

Relative Sea-level Changes of the Lower Cretaceous Deposits in the Chotts Area of Southern Tunisia

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Abstract: A transition facies between evaporate and clay, carbonate and siliciclastic deposits occurs within the Lower Cretaceous of Southern Tunisia. The sedimentary deposits comprise four major transgressive-regressive sedimentary sequences with distinctive sabkha, tidal to shallow carbonate marine platform, and mixed siliciclastic ramp environments. Sedimentation rates, as well as thickness and facies changes were controlled by tectonic, climatic and eustatic factors. Transgression pulses encompassing the whole Late Hauterivian–Barremian, Early Aptian and Late Albian have controlled the basin infill. Evaporate and siliciclastic systems pass gradually to carbonate deposition in the Chotts area. Our sedimentation model helps to decipher the roles of tectonics and, to a lesser extent, climate and palaeogeographic changes as the key factors of evaporate, carbonate and siliciclastic deposit sequences. Furthermore, sea level changes exert additional control on their environmental differentiations in such an ancient sedimentary basin. The sedimentary environments and palaeogeography in the Chotts chain during Hauterivian to Albian time are also reconstructed.

Key Words: Lower Cretaceous, depositional environment, palaeogeography, Chotts area, Tunisia

Alt Kretase Çökellerindeki Göreceli Deniz Seviyesi Değişimleri, Chotts Bölgesi, Güney Tunus

Özet: Güney Tunus Alt Kretase birimlerinde evaporit ve kil ile karbonat ve silisiklastik çökeller arasında bir geçiş fasiyesi bulunur. İstif, belirgin sebka, karışık silisiklastik ramp, ve gelgit ortamından sıg deniz karbonat platformuna kadar değişen ortamları temsil eden dört farklı transgresif-regresif birimleri içerir. Sedimentasyon oranı, kalınlık ve fasiyes değişimleri, tektonizma, iklim ve östatik değişimler gibi değişkenler tarafından denetlenmiştir. Geç Hauteriviye–Barremiye, Erken Aptiye and Geç Albian dönemindeki transgresif olaylar havza dolgusunu kontrol etmiştir. Chotts bölgesinde, evaporitler ve silisiklastik sistemler karbonatlara doğru dereceli bir geçiş gösterirler. Modelimiz, tektonizmanın rolünü deşifre ederken, daha az oranda da olsa iklim ve paleocoğrafik değişimlerinde evaporit, karbonat ve silisiklastik çökellerin oluşumunda anahtar değişkenler olduğunu ortaya koymaktadır. Ayrıca, bu tür eski sedimanter havzalarda deniz seviyesindeki değişimlerde ortamların farklılaşmasını kontrol eden ilave değişkenler arasında yer almaktadır. Bunlara ilaveten, Hauteriviye'den Albiye'e kadar olan dönemi kapsayan zaman dilimi için Chotts bölgesinin sedimanter ortamları ve paleocoğrafyası da tartışıldı.

Anahtar Sözcükler: Alt Kretase, çökelim ortamı, paleocoğrafya, Chotts bölgesi, Tunus

Introduction

Tunisia is located at the northern edge of North Africa, bounded by the Mediterranean Sea, Algeria and Libya (Figure 1). In this region, Late Carboniferous to present-day sedimentary events were summarised in previous studies and compilations by De Lapparent (1954) and more recently by Fakhraoui (1983), Ben Youssef *et al.* (1985) and Ben Ismail (1991).

The study area is situated in central eastern Tunisia and shows Mid-Cretaceous deposits comprising carbonates, marl, clay, sandstone, limestone and dolostone. The latter extend for over 100 km and include the Northern Chotts

chain, from the Smaïa outcrop in the west, to the east near Roumana outcrop in the El Meida region and in the Southern Chotts chain, from Radouane outcrop in the west to near Khachem Errabib outcrop in the east (Figure 1). Previous work done by Memmi (1983) and Burolet (1989) focused either on the stratigraphic or palaeontologic aspects of the local series and the main published results show six distinctive changes in depositional facies. More recently, M'rabet (1987) proposed a reappraisal of the detailed stratigraphy in southern Tunisia. The major aims of this paper are: (i) to reconstruct the depositional environments of sedimentary sequences in the Chotts area and (ii) to discuss the role of

either eustatic and/or tectonic as the controlling factors of Mid-Cretaceous sedimentation at the transition between the southern flat-lying Saharan platform and the northern Atlas domain.

Geological Setting

Cretaceous

The Early Cretaceous comprises complex deltaic deposits derived from the northern Sahara and shallow marine facies nearer the Chotts chain in the south of Tunisia. The Barremian–Aptian in central and South Tunisia is characterized by carbonate and detrital deposits. Facies and thickness variation are controlled by structural factors associated with halokinesis events, which seem to play a major role in sedimentary deposition (Pervinqui re 1911; Bismuth *et al.* 1967; Khessibi 1978; Burolet & Busson 1983; Abbes *et al.* 1986; Chikaoui *et al.* 1991; Chaabani 1994; Ben Youssef 1998; Ouajaa 2003; Srarfi 2006). During the early Albian stage, a large part of Tunisia (Saharan platform, Djefara, central and eastern Tunisia) was emergent. Only the northern part of Tunisia, the Chotts chains in the south of Tunisia and the Gafsa basin have a continuous sedimentary record during the Albian. The Cretaceous carbonate facies of this zone generally change from a subcontinental domain in the Sahara Platform to a marine domain in the Chotts chain in southern Tunisia. The N120  and Negrine Tozeur faults mark the limit between the Tunisian Atlas and the Saharan Platform (Zouari 1995; B dir *et al.* 2001) and controlled the structure of the Chotts chains. The Tertiary compressional movements strongly affected all the Lower Cretaceous basement which underlies the area, and especially near the Chotts chain, where Lower Cretaceous folding on NW–SE and E–W axes may reflect the wrinkled structure of the study area (Figure 2) (Abdeljaoud 1983; Zargouni 1985; Abdallah & Rat 1987; Chaabani *et al.* 1992; Boukadi 1994; Bouaziz *et al.* 2002; B dir *et al.* 1992; Zouaghi *et al.* 2005).

Sequences, Facies, and Deposit Environment

The Lower Cretaceous rocks of southeastern Tunisia consist of four major transgressive-regressive sedimentary sequences, identified by sea level, lithology and their biostratigraphic content changes. Each sedimentary sequence is bounded by an emersion surface (Figures 3A, B & 4).

Sequence I (Bouhedma: Upper Hauterivian)

Lithology and Lateral Evolution

This sequence is considered to be late Hauterivian age (Busson 1967; Peybernes *et al.* 1985) and consists of an alternating sequence of anhydrite, limestones and claystones. They have pack-grainstone textures and often contain abundant bioclastic debris (bivalves). This sequence is composed of repetitive mixed carbonate-clay-evaporate cycles (Figure 3C). Each cycle, less than 10 m in thickness and called an elementary sequence, starts with carbonate (0.5 m) and occasionally with shale. The carbonates generally consist of laminated dolomites also exhibiting dome-shaped stromatolites. Within the upper part of the Bouhedma formation, the clays have a thickness varying from 13 to 20 m. The top is predominantly gypsum with anhydrite beds having a thickness varying from 0.5 to 0.8 m. Gypsum beds are laminated and may exhibit chicken wire and porphyroblastic structures (Figure 3D). The base of this sequence is characterized by basal limestone up to 2 m thick which may be replaced by laminated, poorly bioclastic fine dolomites. Petrological study reveals the presence of dissolved micronodules of gypsum with blocky calcite fill. These features suggest that the brecciated dolomites resulted from dissolution of former associated evaporates and not from tectonic instability, as postulated by M rabet (1987). The basal part of the breccias is locally marked by stromatolitic laminations.

Depositional Environment

The first sequence deposits correspond to a shallow marine carbonate platform formed in a subaqueous evaporitic environment. The very thick anhydrite section logged with dolomite and limestone, which is over 30 m thick, records a long period of supratidal to evaporitic sabkha deposition. The clay-evaporates which are over 15 m thick, include laminated subaqueous gypsum. The petrology of the limestone is typical of a shallow marine shelf, inner to marginal environment where continental influences are increasing. This sequence is characterized by the absence of foraminifera. However, a lower proportion of lamellibranchs and bioclasts of the bivalves was observed (Figure 4).

Sequence II (Sidi Aich Barremian)

Lithology

These sequences are composed of shaly sands and ferruginous sandstones. These sandy bodies are generally

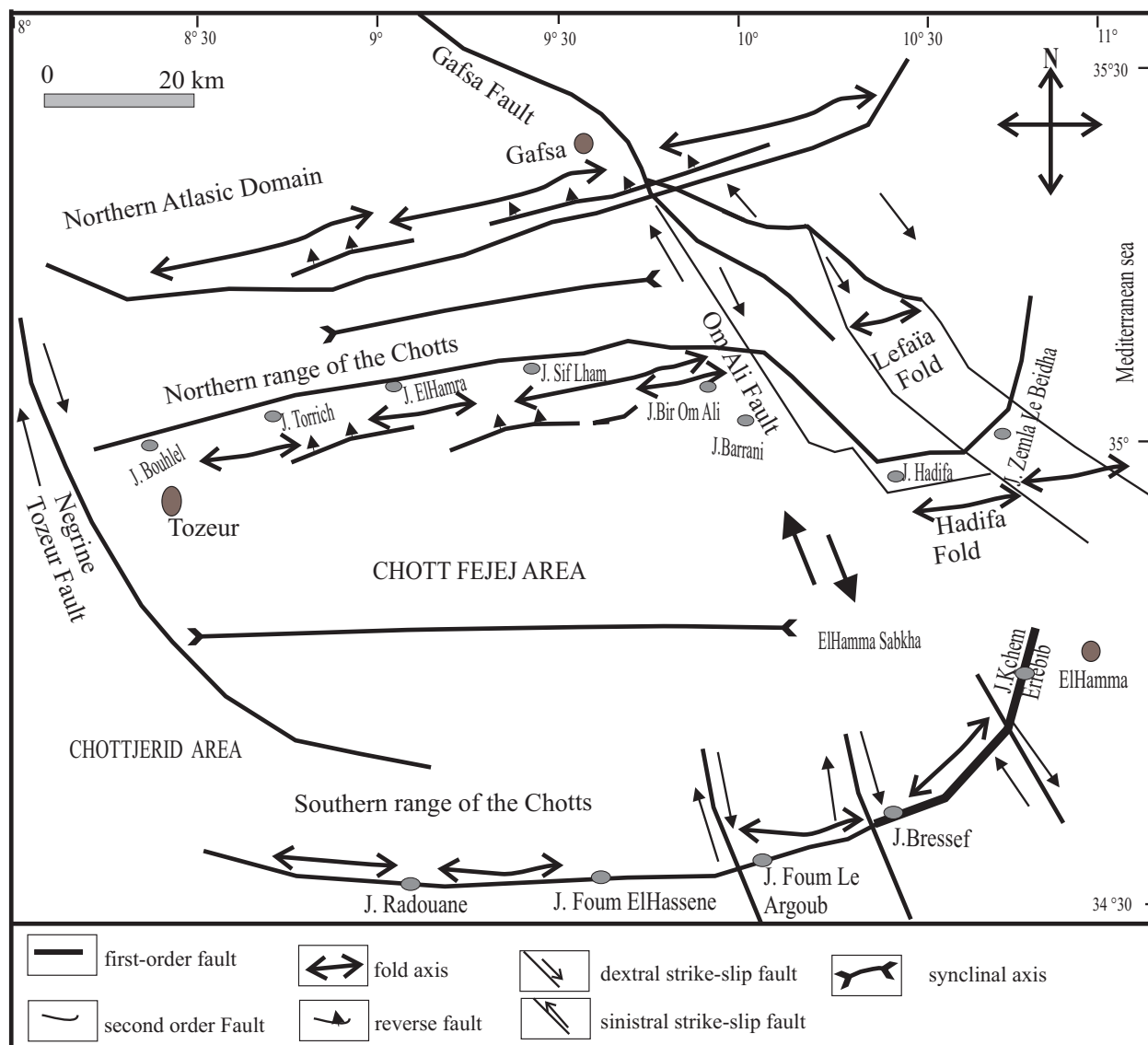


Figure 2. Tectonic setting showing the main outcrop lineaments in Southern Tunisia (Fakhraoui 1990).

lenticular, up to 3 m thick and have a sequence repetition. Above, most of the sequence consists of sandy to shaly coarsening-upwards sequences exhibiting cross-stratification, indicating fluvial transport. Wood debris is locally present. These coarsening-up sequences are intercalated with decimetric silt claystone or sands exhibiting current ripples. This sequence, characterized by lenticular sand bodies up to 2 m thick, has an erosive base and exhibits planar cross stratification, indicating transport from southwest to northeast. Laterally extensive fine- to

medium-grained cross-bedded sandstones and fining-up units occur in the channels. They contain large numbers of silicified wood fragments.

The cross-bedded sandstone facies (Figure 3E, F) is composed of thick sandstone channels associated laterally with typical silt claystone beds. The channels are generally 4–6 m thick, but may exceed 10 m in thickness, and are laterally extensive. They are generally coarse grained, often with clay rip-up clasts, and contain large channel cross-beds.

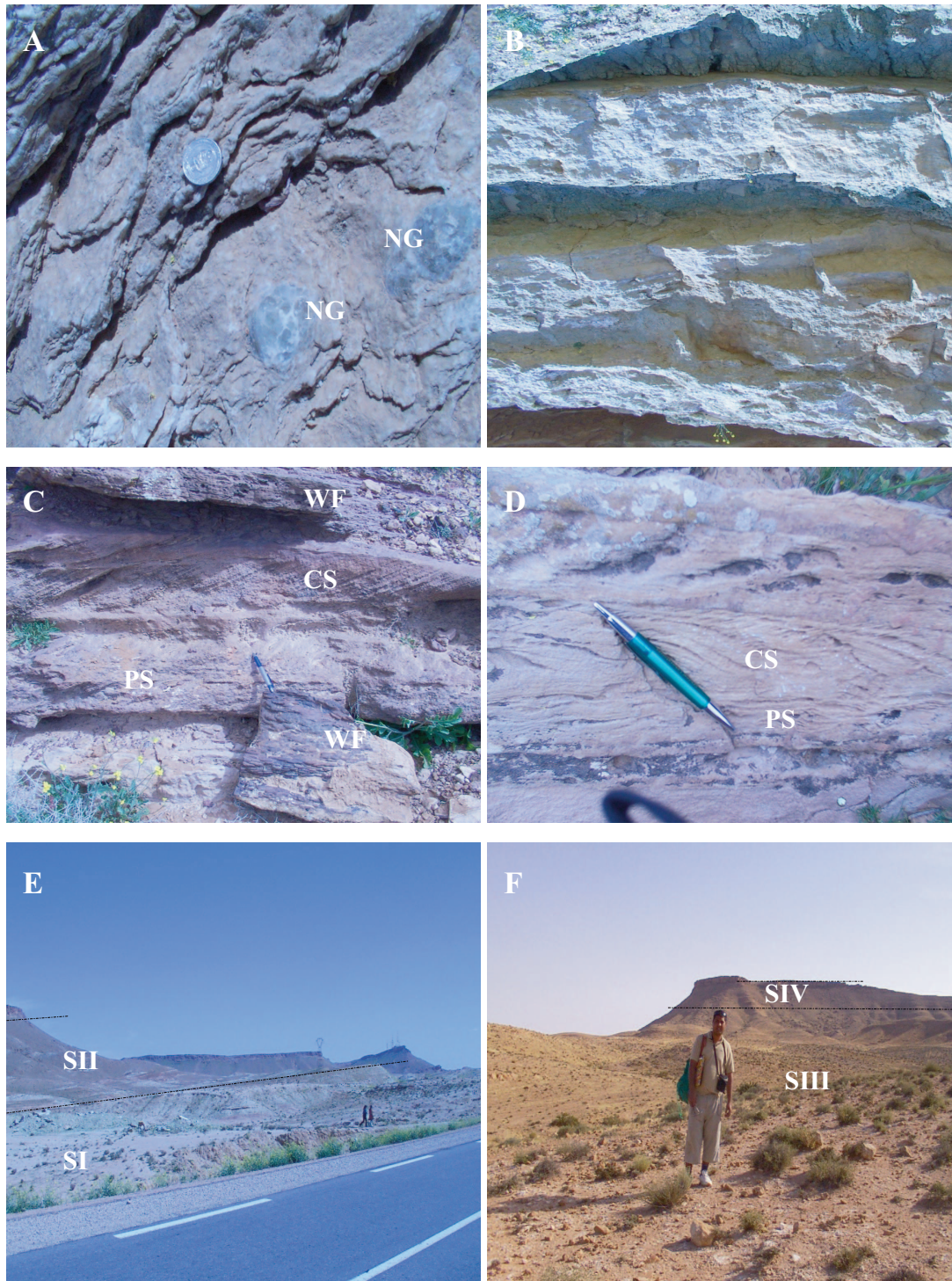


Figure 3. Field views of some particular segments of Lower Cretaceous sections. (A, B) general view of the typical Bouhedma clay (SI) overlain by the Sidi Aïch sandstones (SII), and the Orbata carbonates (SIII) and the Zebbag Shaly limestone (SIV). Hauterivian to Albian, Zemla El Beidha section; (C) thin-bedded calcareous sandstones or siltstones with evaporate containing bivalves and intraclasts, sequence I; (D) Laminated gypsum associated with nodular gypsum and porphyroblastic structure (NG– nodular gypsum), Sequence I, Hauterivian, El Hamra section; (E) Large numbers of silified wood fragments (WF– wood fragments), Sequence II, Barremien, Foun El Argoub section; (F) planar and cross stratification (CS) in the sandstone (PS– planar stratification), Sequence II, Barremian, Bir Oum Ali section.

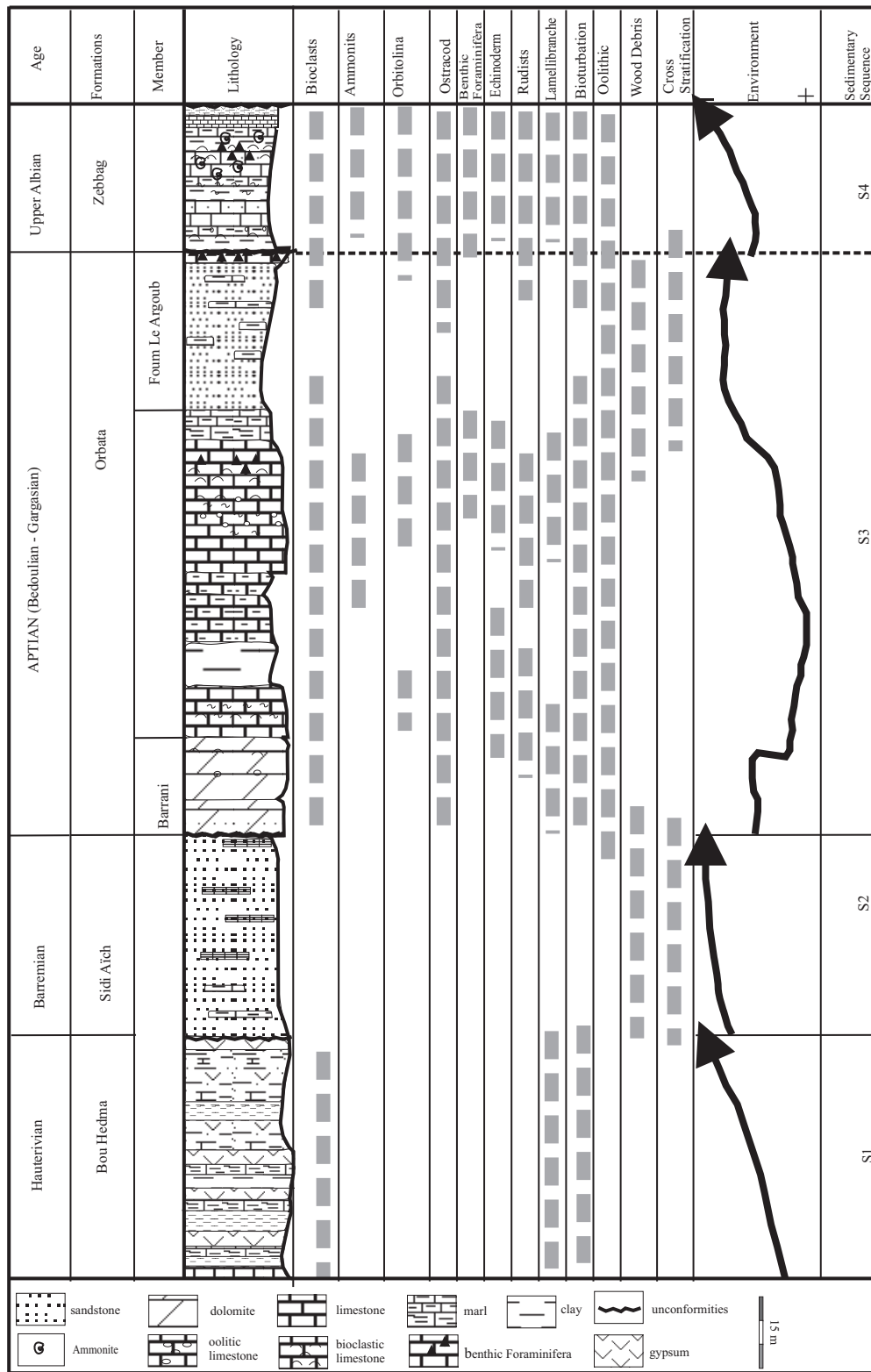


Figure 4. Synthetic biostratigraphic column of Hauterivian–Albian sequences in the Chotts region.

Depositional Environment

Cross-bedded sandstone and fining-up parasequences characterize a fluvial environment. Large fluvial channels represent major meandering rivers which were outlined by channel lags, pebbles and wood fragments (Figure 3C, D). The sandstones and siltstones are well sorted, with subangular to subrounded quartz grains. Cementation is poor, with patchy siliceous and dolomitic cement (Figure 5D). The ferruginous sandstones and the siltstones suggest a fluvial environment.

Sequence III (Orbata: Aptian)

Lithology

In the northern part of the Chott Fedjedj area, the Barrani and Bir Oum Ali outcrops provide a composite section of the Orbata Formation, showing three members: a lower member, the Barrani dolomite, with middle horizons of limestone and marl at its base, rich has a fauna of Echinoids, Rudists and foraminifera indicating a Late Barremian and Bedoulian age (Figure 5B, C). A thick middle member, made up of interbedded often dolomitic limestone, and marl, grades up and laterally to evaporate in the upper part; *Choffatella decipiens*, *Orbitolina parva*, *Cylindroporella sugdeni*, etc. suggest a Bedoulian to Gargasian age (Figure 4).

The upper member is made up of marl, sand and calcarenites, capped with a bank of limestone containing Rudists, and foraminifera, including *Orbitolina parva*; and *Mesorbitolina texana*, etc. In the sand-shale member, ammonites were found, including *Deshaysites callidiscus*, *D.cf. planus*, *D. weissii*, *D. furcata*, *Valdorsella* sp. and fragments of *cheloniceratidae*. This fauna is middle Bedoulian to Gargasian in age. The top of this upper member is eroded and there is sand and gravel at the base with 1.5 m of overlying sandy clay. They represent the top of the Orbata formation, which is dated as Gargasian by Foraminifera (*orbitolina minuta*, *Orbitolina texana* and *paracoskinolina tunesiana*) (Figure 4).

South of the Chott Fedjedj, at Fom El Argoub section, this formation is thinner. The upper member has been eroded by scouring beneath a coarse-grained gravel and sand unit, with fossil wood remains.

The lower part of the Orbata formation is composed of massive dolomites (Busson 1967; Ben Youssef *et al.* 1984; Kamoun 1988) which are finely to medium crystalline and often show relict sedimentary textures.

Most of sequence III (25–40 m thick) consists of locally bioclastic dolomites, overlain by mud-wackestones containing ostracods and some bioturbation. Carbonates are mostly preserved as limestones characterized by several textures and components. The following microfacies were observed.

The Bedoulian microfacies, is represented by micrites with fragments of rudists (Figure 5B). The crystallized dolomites derived from biomicrosparticles with echinoids and oolites and slightly marly micrites with abundant *Orbitolina lenticularis* and rare verneuilinids that have been observed in the Upper Aptian of the Bir Oum Ali and Hamra outcrops (Figure 5E, F).

In the Hamra outcrop, microfacies are represented by finely porous micrites with rare small foraminifera such as ophthalmidids and polymorphinids, or micrites with ostracods and polymorphinids. Only a major regressive episode is marked by erosion at the base of the giant cross-bedded sandstone sequence of Fom El Argoub. These sequences, which have been observed in the Upper Aptian (Gargasian) in many sections of the Chotts chain (Bishop 1975, 1988; Ben Youssef *et al.* 1984; Zargouni & Biely 1986) contain abundant terrestrial invertebrate trace fossils and accumulations of fossil wood (Figure 3C). As observed above, sandstones with subangular to subrounded quartz grains, on the upper Fom El Argoub outcrop suggest strong detrital influences and channel deposits.

Depositional Environment

Within Sequence III, the basal Orbata formation contains shallow marine deposits including metric mixed cycles of subtidal shales or bioclastic dolomites passing upwards to intertidal algal mats and then to supratidal or sabkha environments. The upper part of the Orbata formation reflects a slight but clear marine deepening and renewed transgression. Within the upper part of this formation these deepening marine environments revert to a very shallow marine platform lacking shale: sands are organized in a succession of coarsening- and thickening-upwards sequences. The sands are associated with intercalations of evaporates and laminated dolomites. This environment became shallower and was influenced by fluvio-marine siliciclastics derived from the Sahara Platform. This terrigenous influence becomes more and more important, ushering in the southern Chotts fluvial complex sedimentation.

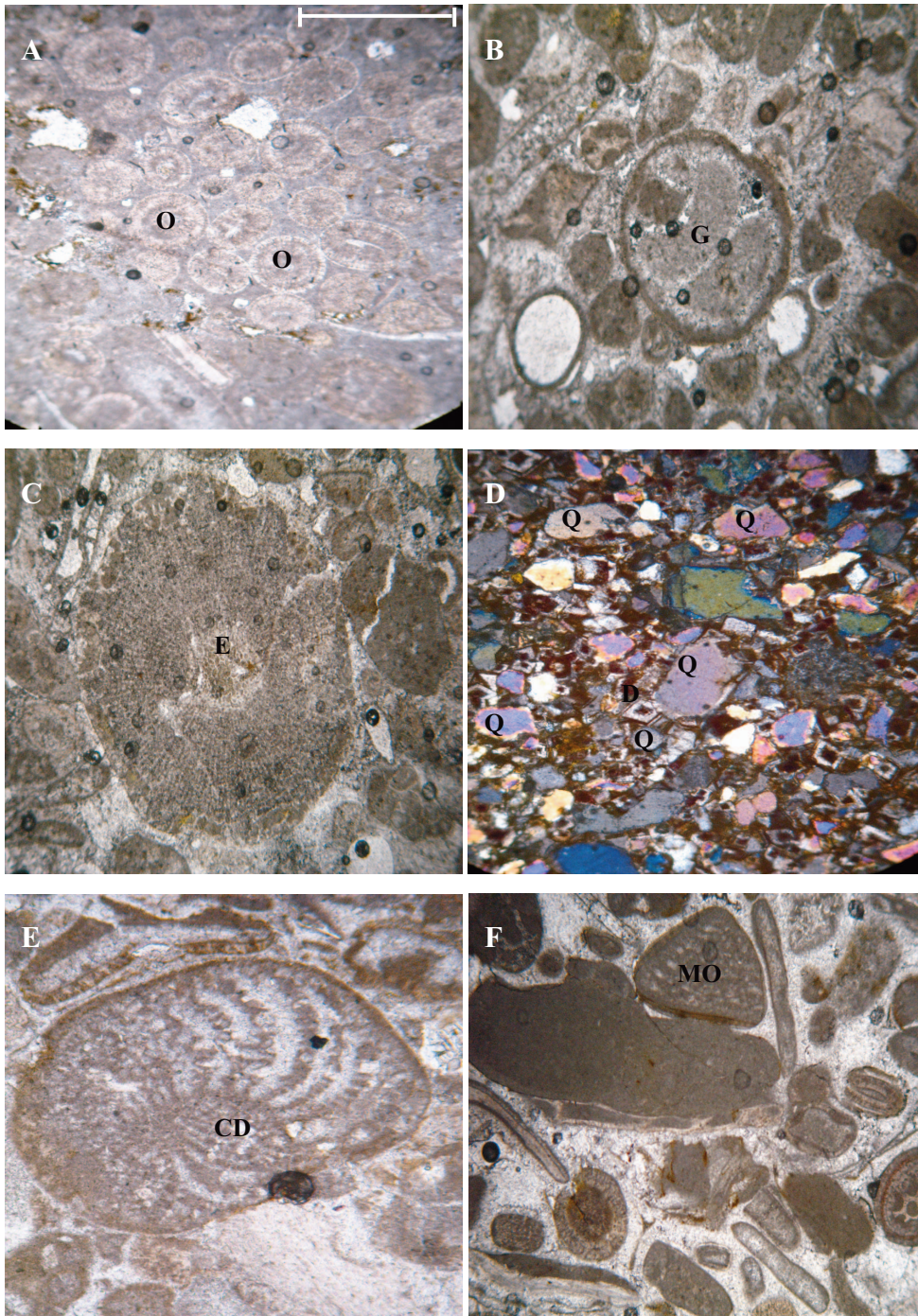


Figure 5. Photomicrographs of selected samples in the Lower Cretaceous section (white bar is the scale: 0.5 mm and valid for all photographs): (A) oolitic pack-grainstone including bioclastic fragments (O– oolite), sequence IV, Albian, Khachem Errebib section; (B) micrites with fragments of rudists and gasteropods (G– gasteropods), sequence III, Bedoulian, Bir Oum Ali section; (C) biomicrosparites with echinoderm debris, (E– Echinodermata), sequence III, Bedoulian, Bir Oum Ali section; (D) the Fom El Argoub sandstone composed by quartzarenite with cement characterized by fine dolomite rhombs average 20 μm in diameter (Q– Quartz, D– dolomite rhombs), sequence III, Gargasian, Fom El Argoub section; (E) wacke-mudstone with abundant ostracods benthic foraminifera (CD– Chaffotella Deciapiens), sequence IV, Albian, Bir Oum Ali section; (F) marly micrites with benthic foraminifera (MO– Mesorbitolina orbitolina minuta), sequence III, Aptian, Bir Oum Ali section.

Sequence IV (Lower Zebbag: Albian)

Lithology

In continuity with the late Aptian regressions, clear low sea level stands at the beginning of the Albian, and tectonic factors caused a general lack of sedimentation in central and Southern Tunisia (Ben Youssef & Peybernes 1986).

The fourth sequence averages 90 m in thickness and corresponds to the lower part of the Zebbag formation (Busson 1967). This sequence starts with hard limestones with a clear erosive base which locally contain reworked micritic clasts from the underlying sequence III (Figure 4). This carbonate-rich sequence contains significant fossils (ammonites [*Knemiceras* cf. *gracile*, *Knemiceras*. Gr. *Compressum*], nautiloids, echinoids, brachiopods) indicating an late Albian age (Arnauld 1956). These carbonates are intercalated with fossiliferous marls. They have pack-grainstone texture and contain abundant oolites (Figure 5A), lithoclasts, foraminifera, gasteropods, and echinoids (Figure 5B, C). Micrite content increases upwards and the limestone textures progressively change from pack-grainstone to wacke-mudstone; within the latter, the fauna decreases in diversity and abundance and the uppermost beds contain only brachiopods and rare foraminifera (Figure 5E).

Depositional Environment

In the Chotts region, the Zebbag formation, clearly transgressive, reflects mixed marl-carbonate ramp sedimentation. The lower part of this formation, with prograding distal bars, suggests a progressive deepening of the marine environment. This deepening, also confirmed by the overlying ammonites, nautiloids and echinoids rich limestones, represents the maximum of the transgression initiated during the Late Albian.

The basal echinoids and brachiopod-rich shale part reflects an acceleration of the marine deepening started at the base of the Zebbag formation. The associated fossiliferous carbonate intercalations also suggest deep marine conditions.

Discussion of Sedimentation Controls

The lateral and vertical evolution of Hauterivian–Albian thicknesses and facies, and hence, of their corresponding environments in southwestern Tunisia, indicate two distinct palaeogeographic zones, whose sedimentary characteristics

remain relatively homogeneous during the Late Cretaceous. A resistant slowly subsiding and relatively very shallow marine platform in the south Chotts (Kebili area) and the Gafsa area was characterized by a progressive subsidence towards the North.

In summary, Lower Cretaceous sedimentation in southwestern Tunisia was controlled by E–W and N120° fault systems most probably inherited from Late Palaeozoic to Early Mesozoic rifting between the African and European plates (Bouaziz *et al.* 2002). This structure also represents a major feature of the transition, within the North African margin, between the stable Saharan platform basin and the less stable Tethyan basins in central and northern Tunisia.

Climatic control indicators include the gypsum and carbonate sedimentation, particularly observed within the Hauterivian to Albian sediments (Bouhedma, Sidi Aïch, Orbata and lower Zebbag), which indicate an arid palaeoclimate in southern Tunisia during this period. The overlying Barremian siliciclastics, locally rich in wood debris, may suggest climatic evolution to more humid conditions. However, these siliciclastic deposits are often intercalated with carbonates (locally rich in oolites), which imply a temporary pause in terrigenous input and, consequently, may reflect somewhat semi-arid conditions. In addition, the arid climate has favoured, in both areas, the close association of carbonate and siliciclastic sediments. The Lower Cretaceous deposits of southern Tunisia correspond to four transgressive-regressive sequences. The transgressive episodes occurred during the Hauterivian–Barremian, Bedoulien–Gargasian and Late Albian–Vraconian intervals. These transgressions have been recognised in central and northern Tunisia and induced subtidal carbonate sedimentation (Fakhraoui 1983; Ben Youssef *et al.* 1985). Such transgressions caused a general opening and increasing subsidence of the marine environments in the Chotts regions. The Barremian regression is followed by a transgression in the Bedoulian. The latter illustrates a return to near-shore shallow marine conditions, perhaps influenced by a local lagoonal or tidal environment. This period is characterized by regressive deposits which consist of evaporite and siliciclastic successions (Lefranc & Guiraud 1990). Sea-level rise induced the deposition of coarsening- to fining-upward Albian sequences. In addition to transgressive pulses, tectonic tilting may also be indicated in southeastern Tunisia (M'rabet 1987; Ghanmi & Potfaj 1991; Ben Youssef 1998).

Conclusions

The Lower Cretaceous deposits record four transgressive-regressive sequences. Sea-level changes and climatic conditions recorded an evolution from carbonate tidal flats to sabkha and a closed evaporitic basin. A shallow marine platform is indicated by the distribution of facies, high faunal diversity and sedimentary structures. Transgressive periods during the Late Hauterivian, Bedoulian and Albien are related to marine invasion and an increasing subsidence rate.

These vertical and lateral transitions of environment systems were also largely controlled by tectonic activity.

References

- ABBES, C.H., ABDELJAOUAD, S. & BEN OUEZDOU, H. 1986. Carte Géologique d'El Hamma au 1/100.000. *Institut National de recherche Scientifique de Tunisie et Service Géologique Nationale d'Office Nationale de Mines* Tunisie.
- ABDALLAH, H. & RAT, P. 1987. Le rôle de la faille de Gafsa dans le jeu transgressif et régressif au Crétacé supérieur de la Chaîne Nord des Chotts (Tunisie). Extrait de Mémoire Géologique Université de Lyon (France), 233–242.
- ABDELJAOUAD, S. 1983. *Etude Stratigraphique, Sédimentologique et Structurale de l'extrémité orientale de la Chaîne des Chotts*. Thèse de 3^{ème} Cycle, Tunis.
- ARNOULD, S. 1956. Contribution à l'Etude des Enganoceratidae (les couches à knémiceras de sud tunisien). *Annale Géologique de Mines de Tunis* 20, 47, p. 12.
- BÉDIR, M., BOUKADI, N., TLIG, S., BEN TIMZAL, F., ZITOUNI, L., ALOUANI, R., SLIMANE, F., BOBIER, C. & ZARGOUNI, F. 2001. Subsurface Mesozoic basins in the central atlas of Tunisia, tectonics, sequence deposit distribution and hydrocarbon Potential. *American Association of Petroleum Geologists Bulletin* 85, 885–907.
- BÉDIR, M., ZARGOUNI, F., TLIG, S. & BOBIER, C. 1992. Subsurface geodynamics and petroleum geology of transform margin basins in the Sahel of Mahdia and El Jem (Eastern Tunisia). *American Association of Petroleum Geologists Bulletin* 76, 1417–1442.
- BEN HAJ, A.M., JEDOUJ, Y., DALI, T., BEN SALEM, H. & MEMMI, L. 1985. *Carte Géologique de la Tunisie 1/500000*. Office Nationale des Mines; service géologique nationale.
- BEN ISMAIL, H. 1991. *Les Bassins Mésozoïque (Trias à Aptien) du Sud de la Tunisie: Stratigraphie intégrée, caractéristiques Géophysiques et Evolution Géodynamique*. Thèse Doctorat D'Etat. Faculté de Sciences de Tunis. Université de Tunis II.
- BEN YOUSSEF, M. 1998. *Stratigraphie génétique du Crétacé de la Tunisie ; Micropaléontologie, Stratigraphie Séquentielle et Géodynamique des bassins de la marge sud et péri Téthysienne*. Thèse de Doctorat D'Etat. Faculté de Sciences de Tunis Université de Tunis II.
- BEN YOUSSEF, M., BIELY, A., KAMOUN, Y. & ZOUARI H. 1984. Nouvelles données sur l'Aptien et l'Albien dans la région de Médenine (Tunisie méridionale). 10^{ème} Association of Scientific and Technical Research, Bordeaux, p. 51.
- BEN YOUSSEF, M., BIELY A., KAMOUN, Y. & ZOUARI, H. 1985. L'Albien moyen supérieur à Knémiceras forme la base de la grande transgression crétacée au Tebaga de Médenine. *Compte Rendu d'Académie de Sciences de Paris* 300, 965–968.
- BEN YOUSSEF, M. & PEYBERNES B. 1986. Données micropaléontologiques et biostratigraphiques nouvelles sur le Crétacé inférieur marin du Sud tunisien. *Journal of African Earth Sciences* 5, 217–231.
- BISHOP, W.F. 1975. Geology of Tunisia and Adjacent Parts of Algeria and Libya. *American Association Petroleum Geologists Bulletin* 59, 413–450.
- BISHOP, W.F. 1988. Petroleum Geology of East-Central Tunisia. *American Association Petroleum Geologists Bulletin* 2, 1033–1058.
- BISMUTH, H., BONNEFOUS, J. & DUFAURE, Ph. 1967. *Mezozoic Microfacies of Tunisia*. Petroleum Exploration Society of Libya, Guide Book to the Geology and History of Tunisia, 159–214, Tripoli.
- BOUKADI, N. 1994. *Structuration de l'Atlas de Tunisie : Signification géométrique et cinématique des noeuds et des zones d'interférences structurales au contact de grands couloirs tectoniques*. Thèse Doctorat D'Etat. Faculté de Science de Tunis. Université de Tunis II.
- BOUAZIZ, S., BARRIER, E., SOUSSI, M., TURKI, M.M. & ZOUARI H. 2002. Tectonic evolution of the northern African margin in Tunisia from paleostress data and sedimentary record. *Tectonophysics* 357, 227–253.
- BUROLLET, P.F. 1989. Les événements du Crétacé moyen au Sud de la Méditerranée. In Colloque, les événements de la partie moyenne du Crétacé (Aptien à Turonien). *Géobios, Mémoire Spécial* 11, 69–81.
- BUROLLET, P.F. & BUSSON, G. 1983. Plateforme Saharienne et Mésogée au cours du Crétacé. *Notes Mémoires de la Compagnie Française de Pétroles* 18, 17–26.

The rapid lateral facies changes are mainly controlled by major lineaments that separate areas corresponding to tilted blocks, each characterized by a distinct local environment.

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- BUSSON, G. 1967. Le Mésozoïque Saharien. 1 ère partie : l'Extrême Sud Tunisien. *Centre Recherche Zones Arides, services Géologique*, n° 18, p. 194, Edition Centre Nationale de Recherche Scientifiques.
- CHAABANI, F. 1994. Variations Sédimentaires sous contrôle Tectonique durant le Sénonien supérieur au niveau de la passe de Chemsî (Tunisie centro-méridionale): Cadre océanographique et implications paléogéographiques. In: *The Proceedings of the 4th Tunisian Petroleum Exploration Conference, Tunis, May 1994, Entreprise Tunisienne d'Activités Pétrolières*, 443–457.
- CHAABANI, F., TURKI, M.M. & GARGOURI-RAZGALLAH, S. 1992. L'Aptien à l'Est de Gafsa. Etude biostratigraphique, sédimentologique et cadre géodynamique. *Notes Service Géologique de Tunis* 59, 43–57.
- CHIKAOUI, M., TURKI, M.M. & DELTEIL, J. 1991. Témoignages de la structurogenèse de la marge téthysienne en Tunisie, au Jurassique terminal -Crétacé (Région du Kef, Tunisie septentrionale). *Géologie Méditerranéenne. Tome XVIII* 3, 125–133.
- DE LAPPARENT, AF. 1954. Les Gisements Cénomaniens de la falaise du Dahar (extrême Sud tunisien). *Notes du Service Géologique de Tunisie*, 5–7.
- FAKHRAOUI, M. 1983. *Etude Stratigraphique et structurale des Chaînes des Chotts : Evolution Géométrique et Cinématique liée à l'accident Sud-Atlantique*. Thèse 3ème Cycles. Université de Tunis. 243 p.
- FAKRAOUI, M. 1990. *Carte Géologique au 1/100 000 ème de la Tunisie. Feuille n° 73. Bir rakeb*, Service Géologique de la Tunisie.
- GHANMI, M. & POTFAJ, M. 1991. Données Stratigraphiques sur la Chaîne de Tebaga de Kebili Jebel Aziza (Tunisie méridionale) : Conséquences Paléogéographiques et Tectoniques. *Notes du Service Géologique Tunisie* 58, 21–28.
- KAMOUN, F. 1988. *Le Jurassique du Sud-tunisien, témoin de la marge Africaine de la Téthys: Stratigraphie, Sédimentologie et Micropaléontologie*. Thèse doctorat de 3ème Cycle. Université Paul Sabatier. Toulouse.
- KHESSIBI, M. 1976. Observations Géologiques dans le Jebel Kebar Mouvements tectoniques anté Cénomaniens. *Notes Service Géologique Tunisie* 42, 21–27.
- LEFRANC, J.P.H. & GUIRAUD, R. 1990. The Continental intercalaire of Northwestern Sahara its equivalents in the neighbouring regions. *Journal of African Earth Sciences* 10, 27–77.
- M'RABET, A. 1987. *Stratigraphie, sédimentation et diagenèse carbonatée des séries du crétacé inférieur de Tunisie centrale*. Thèse de Doctorat D'Etat. Faculté de Science de Tunis. Université de Tunis.
- MEMMI, L. 1983. *Age des Couches à Knemiceras de Fom El Argoub, Ragoubet Zirzaou et Oued Zitoun. Rapport paléontologique*. Service Géologique National de Tunisie, Rapport inédit S-69.
- OUAJAA, M. 2003. *Etude Sédimentologique et Paléobotanique du Jurassique Moyen – Crétacé Inférieur du Bassin de Tataouine (Sud-Est de la Tunisie)*. Thèse de Doctorat Université De Claude Bernard-Lyon.
- PERVINQUIÈRE, L. 1911. Sur la Géologie de l'Extrême Sud tunisien et de la Tripolitaine, spécialement des environs Ghadamès. *Compte Rendu d'Académie de Science* 23, p. 153.
- PEYBERNES, B., ALMERAS, Y., BEN YOUSSEF, M., KAMOUN, F., REY, J., MELLO J. & ZARGOUNI F. 1985. Nouveaux éléments de datation dans le Jurassique du Sud tunisien (Plateforme saharienne). *Compte Rendu d'Académie de Science, Paris, série II* 300, 113–118.
- SRARFI, D. 2006. *Biostratigraphie, biodiversité, taphonomie et paléo environnements des niveaux à vertébrés du Jurassique-Crétacé du Sud-Est de la Tunisie. Implications paléobiogéographiques*. Thèse de Doctorat Université De Claude Bernard-Lyon1.
- ZARGOUNI, F. 1985. *Tectonique de l'Atlas méridional de Tunisie, évolution géométrique et cinématique des structures en zone de cisaillement*. Thèse d'Etat, Université Louis Pasteur, Strasbourg-Paris.
- ZARGOUNI, F. & BIELY, A. 1986. Introduction aux Cartes Géologiques du Sud de la Tunisie : Nomenclature, Subdivisions et Notations Adoptées. *Revue de Science de la Terre* 4, 1–9.
- ZOUARI, H. 1995. *Evolution Géodynamique de l'Atlas Centro-Méridional de la Tunisie: Stratigraphie, Analyse Géométrique, Cinématique et Tectono-Sédimentaire*. Thèse Doctorat d'Etat, Université de Tunis II.
- ZOUAGHI, T., INOUBLI, M. & BEDIR, M. 2005. 2 Seismic Interpretation of strike-slip Faulting, Salt Tectonics, and Cretaceous Unconformities, Atlas Mountains, Central Tunisia. *Journal of African Earth Sciences* 43, 464–486.

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