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COMPARATIVE STUDY OF THE LOWER AND MID-CRETACEOUS SEQUENCES ON DIFFERENT MAGHREBIAN SHELVES AND BASINS — THEIR PLACE IN THE EVOLUTION OF THE NORTH AFRICAN ATLANTIC AND NEOTETHYSIAN MARGINS

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ABSTRACT

Canerot, J., Cugny, P., Peybernès, B., Rahhali, I., Rey, J. and Thieuloy, J.-P., 1986. Comparative study of the Lower and Mid-Cretaceous sequences on different Maghrebian shelves and basins — Their place in the evolution of the North African Atlantic and Neotethysian margins. Palaeogeogr., Palaeoclimatol., Palaeoecol., 55: 213—232.

The Lower and Mid-Cretaceous sequences known from Morocco (coastal Essaouira—Agadir—Safi Basin and Eastern Rif Foreland), in Western Algeria (Daïa Mountains) and finally in Southern Tunisia (Chott Range and Saharian Shelf) are presented from a biostratigraphic and sedimentologic viewpoint.

This work shows, for the period considered, common features in the geodynamic evolution of the different regions, such as:

— generalization of the carbonate facies in the Early Cretaceous (Berriasian) and at the end of the Mid-Cretaceous (Cenomanian—Turonian) times;

— delineation of important discontinuities in the Valanginian and Bedoulian times.

This evolution gives evidence of an undeniable influence of eustatism in this Northern part of Africa.

Nevertheless, detailed differences allow us to distinguish:

— an "Atlantic-type" evolution characterized by discontinuities with gaps (Safi) or sudden variations of thickness (Essaouira—Agadir) at the Berriasian/Valanginian boundary, related to the Neocimmerian rifting and block-faulting phase. Later on, this evolution is underlined by a progressive acceleration of subsidence at the Aptian/Albian boundary, due to the removal of the mid-oceanic doming;

— a "Neotethysian-type" evolution (Eastern Rif Foreland, Western Algeria and Southern Tunisia) where local tectonic movements have probably generated the rapid growth of the external marly Bedoulian basins and the spreading of the Wealdian-type (Valanginian to Barremian) and Utrillas (Albian) terrigenous depositional systems. The latest event is linked to the Austrian tectonic phase responsible of variable gaps towards the Aptian to Albian transition.

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INTRODUCTION

The results presented here are in keeping with the general pattern of the research carried out in North Africa within the I.G.C.P. (UNESCO) 183 (Correlations of Mesozoïc and Cenozoïc of Western Africa) by the "Laboratoire de Géologie sédimentaire et Paléontologie" (Toulouse University) in collaboration with the "Institut Dolomieu" of Grenoble University and the "Service des Etudes Fondamentales du Ministère de l'Energie et des Mines" of Morocco.

Our topic is to review, from both old and new biostratigraphical and sedimentological data, the main features of the Lower and Mid-Cretaceous geodynamic evolution of North Africa. Specifically, we present data from Western Morocco (Safi—Essaouira—Agadir Basins), Northern Morocco (Eastern Rif Foreland), Western Algeria (Tellian Foreland) and South-Eastern Tunisia (Chott Range and Saharian Shelf) (Fig.1).

ATLANTIC MARGIN (WESTERN MOROCCO)

The Lower and Mid-Cretaceous evolution of the Western Moroccan Atlantic margin (Atlas Gulf) can be deduced from field sections situated in the northern part of the Essaouira—Agadir Basin: the Djebel Amsittene (Northern reverse flank of the Amsittene anticline, Carte Géologique du Maroc au 1/100,000, sheet Tamanar), the Zem Zem (Northern flank of the Zem Zem anticline, sheet Khemis des Meskala), the Imi'n Tanout (Djebel Lemgo, sheet Imi'n Tanout) and the Amizmiz (South of Amizmiz village) cross-sections.

Regional syntheses have previously been presented by Choubert and Faure-Muret (1962), Ambroggi (1963) and Duffaut et al. (1966), as well as the recent detailed analyses of the geologists from the german schools of Tübingen (Wiedmann et al., 1978; Butt, 1981; Jansa and Wiedmann, 1982; Wiedman et al., 1982) and Bonn (Behrens et al., 1978; Behrens and Siehl, 1982; Stets and Wurster, 1982). In the present revision we distinguish five main sedimentary units which we designate as megasequences (Figs.2 and 3).

Megasequence I (Portlandian—Berriasian)

Westward (Djebel Amsittene, Zem Zem), this first depositional unit corresponds to a dominantly carbonate inner-shelf formation (Timsilline Fm). It is organized into several decimeter thick shallowing upward sequences (marls → marly - limestones → limestones) which contain a microfauna (*Anchispirocyclina lusitanica* Eg., *Pseudocyclammina lituus* Yok., *Trocholina* gr. *alpina* and *T. elongata* Leup., *Feurtillia frequens* Maync. and a microflora (*Clypeina jurassica* Fav., *Actinoporella podolica* Alth., *Salpingoporella annulata* Car., *Thaumatoporella parvovesiculifera* Rain.) typical of the Late Jurassic and the Berriasian. A rich association of calpionellids found in the Djebel

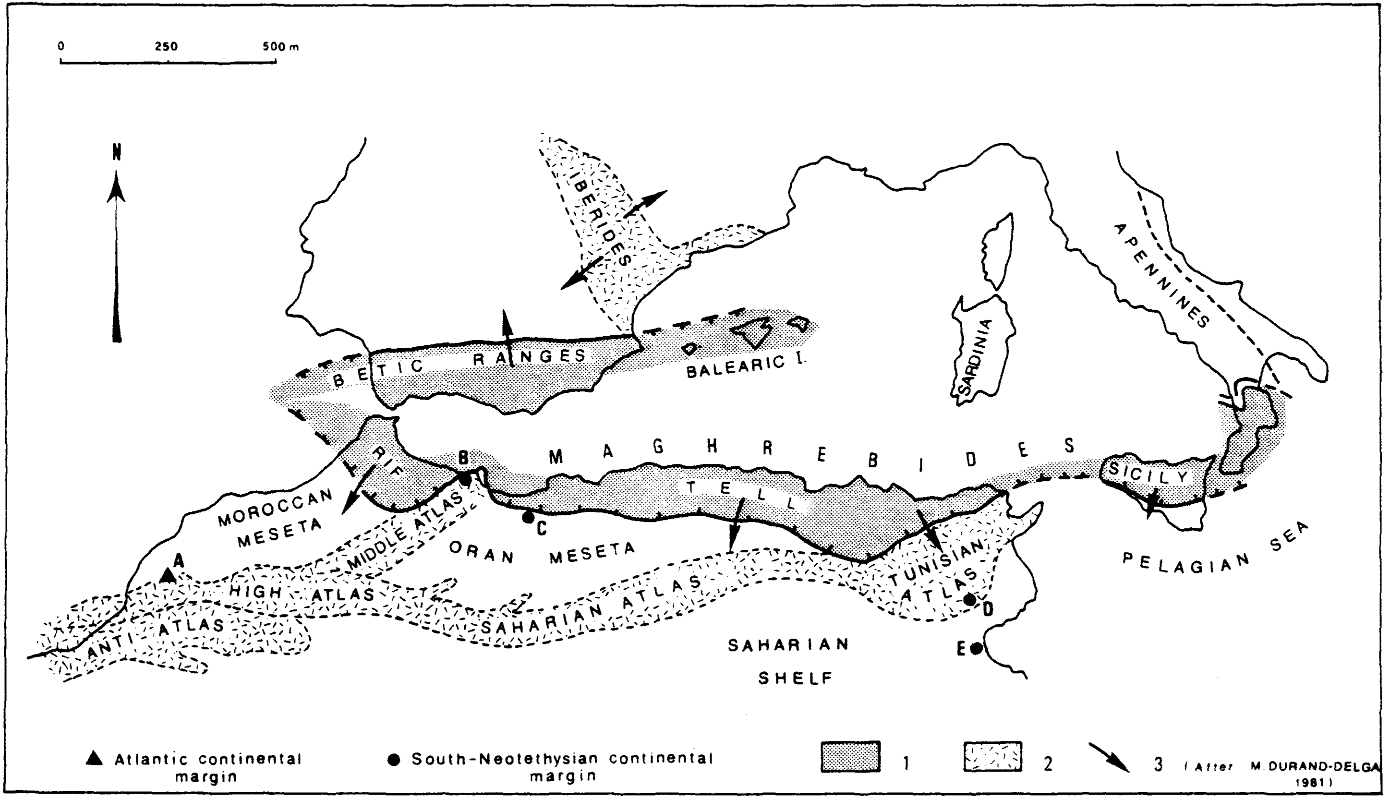


Fig.1. Structural map of the western Mediterranean Sea showing location of the different studied areas on the North African Margins. Atlantic margin: *A* = West Morocco (Essaouira—Agadir—Safi Basins); Neotethysian margin: *B* = North Morocco (Eastern Rif Foreland); *C* = West Algeria (Oran Meseta cover); *D* = South Tunisia (Chott Range); *E* = South Tunisia (Saharian Shelf).

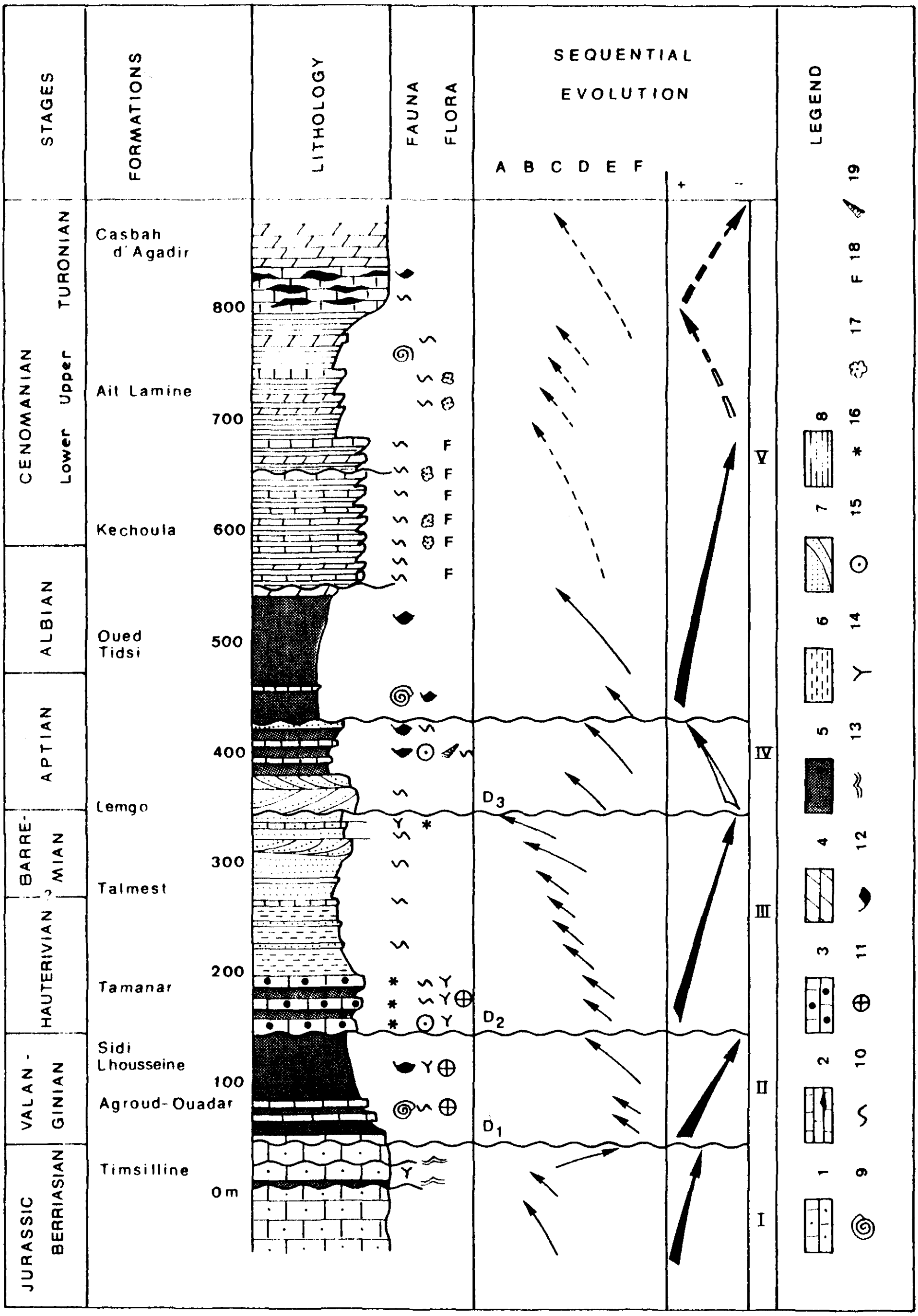


Fig.2. Synthetic section of the Zem Zem lower and middle Cretaceous sequences (West Moroccan Basin). *1* = bioclastic limestones; *2* = limestones with flint nodules; *3* = reef limestones; *4* = dolomites; *5* = marls; *6* = siltstones; *7* = sandstones; *8* = argillaceous marls; *9* = ammonites; *10* = ostreids; *11* = corals; *12* = brachiopods; *13* = stromatolitic layers; *14* = bryozoa; *15* = serpulids; *16* = echinids; *17* = dasycladacea; *18* = foraminifera; *19* = gastropods. Sequential evolution: *A* = continental; *B* = littoral; *C* = inner shelf; *D* = reef or middle shelf; *E* = outer shelf; *F* = basin. + = more marine; — = less marine.

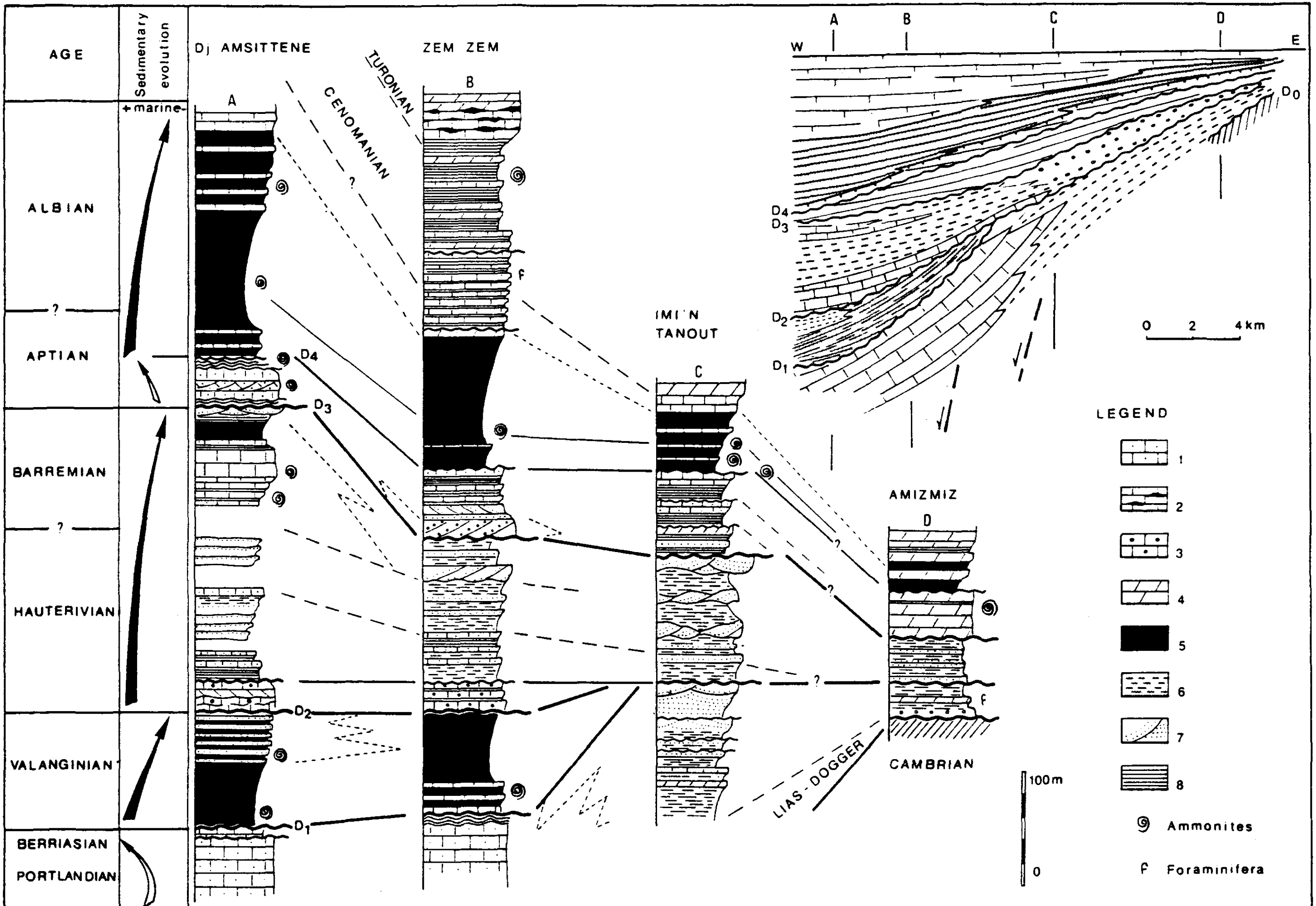


Fig.3. Stratigraphical and sedimentological correlations between the lower and middle Cretaceous sections of the Essaouira—Agadir Basin in the West Moroccan Margin. For explanation of the legend see Fig.2.

Amsittene (Brun, 1962) or near Safi (Canérot et al., 1982), as well as the presence of ammonites near Essaouira (Wiedmann et al., 1982) yield a Berriasian age for the upper layers of the carbonate formation.

Eastward, the shallow-marine Timsilline limestones and marls interfinger with fluviodeltaic argillaceous, silty, sandy, occasionally conglomeratic, pink or yellowish sediments gradually thinning towards the Atlas Hercynian core. In the area south of Amizmiz, the discovery of *Anchispirocyclina lusitanica* in a thin dolomitic level (Fig.3) proves that this terrigenous complex (reaching a maximum thickness of 40 m and overlying Cambrian schists) is a lateral equivalent to the western carbonate formation.

Megasequence II (Valanginian)

This second unit is represented by a thick (up to 200 m) greenish, mainly marly succession (Sidi Lhousseine Fm), rich in pelagic foraminifera (Wiedmann et al., 1978) and ammonites. It outcrops in the western part of the study area where it overlies the Timsilline limestones. The regional D1 discontinuity separates rocks of Berriasian and Valanginian age. In the Djebel Amsittene sections, the Sidi Lhousseine marls contain *Karakaschiceras biassalense* (Karak.), *K.* aff. *pronecostatum* (Felix), *Olcostephanus* gr. *atherstoni* Sharpe cf. var. *densicostata* Weg., *Thurmanniceras campylotoxum* (Uhl.) and *Kilianella (Luppovella)* gr. *superba* (Sayn.) in their lower part and *Cymatoceras* aff. *neocomiense* (D'orb.), *Kilianella* sp., *Thurmanniceras campylotoxum*, *Karakaschiceras biassalense*, *Olcostephanus psilostomus* (Neum. and Uhl.) sp. juv. and *O.* cf. *guebhardi* Kil. towards the top. These associations characterize the Lower Valanginian (*Campylotoxum* zone).

The Sidi Lhousseine marls suggest the sudden establishment of a Valanginian open-sea basin above the previous Berriasian shelf. This basin advances eastward as shown by the outer shelf Zem Zem limestones (Agroud Ouadar Fm) and deepened westward as indicated by the turbiditic slumped sandstones of the Djebel Amsittene (Fig. 3).

Megasequence III (Hauterivian—Barremian)

The Valanginian marls of the Djebel Amsittene are followed, through a hardground (D2 discontinuity), by a thick (more than 300 m) carbonate and terrigenous complex of three successive units forming a general filling-up megasequence:

— an Upper Valanginian ?/Lower Hauterivian reef complex (Tamanar Fm: 20—30 m) consisting of juxtaposed coral and bryozoa patch reefs, prograding bioclastic bars with *Choffatella* and algae and marls with ostreids and brachiopods;

— a terrigenous deltaic red succession (Talmest Fm: 150—200 m) showing many fining-upwards (sandstones → siltstones → clays → limestones) sequences. Their Hauterivian age suggested by Wiedmann et al. (1978) for the

Essaouira section, is also confirmed for the Zem Zem section based on echinids and brachiopods (Canérot et al., 1982);

— and finally carbonate lumachelle (Taboulaouart Fm) containing *Paraspiticeras percevali* (Uhlig), *Crioceratites* sp., followed by green marls with *Cymatoceras neocomiense* (D'Orb.), *Moutoniceras moutonianum* (D'Orb.), *Nicklesia pulchella* (D'Orb.), *Pulchellia compressissima* (D'Orb.), *Pulchellia* (?) aff. *reideli* (Burgl.) from the Lower Barremian (*Compressissima* and *Moutonianum* zones). Some sandy coastal bars cap this third carbonate unit with a thickness of about 50 m.

Hauterivian reef and deltaic deposits are represented in the Zem Zem area, overlain by a sandy coastal complex (Lower Lemgo bars) of Barremian age. Eastward, the terrigenous Hauterivian and Barremian complex onlaps the Tamanar reef complex, above the D1 discontinuity (Fig.3). The fluviatile character of these deposits also becomes stronger towards the east.

The D3 discontinuity covering this third megasequence, overlies various deposits (ferruginous incrustations of Amizmiz and Imi'n Tanout; Zem Zem dolomitic beds; purplish stromatolitic beds of the Djebel Amsittene) indicating the widespread emersion of the NW Atlas Gulf area towards the end of the Barremian or the beginning of the Bedoulian.

Megasequence IV (Aptian)

This depositional sequence of about 15—20 m thickness, corresponds to the progressive submergence and establishment of a new carbonate shelf (bioclastic limestones and dolomites, followed by nodular limestones and marls).

In the Djebel Amsittene, the sediments are mainly Bedoulian (Early Aptian) in age as indicated by the presence of *Neohibolites semicanaliculatus* (Blainv.), *Procheloniceras* cf. *stobieckii* (D'Orb.), *Cheloniceras* sp. juv. gr. *cornuelianum* (D'Orb.) and *Dufrenoyia* cf. *dufrenoyi* (D'Orb.) from the base of the sequence and *Procheloniceras* cf. *pachystephanum* (Uhl.) and *Cheloniceras* gr. *seminodosum* (Sinz.) towards the top. The incursion of marginal seas is diachronous to the east. This is indicated by the progressive influence of marine conditions within the Gargasian (limestones with *Cymatoceras* sp. and *Tropaeum* sp. of Zem Zem; limestones and marls with *Cheloniceras* (*Epicheloniceras*) sp., *Cheloniceras* (Epich.) cf. *subnodosocostatum* (Sinzow) and *Colombiceras* cf. *discoidalis* of the *subnodosocostatum* zone near Imi'n Tanout then within the Clansayesian; limestones and marls with *Pseudoaustraliceras* gr. *ramoseptatum* (Anthula)—*pavlovi* (Wass.), *Zuercherella* cf. *zuercheri* (Jacob and Tobler), *Uhligella toucasi* (Jacob), *Acanthohoplites* cf. *bergeroni* (Seunes), *Acanthohoplites* sp., *Nolaniceras* cf. *rigidus* (Breist.), *Nolaniceras* sp., *Hypacanthoplites* aff. *sigmoidalis* Casey, *H.* gr. *jacobi*—*plesiotypicus*, *H.* aff. *anglicus* Casey of the *Jacobi* zone in Imi'n Tanout; limestones with *Cymatoceras neckerianum* (Pict.), *Acanthohoplites* aff. *sigmoidalis* of this same *Jacobi* zone in Amizmiz.

The diachroneity of the Ammonite fauna documents the progressive eastward onlap of the carbonate shelf during the Aptian. The numerous small discontinuities and condensed layers shown at the top of the sequence in the Djebel Amsittene correspond in our opinion to missing stages linked to the abrupt rise of the sea level related to the eastward Aptian transgression.

Megasequence V (Albian—Cenomanian)

The last sedimentary unit studied is a well developed shallowing upwards sequence of more than 200 m which, in the Djebel Amsittene section, begins with green, circalittoral (external basin) marls (Oued Tidsi Fm) of the Lower Albian (*Protanisoceras* sp. and *Leymeriella* cf. *tardefurcata* beds of Wiedmann et al., 1978, in the Essaouira section), followed by beige, equally external, marls of the Mid-Albian (*Oxytropidoceras (O.) roissyanum* (D'Orb.) layers) and Vraconnian (*Pervinquieria* cf. *fallax* Breist. beds) times, then, finally, by limestones with benthic foraminifera and algae representing the establishment of a new generalized carbonate shelf by Cenomanian time (Kechoula and Ait Lanine Fm).

Eastward, the thickness of the marly Oued Tidsi formation gradually thins whereas, the carbonate facies of the Mid Cretaceous shelf appears progressively earlier (see Zem Zem and Imi'n Tanout sections, Fig.3).

Conclusion

The biostratigraphical and sedimentological analysis of the four reference sections from the Western Atlas Basin, from Djebel Amsittene, Zem Zem, Imi'n Tanout and Amizmiz reveal the main following features:

— a newly established correlation between the inner-shelf Timsilline limestones (Portlandian—Berriasian) and the fluvio-deltaic red to yellowish beds which, eastward, unconformably overlie the Atlasic hercynian core;

— the rapid establishment (D1 discontinuity) of the marly Valanginian basin in the Western part of the area studied;

— the eastward diachronous onlap (D2 discontinuity) of the Hauterivian to Barremian, fluvio-deltaic (Wealdian-type) complex;

— the generalized tendency of regression towards the Barremian to early Aptian (Bedoulian) transition (D3 discontinuity);

— the diachronous (eastward coastal onlapping) character and the general thinning of the Aptian carbonates;

— the numerous discontinuities towards the Aptian to Albian boundary, linked to the deepening of the basin and the eastward migration of the shelf edge;

— the strong subsidence (high sedimentation rates) during the deposit of the Oued Tidsi Albian marls;

— and finally the progressive establishment of the westward prograding carbonate shelf, during Albian to Cenomanian time.

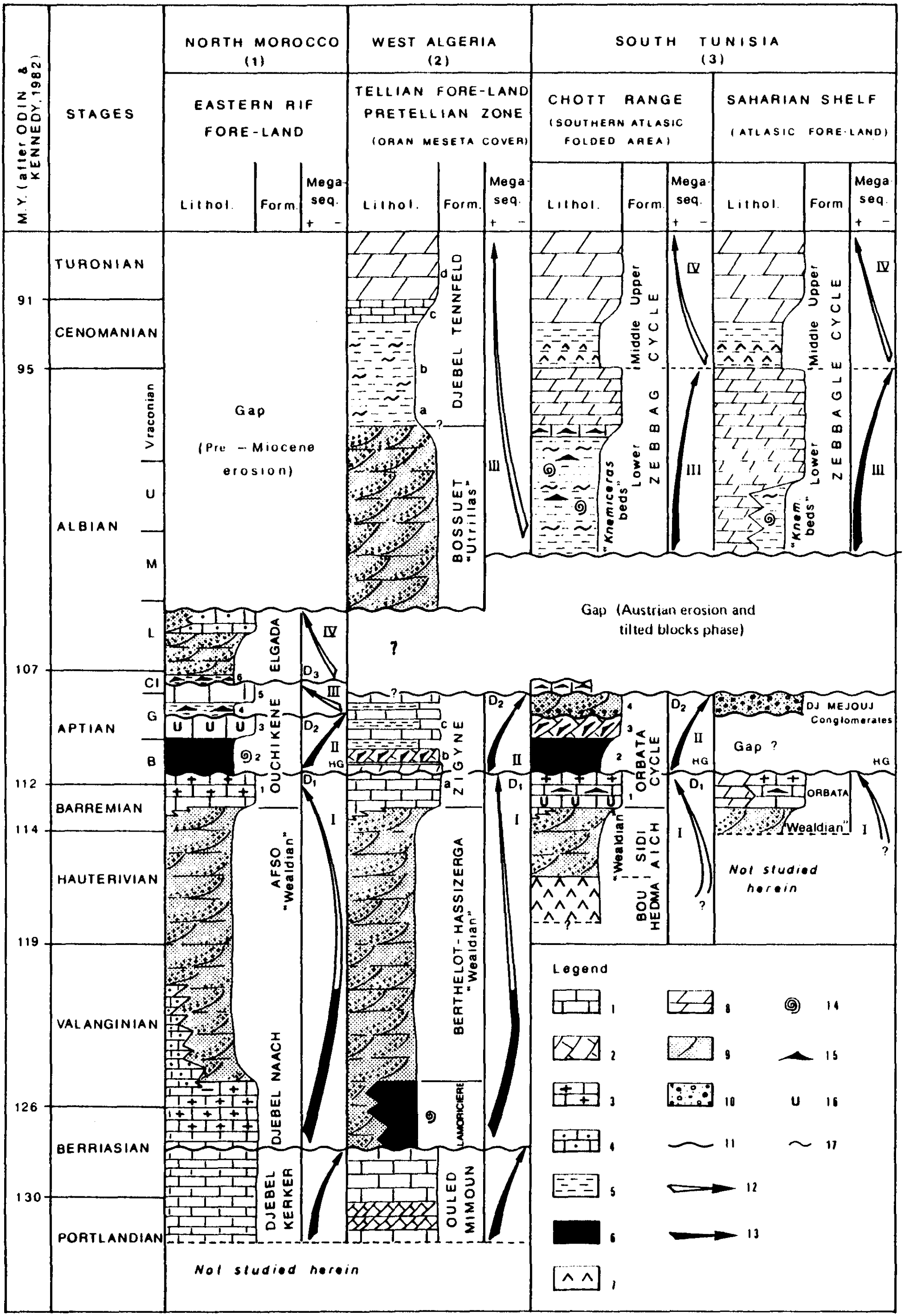
NEOTETHYSIAN MARGIN (NORTH MOROCCO, WEST ALGERIA, SOUTH TUNISIA)

North Morocco

Situated in an intermediate position between the Eastern Rif to the northwest and the Mid-Atlas to the south-southeast, the Rif foreland (Gareb Range) is characterized by a thick Lower Cretaceous sequence (Hamel, 1968) corresponding to the Berriasian—Albian interval. Cretaceous deposits younger than Albian are not known because this area was eroded before Miocene. The Early Cretaceous, not detailed here, was recently examined by Benest and Donze (1979, 1980). The Hauterivian—Albian interval, particular topic of our analysis (after the preliminary studies of Canérot et al., 1981, 1984 and of Cugny et al., 1984, partly interpreted again) corresponds to a post-Wealdian thick "Urgonian Complex" (about 400 m) which we subdivide into 4 megasequences separated by regional or local discontinuities. Only the second megasequence is regressive, the three others are transgressive.

Megasequence I (Valanginian ?/Hauterivian—Early Bedoulian)
This first sequence forms the transgressive part of the megacycle which has its base in the Upper Berriasian carbonate reef "Dj. Naach formation" (Benest and Donze, 1979 and 1980). Our discussion starts with the most fluviatile member (Upper Valanginian ?—Hauterivian) of the Wealdian complex, referred to as the "Afso sandstones" (250 m). In the Upper part of this complex (Hauterivian—Lower Barremian), prodeltaïc deposits (with marine fauna) first appear and progressively give way to carbonate bar facies of the "Marl and reef limestones with *Floridae* Algae" unit (110 m), first part of the "Ouchikene group" (see no. 1, section 1, Fig.4). The main discontinuity, called D1, corresponds to a hard-ground (not ferruginous) capping the last calcareous bed. This upper bed contains *Salpingoporella ? dinarica* Radoičić, a dasycladale prooving the Upper Barremian—Early Bedoulian (Lower Aptian) age of the upper part of the formation. Therefore, the D1 discontinuity is probably intra-Bedoulian.

Megasequence II (Middle Bedoulian—Early Gargasian ?)
This regressive, basin fill sequence of about 200 m begins by a sudden deepening marked by the accumulation of external terrigenous deposits belonging to the "*Deshayesites* and Echinid Marls" (no. 2). Subdivided into about twenty regressive sequences pelites → shelly/marly limestones and/or "orbitolinites", this basinal formation contains ammonites from the zone III and IV of Bedoulian (*Deshayesi* and *Bowerbanki* zones) with: *Deshayesites* gr. *deshayesi—weissi*, *Cheloniceras* gr. *cornuelianum—crassum*, *Tropaeum* sp. and *Epancyloceras* cf. *fractum* (Casey). In the Orbitolines-bearing beds we found abundant *Palorbitolina lenticularis* (Blum.) and, only to the top of the formation, *Praeorbitolina cormyi* Schroeder (Middle—Early Late Bedoulian).



M.Y. (after ODIN & KENNEDY, 1982)
STAGES
NORTH MOROCCO (1)
EASTERN RIF FORE-LAND
WEST ALGERIA (2)
TELLIAN FORE-LAND PRETELLIAN ZONE (ORAN MESETA COVER)
SOUTH TUNISIA (3)
CHOTT RANGE (SOUTHERN ATLASIC FOLDED AREA)
SAHARIAN SHELF (ATLASIC FORE-LAND)
Lithol.
Form.
Mega-seq.
+ −
TURONIAN
91
CENOMANIAN
95
Vraconian
U
ALBIAN
M
L
107
Cl
G
APTIAN
B
112
BARREMIAN
114
HAUTERIVIAN
119
VALANGINIAN
126
BERRIASIAN
130
PORTLANDIAN
Gap
(Pre – Miocene erosion)
DJEBEL TENNFELD
BOSSUET "Utrillas"
Middle Upper
ZEBBAG CYCLE
Lower
"Knemiceras beds"
"Knem. beds"
Gap (Austrian erosion and tilted blocks phase)
ELGADA
OUCHIKENE
AFSO "Wealdian"
DJEBEL NAACH
DJEBEL KERKER
ZIGYNE
BERTHELOT-HASSIZERGA "Wealdian"
LAMORICIERE
OULED MIMOUN
ORBATA CYCLE
"Wealdian"
SIDI AICH
BOU HEDMA
DJ MEJOUJ Conglomerates
Gap ?
ORBATA
"Wealdian"
Not studied herein
HG
D1
D2
D3
I
II
III
IV
Legend
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Not studied herein

The filling-up of the basin ends with the establishment of an Urgonian shelf corresponding to the "Rudistid limestone and dolomite" unit (35 m), including the successive development of bar facies, with madreporaria and rudistids followed by lagoon facies, with rudistids and dasycladales. The D2 discontinuity caps the megasequence.

Megasequence III (Upper Gargasian—Early Clansayesian ?)

This minor transgressive sequence of 70 m shows the evolution in the proximal environment, of a subsiding lagoon filled up by the "Lower mesorbitolinid Marl" unit (no. 4); containing *Orbitolina* (*Mesorbitolina*) *parva* Doug., *O.* (*M.*) *minuta*, Doug., *O,* (*M.*) *texana* (Roem.), with hemisphaeric embryo, and *Paracoskinolina tunesiana* Peybernès. This unit overlies a high-energy zone deposit of the "gravelly limestone" unit (no. 5).

Megasequence IV (Clansayesian proparte—Early/Middle ? Albian)

Also transgressive, this last megasequence (60 m) of the Gareb Cretaceous begins with deposits of subsiding lagoon/proximal basin that are similar in facies and microfauna to the oldest deposits of the previous megasequence. These deposits, forming the "Upper Mesorbitolinid marl" unit, contain abundant well-preserved dasycladales showing their internal character. The top of the megasequence IV reaches the distal shelf with the deposition of Vimport *Floridae* bioclastic limestones (*Paraphyllum primaevum* Lem., abundant). This evolution is perturbed by prodeltaic terrigenous deposits (El Gada cross-bedded red sandstones) which separate the two previously-mentioned fossiliferous levels. Therefore, the "El Gada sandstones" are also marine because they contain allodapic fragments of echinids, bryozoa and *Floridae* algae cemented by carbonate. The conspicuous continuity of sedimentation within the "Uper Mesorbitolinids marls" (Clansayesian) makes us tend to link them to Lower (—Middle ?) Albian rather than to a younger part of this stage. Nevertheless, no paleontological indication allows us to confirm this hypothesis. We could also imagine a younger age (Upper Albian: "Utrillas" facies) and the gap of the Lower/Middle Albian in connection with the well-known Austrian tectonic phase in numerous sections from Algeria and Tunisia.

Fig.4. Stratigraphical and sedimentological correlations between the Lower and Middle Cretaceous sections on the Neotethysian margin of North Morocco, West Algeria and South Tunisia. *1* = inner shelf limestones; *2* = carbonate bars with cross stratification; *3* = carbonate bars, madreporic reefs; *4* = outer shelf limestones; *5* = inner-basin marls and calcareous marls; *6* = outer-basin marls and calcareous marls; *7* = evaporites; *8* = dolomites; *9* = cross-bedded (fluvio-deltaic) sandstones; *10* = conglomerates; *11* = discontinuity (*HG* = Hard Ground); *12* = opening megasequence (+ = more marine; — = less marine); *13* = basin-fill megasequence; *14* = ammonites; *15* = orbitolinids; *16* = rudists (Urgonian facies); *17* = lamellibranchiata (lumachelle). (*1*): after Canérot et al. (1981, 1984) partly modified. (*2*): after Peybernès et al., 1984. (*3*): after Ben Youssef and Peybernès (1985).

West Algeria

Between the Tellian trough, with pelagic sedimentation, to the North (Djebel Tessala) and the continental realm, with fluviatile sedimentation, to the South (Saharian Atlas), the Pretellian Zone of the Oran region shows, in the Daïa Mounts, almost exclusively shelf-type Cretaceous facies with interbedded carbonates, marls and detritic fluvio-deltaïc deposits. The stratigraphy of the Lower/Middle Cretaceous has been well known since the works of Auclair and Biehler (1967). It was recently revised by Benest (1981) for the Late Jurassic—Early Cretaceous and by Peybernès et al. (1984) for the Barremian—Cenomanian interval. We will review this latter interval which corresponds to a thick sequence which we divide into three megasequences. These sequences are successively transgressive, regressive and again transgressive (section 2, Fig.4).

Megasequence I (Valanginian ?/Hauterivian—Early Bedoulian)

The thick basal sequence (up to 700 m) forms the transgressive part of a megacycle including the three following depositional units: "Lamoriciere clays" (distal terrigenous deposits, Berriasian—Valanginian transition); "Berthelot—Hassi Zegla sandstones" (Wealdian, Upper Berriasian ?—Lower Barremian); member (a) of the "Zigyne limestones" (Upper Barremian—Early Bedoulian). The main discontinuity (D1) capping the megasequence I is located above the lagoonal carbonates of the Zigyne unit, member (a), bearing dasycladales like *Salpingoporella ? dinarica*. Nothing proves that a gap corresponds to the discontinuity D1.

Megasequence II (Middle Bedoulian—Gargasian ?)

This regressive, basin-fill sequence successively includes members (b) and (c) of the Zigyne formation (100 m). A bar facies (b), more or less dolomitized, occurs at the base of this sequence and contains *Praeorbitolina cormyi* and *Palorbitolina lenticularis* cross-bedded "orbitolinites" (Middle Bedoulian). The sequence is capped by lagoonal facies (c) containing rarefied fauna (hyper salinity ?). The Gargasian age proposed for member (c) is based on continuous sedimentation with the underlying Bedoulian levels and on the last occurrence of *Choffatella decipiens* Schlumb. The sequence gradually thins and becomes more and more dolomitic towards the East (Djebel Tennfeld), close to an area (Frenda Mounts) corresponding to a high during Lower Cretaceous (Late Berriasian—Middle Albian).

Megasequence III (Middle/Late Albian—Turonian)

This last megasequence (100—120 m of thickness) is subdivided into two main depositional units, the "Bossuet sandstones" (fluvio-deltaic "Utrillas"-type deposits) at the base and the "Djebel Tennfeld carbonate formation" at the top. The transition between these two units is gradual. In sections such as the Djebel Cheguiga, where the Tennfeld unit is not completely transformed by dolomitization, it can be divided into four members which illustrate the transgressive evolution in the proximal realm: (a) versicoloured marls; (b) lumachellic marls (with ostracodes from Upper Albian/Cenomanian); (c) ovalveolinid, cuneoline and lituolidae limestones and dolomites (Middle/Upper Cenomanian); (d) massive dolomites forming a famous cliff (Upper Cenomanian ? — Turonian).

The presence of an important gap between the megasequences II and III is not paleontologically obvious as we do not know the exact age of the basis of the "Bossuet sandstones". If this gap exists, it is probably related to the Austrian tectonic phase as in other regions (cf. Tunisia, Spain, etc.). The Austrian tectonic phase is marked by widespread erosion followed by sandy accumulations on the Spanish "Utrillas" facies pattern. A main discontinuity D1 corresponds with this gap and in this region is marked by the sudden appearance of the "Bossuet sandstones" over the "Zigyne limestones" and their stratigraphic thinning towards the east (Djebel Tennfeld), close to the area of maximum erosion (Frenda Mounts).

South Tunisia

In the South of the Tunisian trough, the marine deposits of the Lower/Middle Cretaceous are an almost exclusively shelf-type facies, towards the south of the Gafsa Mounts, in the Chott Range (Southern Atlasic realm) and on the Saharian Shelf. Further studies recently undertaken by one of us (B. P.) in collaboration with the Office National des Mines and the Institut National de Recherche Scientifique et Technique of Tunisia (Peybernès et al., 1984; Ben Youssef and Peybernès, 1985) enabled us to improve the stratigraphy of the Barremian—Vraconian interval by a micropaleontological biozonation. This work allowed us to delineate the magnitude of the depositional gaps to propose a revised subdivision and to develop an improved correlation of the southern sequence with that previously established in the transitional shelf—trough realm of Central Tunisia (M'Rabet, 1981; Bismuth et al., 1982).

Southern Atlasic realm (Chott Range)

Lower/Middle Cretaceous strata crop out on both banks of the Chott El Fedjadj (in the Northern Range in the north and in the Tebaga of Kebili in the south) inside of a structural unit stretched between two main NW—SE fault zones: the South Tunisian Fault (or Gafsa Fault) in the northeast and the South-Atlas Fault in the southwest. The studied stratigraphic interval corresponds to the traditional formations created by Burollet (1956): "Sidi Aïch" (predominating sands and Wealdian facies), "Orbata" and "Lower Zebbag" (predominating carbonates) which represent three successive megasequences (I: transgressive, II and III: regressive).

Megasequence I (Barremian—Early Bedoulian)

The megasequence begins in the Wealdian-type fluviatile sands of the Sidi Aïch Formation and ends at the top of the member (1) of the Orbata Formation. In this sequence, we can follow the evolution, gradual (north) or abrupt (south), of these sands towards the proximal reef-type carbonates of the member (1; called Berrani) of the Orbata Formation. An important regional discontinuity D1, marked by a ferruginous hard-ground, caps the megasequence over the last Madreporaria biostromes. The middle part of the member "Berrani" can be assigned to the Barremian—Bedoulian transition because of the following association: *Palorbitolina lenticularis*, *Orbitolinopsis* gr. *cuvillieri—kiliani* and *Salpingoporella ? dinarica*. Towards the south, the Berrani member thins from 25 m in the Northern Range (Bir-Oum-Ali) to 3—4 m in the Tebaga of Kebili.

Megasequence II (Middle Bedoulian—Early Clansayesian)

The upper three members of the Orbata Formation are contained within this basin-fill sequence. We can observe the transition from distal basin facies (*Toxaster* marls, member 2, Middle/Upper Bedoulian) to bar facies (cross-bedded "orbitolinites", member 3, Lower Gargasian thanks to *O.* (*M.*) *parva*, alone), which become interbedded with fluvio-deltaïc facies and lagoonal/mangrove facies (with plant remains) (member 4, called Foum-El-Argoub) which contain sands with vertebrates and floated wood. This regressive megasequence corresponds, on the northern bank of the Chott, to a real megacycle: it is completed by a thin carbonated level (lagoonal) containing an Upper Gargasian/Clansayesian microfauna: *Paracoskinolina tunesiana*, *O.* (*M.*) *texana* with hemisphaeric embryo, *O.* (*M.*) *minuta* etc. Above, a regional discontinuity D2 caps the sequence before the deposit of the oldest "*Knemiceras* beds" (basis of the Zebbag Formation).

Megasequence III (Middle ?—Late Albian)

In this proximal basin-fill sequence, the "*Knemiceras* beds" (carbonates, clays and lumachelles of littoral facies) are progressively dolomitized. The dolomites forming the top of the sequence are primary (intertidal stromatolitic laminated levels). The age of the *Knemiceras* beds is Middle(?) and Upper Albian according to the numerous ammonites of this genus. They reach the Vraconian sub-stage at their top (association of the orbitolinids: *Simplorbitolina ? bronnimanni—Neoiraqia convexa*). This constrains the age of the discontinuity to the upper part of the Clansayesian and the lower part of the Albian.

Megasequence III, called "Lower Zebbag" may be correlative to the distal "Selloum sequence" of Central Tunisia (Bismuth et al., 1982).

Megasequence III is followed by Megasequence IV, which we have not studied here. The latter is a transgressive sequence (correlative to the "Ben Younes sequence" of Central Tunisia, cf. Boltenhagen and Mahjoub, 1974 and Bismuth et al., 1982); that records the evolution from evaporitic marls

(Lower—Middle Cenomanian) to the massive dolomitic Cliff (Upper Cenomanian—Turonian) well-known in these presaharian areas (Middle and Upper Zebbag Formation).

Saharian Shelf

In spite of the thinning of some marine levels, the Lower/Middle Cretaceous sequence of the Tebaga of Medenine and of the Northern part of Dahar records the same general pattern of deposition with the Chott sequence discussed above. The Megasequences I and III can be easily identified and present similar ages and sedimentologic evolutions:

— Megasequence I begins with the Wealdian-type sands and clays and ends with an equivalent of the Berrani member of the Orbata Formation (capped by an important hard-ground). The first marine level underlining the Lower Cretaceous on-lap is, like previously, Upper Barremian—Early Bedoulian;

— the base of the Albian transgression is also Middle (?)—Upper Albian, considering the local discovery (Chabet-El-Ouagli) of some meters of "*Knemiceras* beds" over megasequence I. This transgression seems to be better developed towards the south (Guermessa and Bir-Hiteur sections) with an overflowing of the Albian beds over the Wealdian (but this direct overlap is not paleontologically constrained).

The main difference between the Chott Range and the Saharian Shelf lays in the discontinuity of megasequence II. Maybe, the latter could only be partial if the lenticular Dj. Mejouj conglomerates (with Permian pebbles), intercalated between the two discontinuities D1 and D2, locally distinct, are a proximal equivalent of the Foum-El-Argoub sands.

Conclusion

The detailed biostratigraphic analysis of the Lower/Middle Cretaceous of South Tunisia (Chott Range, Saharian Shelf) reveals the following data:

— the stratigraphic discontinuity, of variable duration, removed much of the Aptian and Lower Albian. It corresponds to the Clansayesian pro-parte/ Lower to Middle (?) Albian interval in the Chott Range, to the Middle Bedoulian/Lower—Middle ? Albian interval on the Saharian Shelf (with probable Southward pinching out of the marine infra-Albian beds). This gap is not an isolated fact in Tunisia: we can also find it, with a variable amplitude, in Central Tunisia, in the Kasserine area for example (Bismuth et al., 1982) where Vraconian/Upper Albian overlaps variable levels of Aptian or Albian. We can explain this gap with the distensional movements of the Austrian phase (Chihi et al., 1984), at the origin, during Late Aptian and Albian, of tilted blocks (limited by NW—SE faults) of which the tops are eroded or emerged;

— the Gargasian age of the fluvio-deltaïc sands capping the Orbata Formation in the Chott Range. This regressive episode in the middle part of the

Aptian corresponds to the sudden fall of the global sea-level during the Upper Gargasian (Vail et al., 1977);

— the Middle (?)—Upper Albian age of the first level of the Albian on-lap, the "*Knemiceras* beds" forming in these areas (up to the Gafsa Mounts) the basis of the Zebbag formation.

COMPARISONS

The stratigraphical and sedimentological analysis outlined above form the basis for the correlations of events within the Lower and Middle Cretaceous successions studied in Western and Northern Morocco, Western Algeria and Southern Tunisia.

These data reveal some common features in the geodynamic evolution of the different North African areas such as (Figs.5 and 6):

— the generalization of stable shelves in the Latest Jurassic—Early Cretaceous (Portlandian—Berriasian) and at the end of the Middle Cretaceous (Cenomanian—Turonian) times. The first one is covered by shallow marine carbonates interfingering with terrigenous, deltaïc, then continental sediments (Purbeckian beds) towards the emerged bordering areas. The latter one presents on the contrary a completely carbonate cover;

— the manifestation of important discontinuities towards the top of the

AGE	STAGES	ATLANTIC EVENTS	ATLANTIC MARGIN	TETHYSIAN EVENTS	S. NEOTETHYSIAN MARGIN	
CENOMANIAN	VI	OPENING	STABLE CARBONATE SHELF		STABLE CARBONATE SHELF	UTRILLAS
ALBIAN	V		SUBSIDENT ARGILLACEOUS BASIN		AUSTRIAN TECTONICS	
APTIAN U			THIN CARBONATE SHELF	RIFTING	URGONIAN SHELF	
APTIAN L	IV		INTRA APTIAN TECTONICS		BEDOULIAN BASINS	
BARREMIAN		RIFTING				
HAUTERIVIAN	III		EUSTATIC TRANSGRESSION (carbonates weald clastics)		EUSTATIC TRANSGRESSION	WEALD.
VALANGINIAN						
	II		NEOCIMMERIAN TECTONICS		NEOCIMMERIAN TECTONICS	
BERRIASIAN						
PORTLANDIAN	I		STABLE CARBONATE SHELF		STABLE CARBONATE SHELF	PURBECK.

Fig. 5. Main lower and middle Cretaceous scenarios on the Atlantic and Neotethysian margins of North Africa.

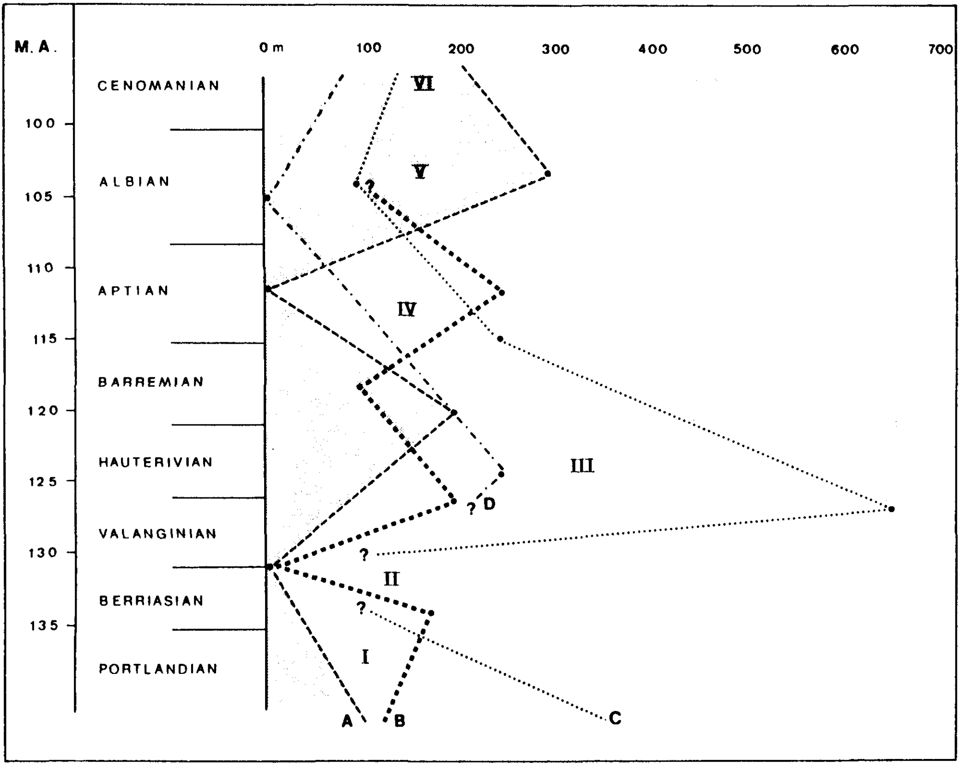


Fig.6. Sedimentation rate during the main stages of the lower and middle Cretaceous evolution of the Atlantic (curve *A*) and Neotethysian (curves *B*, *C*, *D*.) margins of North Africa. (stages I—VI: see Fig.5).

Berriasian and the beginning of the Aptian times, underlain by important modifications in the conditions of sedimentation. These modifications are uniform (Berriasian) or radically opposed (Bedoulian time) on both margins.

We can see in this common evolution the mark of an undeniable influence of eustatism in the northern edge of the African continent. Nevertheless, important differences entitle us to distinguish:

(1) An *Atlantic-type evolution* recognized through the basin-fill sequences of the Western Moroccan Basin and characterized by:

— an important discontinuity towards the Berriasian—Valanginian boundary, related to the Neocimmerian rifting stage;

— a clear thinning of the thickness of the Aptian sediments. Works in progress show that this supply decrease can, at least locally (Oued Tlit), be attributed to diapiric activity linked to the distensions preceding the oceanic opening;

— finally the progressive acceleration of subsidence during the Gargasian, Clansayesian and especially the Albian, due to the removing of the mid-oceanic doming.

(2) A *Neotethysian-type evolution* illustrated within the Early and Middle Cretaceous history of the Eastern Rif Foreland, the Algerian Daïa Mountains and the South Tunisia where local distensive movements could be considered as responsible of:

— the sudden intra-Bedoulian emergence of marly basins, subsequently or laterally filled up by Urgonian carbonates;

— the important spreading of the terrigenous, Wealdian-type discharges in the Valanginian—Early Barremian interval;

— and finally the probable Albian emergence related to the distensive Austrian faulting and followed by a strong erosion inducing the arrival of the detrital "Utrillas" sediments shortly after.

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