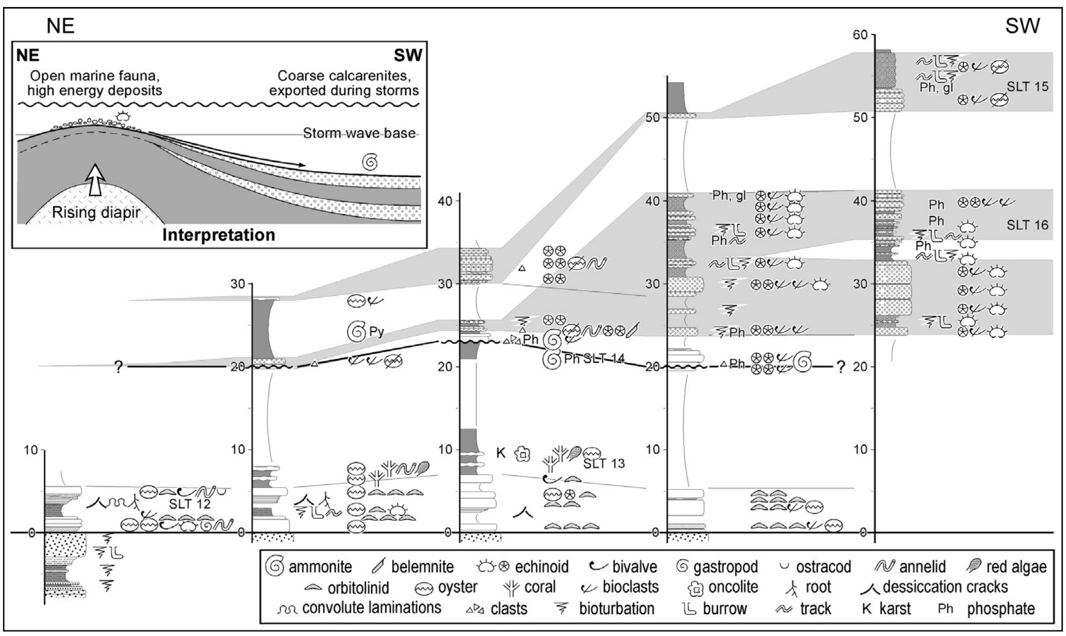

Fig. 7. Stratigraphic sections of the Lower Fahdene Formation, in the Northwestern part of Jebel Slata, showing the lateral thickening of calcarenite beds, interpreted as material exported from an uplifted area, during low sea level periods (see inset).

In the sections located Northwest of Tajerouine (Slata, Henchir El Goussa, Hameima), the sequence boundaries of the Lower Fahdene Formation contain reworked ammonites, locally phosphatised, proceeding from the upper part of the Hameima Formation (Chihaoui, 2009). This indicates that submarine erosion locally removed several tens of metres of sediments, thus suggesting local, but significant uplift.

In Jebel Slata, the carbonate intervals of the Lower Fahdene Formation are replaced by beds of coarse-grained, well-sorted calcarenites, with phosphatic cement, which rework open marine, shallow environment and high energy elements (rounded bioclasts, echinoid fragments, red algae…). In the northwestern slope of Jebel Slata, these calcarenitic beds wedge out toward the Northeast (Fig. 7). We interpret these calcarenite beds as deposited in a shallow marine area submitted to wave energy. During either storms or tectonic movements, these shallow-deposited sediments were swept away and exported to lower areas (Fig. 7). This new paleogeographic setting implies that a local relief had been created in the Jebel Slata area between deposition of the Hameima and Fahdene formations.

In this interval, neither normal faults, nor breccias have been observed in the succession. Thus, erosion is interpreted to be related to the progressive creation of reliefs and slopes. Since the tectonic regime is mostly extensional, we propose that the relief creation is related to diapiric movements (see also Smati, 1986).

While the Upper Hameima Formation was thicker to the Southeast, the Lower Fahdene is much thicker to the Northwest (Fig. 8). This new disposition implies that an inversion of the subsidence pattern occurred at a regional scale between deposition of the Hameima and Fahdene formations (i.e. during the late part of the L. tardefurcata zone). Considering the small-scale extensional structures observed in the deposits of this period, this tectonic movement may be due to differential subsidence controlled by the offset of regional normal faults. However, the Slata section displays a much thinner succession, which supports the interpretation of a salt dome located below this area (Fig. 7) (see also Perthuisot et al., 1998).

Further South, in Jebel El Hamra, the sediments equivalent to the Fahdene Formation (2nd sequence), are marked by large-scale slumps, due to a sliding toward the Southwest of the previously deposited, Early Albian shales and orange-coloured dolomites (Fig. 9). This deformation is associated with metric-scale normal faults that affect the underlying dolomites, and with the plastic deformation of the red dolomite bed. These structures (faults and folds) are sealed by the dolomitic bed that caps the unit (2nd sequence).

Higher in the section, the series of Jebel El Hamra presents significant thickness and facies variations (El Euchi, 1993). The fourth depositional sequence, equivalent to the D. mammillatum zone, is about 25 m thick at the southern tip of the massif, and progressively wedges out northeastwards (Fig. 10), where it is only represented by a 1 m-thick phosphatic conglomerate, representing a condensation and reworking layer. This indicates that deposition took place on a slope dipping to the Southwest, and would

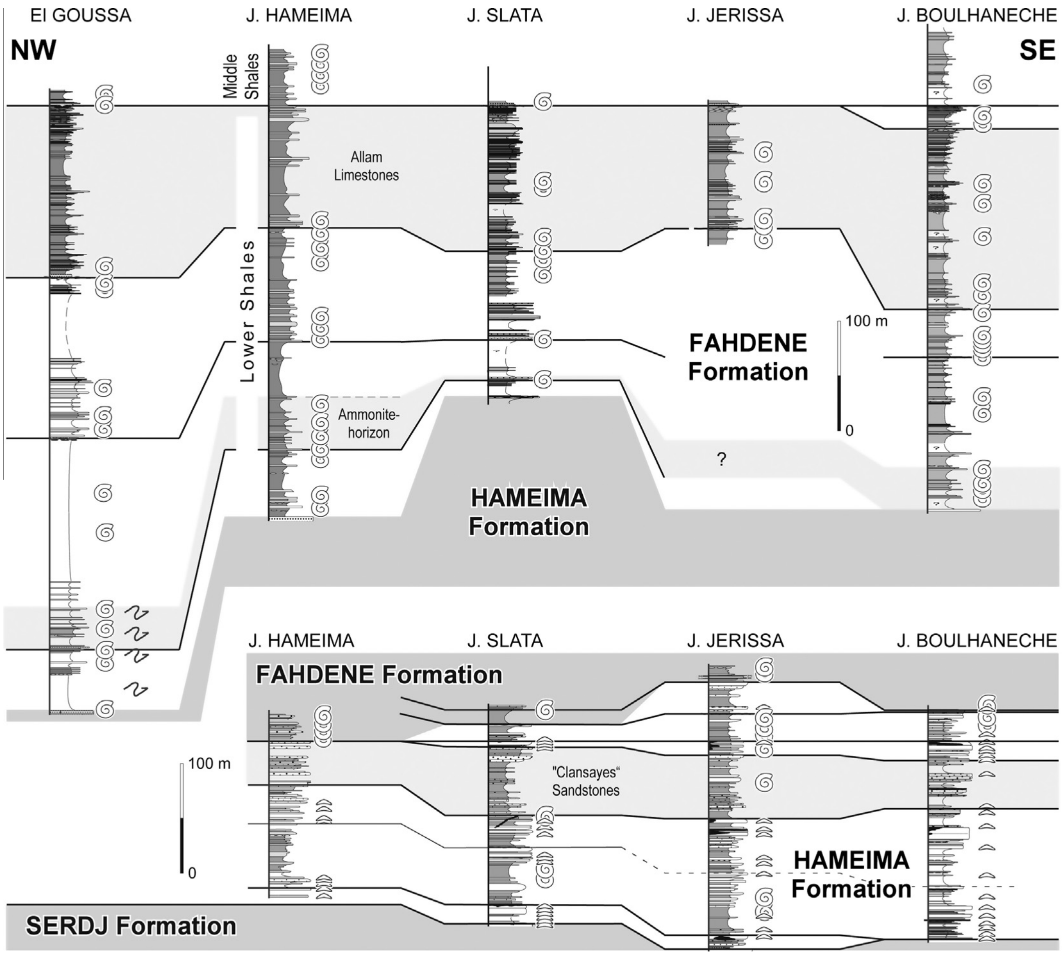

Fig. 8. Correlations of the Hameima (below) and Lower Fahdene (above) formations in the Tajerouine area. Note that the Hameima Fm is thinner toward the NW, whereas the Fahdene Fm is much thicker toward the NW.

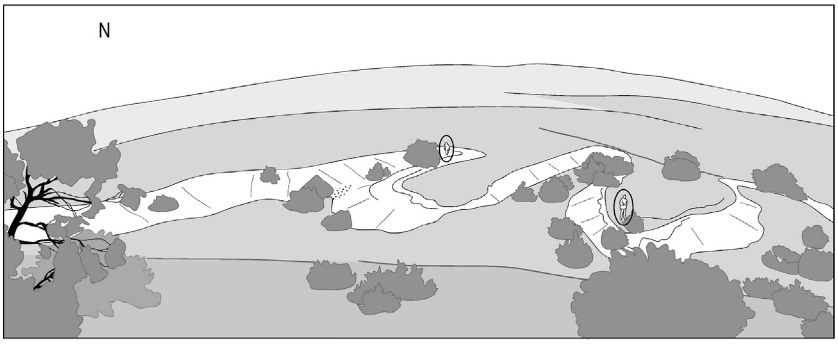

Fig. 9. Slump affecting the dolomite of the 2nd sequence of Jebel El Hamra, equivalent to the Lower Fahdene Formation. The dolomite bed (white) overlies green shales (background), and is overlain by black shales (foreground). Scale is given by the two persons.

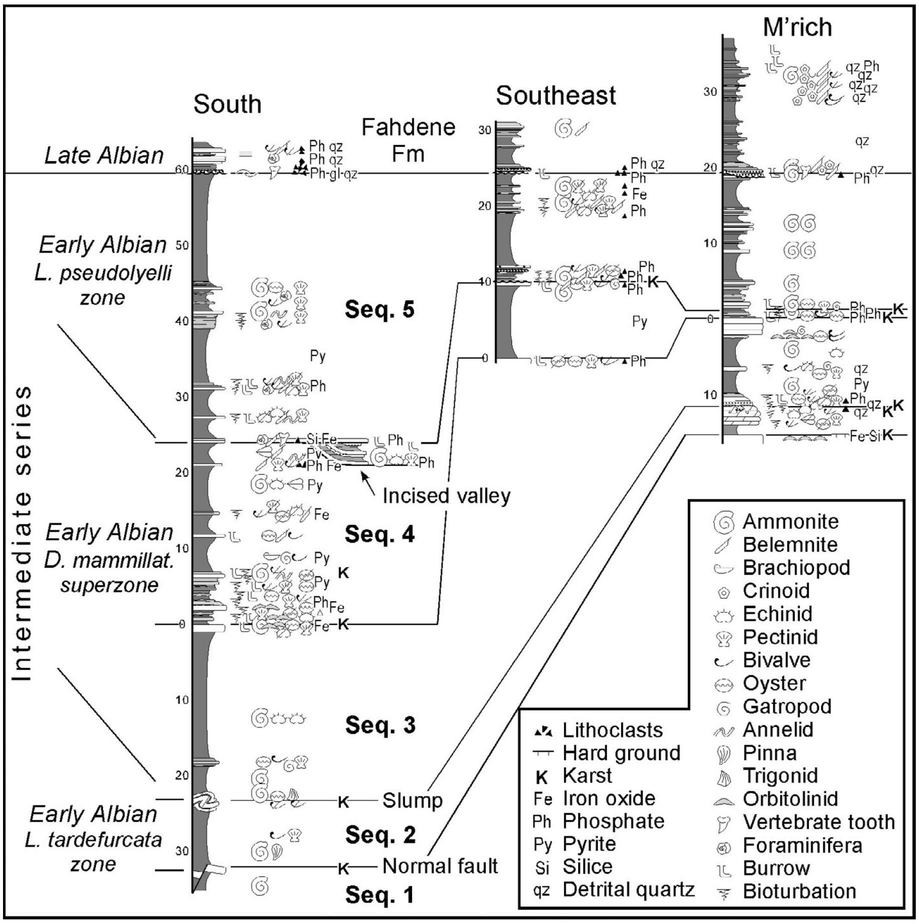

Fig. 10. The Early Albian successions along the Southeastern slope of Jebel El Hamra (location on Fig. 2). Datum is the Late Albian transgression. The 4th sequence wedges out northeastward into a thin, phosphatic condensation layer.

correspond to a reinforcement of the tilt recorded by the slumps observed in the underlying beds (Fig. 9).

4.5. Fahdene Fm: Allam Limestone (end of D. mammillatum zone and L. pseudolyelliceras subzone)

In the Hameima section, reworked, phosphatised ammonites have been found as high as at the base of the "Allam Limestones". Since these ammonites have been identified as *M. ouenzaensis*, they proceed from the top of the Hameima Formation, thus demonstrating that erosions can have removed as much as 200–300 m of shaly deposits from the Fahdene Formation (Lower Shales).

Farther North, Southeast of Guern Halfaya (Fig. 2), the upper part of the "Allam Limestones" contains locally metric-scale olistoliths of massive shelf limestone, associated with small clasts and boulders (Fig. 11, see also Vila et al., 1998). Moreover, these olistoliths contain ammonites that indicate that they proceed from the upper part of the Hameima Formation. This demonstrates, therefore, that deposits normally located more than 300 m below, were cropping out and eroded at the end of Early Albian times.

In the southern tip of Jebel El Hamra, the base of the sequence equivalent to the "Allam Limestones" is marked by a large incised valley, filled by quartz-rich, ammonite-bearing deposits of open marine environment, interpreted as a tidal channel (Fig. 10).

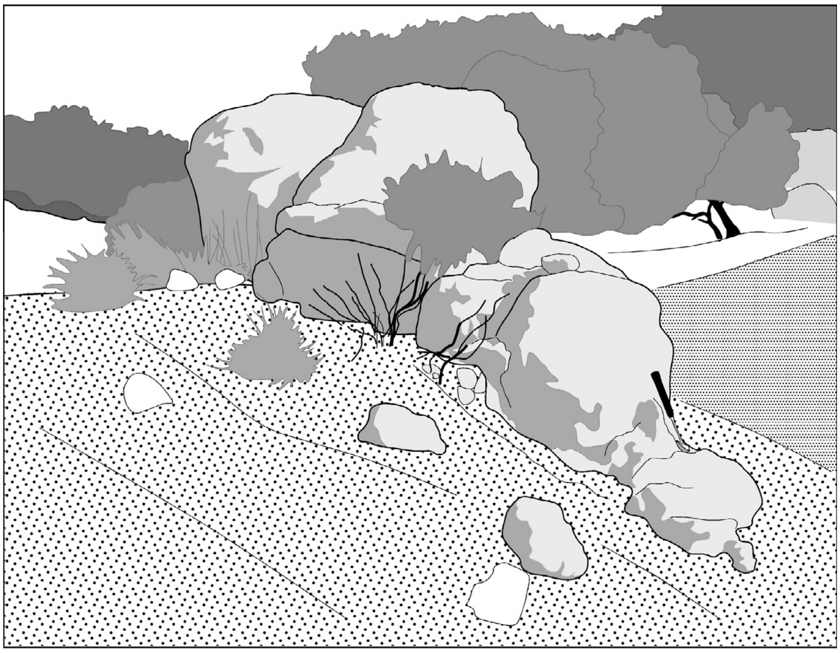

Fig. 11. Olistolith of limestone proceeding from the Hameima Fm, resedimented in the upper part of the "Allam limestones", Southeast of Garn Halfaya. The scale is given by the hammer.

These observations indicate that tectonic deformation increased during the Early Albian. The observed offsets of normal faults and the thickness of the removed deposits were of metric scale in the Hameima Formation or equivalent, of decametric scale in the Lower Fahdene Formation, and of hectometric scale during deposition of the Allam Limestones.

4.6. Fahdene Fm: the "Middle Albian" hiatus and the Late Albian unconformity

In the whole study area, the top of the Allam Limestones is marked by a long lasting hiatus, which encompasses the Middle Albian and the earliest Late Albian, and possibly the latest Early Albian (Jaillard et al., 2005; Chihaoui et al., 2010; Latil, 2011). The overlying Late Albian deposits rest commonly with an angular unconformity on the Early Albian deposits, and the Late Albian deposits are younger as one goes to the South or Southeast.

Correlations between various sections of the Tajerouine area show that submarine erosions took place during this hiatus. As a matter of fact, in the Bou El Haneche section, the "Allam Limestones" are thicker, and exhibit an additional disconformity, which underlines a depositional sequence that is unknown in the other sections (Chihaoui, 2009; Fig. 8). In the Henchir El Goussa, Hameima and Slata sections, the base of the "Allam Limestones" is marked by lens-shaped, fine grained sandstone beds locally preserved in depressions within the erosional, silicified surface that marks the unconformity.

In Jebel Slata, the Late Albian transgression has been extensively studied and described (Smati, 1986; Perthuisot et al., 1988; Vila et al., 2001; Chihaoui, 2009). Its base is locally marked by conglomerates, which can be observed in the lower part of the Late Albian shales. The conglomerates mainly rework Albian and Late Aptian limestones, and the angular unconformity locally exceeds 90° (Perthuisot et al., 1998; Fig. 12).

Farther south, in Jebel El Hamra, the equivalent of the "Allam Limestones" (5th Sequence) is preserved in the Southeastern part, thanks to a NW-trending normal fault that determines a half graben. The upper part of this sequence is marked by a quartz-rich, phosphatic sandstone bed that contains both the reworked ammonite *Lyelliceras lyelli* of early Middle Albian age, and a *Mortoniceras* sp. of Late Albian age, thus demonstrating the hiatus of the Middle Albian (Fig. 10). The play of this fault is sealed by crinoid-rich beds of Late Albian age.

Therefore, the deformation recorded during the Middle Albian hiatus is much more important than that observed during deposition of the Early Albian sediments. This suggests that synsedimen-

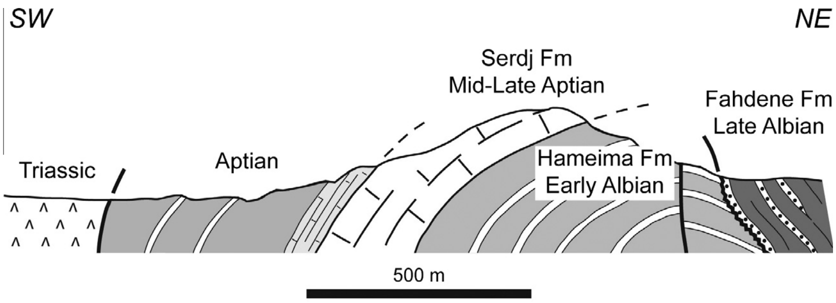

Fig. 12. Structural section across the southern part of Jebel Slata (modified from Perthuisot et al., 1998), showing a strong unconformity of Late Albian deposits on inverted Early Albian strata.

tary deformation increased throughout the Early Albian, and culminated during the Middle Albian.

5. Discussion

5.1. Extension and halokinetic activity

Most authors have related the Albian deformation to halokinetic activity. These relations are, however, complex. If halokinetic movements triggered Albian deformation, the latter should show distinct, local strain regimes controlled by the diapir shape and kinematics, and, therefore, should be diachronous. However, on one hand, the initiation of synsedimentary deformation seems to be roughly synchronous in all the studied areas, which suggests that they are related to regional tectonic processes, rather than to local diapiric movement. On the other hand, most deformation is observed in areas where no diapirs are presently known (Jebel Hameima, Jerissa, Bou El Haneche), and comparable structures have been described in the Chotts area, where Triassic evaporites are reduced or absent (e.g. Abbes and Tlig, 1991; Louhaichi and Tlig, 1993; Barrier et al., 1993; Bouaziz et al., 2002). This indicates that deformations was, at least locally, independent of halokinetic activity. Finally, many authors determined that extension was dominantly orientated ENE–WSW to NE–SW during the Aptian–Albian (Soyer and Tricart, 1987; Martinez et al., 1991; Barrier et al., 1993; Piqué et al., 1998; Bouaziz et al., 2002; Rigane et al., 2010), which suggests that deformations was related to a regionally consistent extensional tectonic regime, rather than to randomly distributed perturbations, as would be expected from isolated salt movements. Therefore, even though local diapirism can have played a role, we propose that diapirism is not the cause, but rather a consequence of the Early to Middle Albian tectonic activity, in agreement with studies carried out in numerous salt provinces (Jackson and Vendeville, 1994) and with theoretical models (Hudec and Jackson, 2007). An extensional regime may lead to local thermal heating, which favours evaporite mobility. In our opinion, the Early Albian extensional tectonic event triggered local halokinetic movements, which culminated in the Middle Albian.

Extensional normal faults and tilted blocks seem to dominate in the southern part of the studied area (Hameima, Bou el Haneche), whereas synsedimentary deformation is represented by large-scale slumps, progressive uplift and significant submarine erosion in the northern area (Slata, Hameima, Henchir El Goussa, Guern Halfaya). This difference in deformation style is probably due in part to the fact that in the northern areas, normal faults are difficult to identify in the thick accumulations of Early Albian shales. However, this difference can also indicate that diapirism was more active and began earlier in the North, or that Triassic evaporites were thicker there.

5.2. Geodynamic interpretation

The Albian tectonic event has been interpreted as resulting, either from the evolution of the Tethyan Ocean, or from the opening of the Atlantic Ocean at equatorial latitude.

In the first interpretation, the tectonic regime recorded in Tunisia would result both, from the sinistral play of the Gibraltar transform zone and from the opening of the Western Neotethyan Ocean (Stampfli and Borel, 2002; "Mesogean Sea" of Dercourt et al., 1986), which separated Tunisia from Apulia (Smati, 1986; Ouali et al., 1986; Martinez et al., 1991; Zouari et al., 1999; Ouali, 2007). However, the Gibraltar transform zone was active since the Jurassic, and the opening of the Western Neotethys occurred before the Albian and continued during the Late Cretaceous (Dercourt et al., 1986; Lemoine et al., 1986; Stampfli and Marchant, 1997). As a consequence, even though these processes may be compatible with the tectonic stress recorded in Tunisia, they cannot explain the Early Albian tectonic crisis and the acme of deformation in the Middle Albian.

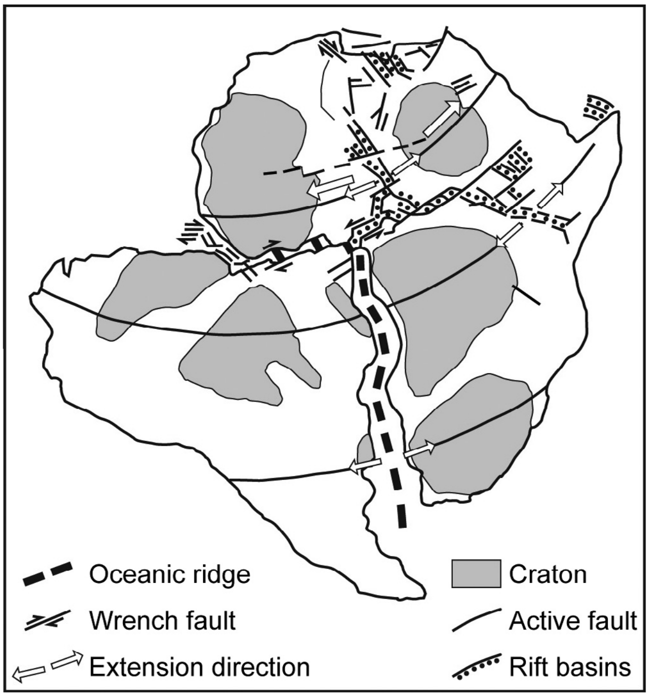

Fig. 13. Tectonic regime of Africa during the Albian (after Guiraud et al., 2005).

The final opening of the Atlantic Ocean at equatorial latitudes occurred in the Late Aptian–Early Albian (Basile et al., 2005), and more precisely between 112 and 106 Ma (Early Albian) according to Moulin et al. (2010). It was associated with an extensional tectonic regime in most of the northern part of Africa in Late Aptian–Ealy Albian times (Guiraud and Maurin, 1992; Guiraud et al., 2005; Bumby and Guiraud, 2005). This latter tectonic crisis resulted in about 40 km of extension in Central North Africa, triggered the opening of a series of extensional basins running from the Benoue Trough in Nigeria and Cameroon to the Sirte Basin in Lybia, and is marked by a ENE–WSW to NE–SE trending extensional tectonic regime (Guiraud et al., 2005; Moulin et al., 2010; Fig. 13). Therefore, this event is coeval with the synsedimentary deformation observed in Tunisia, and its consequences are compatible with the ENE–WSW extensional regime observed in Tunisia during Albian times (e.g. Barrier et al., 1993; Ouali, 2007).

In summary, although the geodynamic evolution of the Tethyan realm may have contributed to the extensional regime observed in Tunisia, we propose that the latter is mainly due to the Albian rifting of the South Atlantic Ocean, which began with an incipient rifting through the northern part of Africa, before to eventually breakup between northeastern Brazil and western Africa (Fig. 13).

6. Summary and conclusion

The biostratigraphic, sedimentological and tectonic studies of the Albian deposits of Central Tunisia provided the following results:

– The classical Mid-Cretaceous tectonic event of Tunisia, sometimes referred to as the "Aptian crisis", is actually of Early to Middle Albian age.

– The intensity of deformation increased during the Early Albian, and seemed to reach an acme during the Middle Albian, marked by a regional, long-lasting sedimentary hiatus.
– Synsedimentary deformation began roughly at the same time, and exhibited the same increasing intensity, in all the studied massifs, thus suggesting that diapirism was not the cause of the deformations. Halokinetic movements may be rather regarded as a consequence of the extensional deformations.
– The nature and distribution of the synsedimentary features point to extensional tectonics. Normal faults and block tilting dominated to the South, whereas slope creation, slumps and submarine erosions were dominant to the North, suggesting that diapirism was more important there.
– The Early to Middle Albian age of synsedimentary deformation in Tunisia suggests that it is related to the final stage of Atlantic Ocean opening, which induced a NE- to ENE-trending extensional regime through the northern part of the African continent.

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