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LITHOSTRATIGRAPHY OF THE LITTORAL DEPOSITS OF THE LAST ONE MILLION YEARS IN THE CASABLANCA REGION (Morocco)

Jean-Pierre TEXIER*, David LEFÈVRE**, Jean-Paul RAYNAL*
et Mohssine EL GRAOUI***

ABSTRACT

Littoral deposits of the Casablanca region have provided most of the stratotypes for the Quaternary marine «stages» of the Maghreb. A part of these deposits is the subject here of a new lithostratigraphic approach mainly based on the study of facies association, as well as diagenetic processes. This has permitted the identification of ten (possibly twelve) high-resolution sequences. These units all probably accumulated over the last million years. The sequences are progradational and, most of the time, record a relatively straightforward history. They result from an abrupt rising followed by a gradual falling of the sea level. Sedimentary structures indicate upper shoreface (sometimes), foreshore, backshore and aeolian dune depositional environments. Runoff and mud- or debris-flow are probably the main processes involved in the deposition of the slope deposits intercalated in this stratigraphic series. Moreover, the results show that the classic chronostratigraphic framework so far used in the Maghreb is inadequate because of incorrect correlations and chronological attributions, previously unidentified formations and the definition of distinct «stages» from the same stratigraphic unit. In view of these problems, this classic framework must be abandoned.

Key-words : Morocco, Casablanca region, littoral deposits, lithostratigraphy, chronostratigraphy, last one million years.

RÉSUMÉ

LITHOSTRATIGRAPHIE DES DÉPÔTS LITTORAUX CONTEMPORAINS DU DERNIER MILLION D'ANNÉES DANS LA RÉGION DE CASABLANCA (Maroc)

Les dépôts littoraux de la région de Casablanca ont fourni la plupart des stratotypes ayant servi à la définition des «étages» quaternaires marins du Maghreb. Une partie de ces dépôts fait ici l'objet d'une nouvelle approche lithostratigraphique basée sur l'étude des associations de faciès et des processus diagénétiques. Ces travaux ont permis d'identifier dix (peut-être douze) séquences haute-résolution. Tous ces dépôts se sont probablement formés au cours du dernier million d'années. Les séquences sont de type progradant et, la plupart du temps, enregistrent une histoire relativement simple. Elles résultent d'une élévation rapide suivie d'une descente graduelle du niveau marin. Les structures sédimentaires témoignent de milieux de type subtidal supérieur (parfois), intertidal, supratidal et dunaire. Le ruissellement ainsi que les coulées de boue ou de débris sont probablement les principaux mécanismes sédimentaires impliqués dans la formation des dépôts de versant intercalés dans cette série stratigraphique. Les résultats obtenus montrent également l'inadéquation du cadre chronologique classique utilisé jusqu'à présent au Maghreb. En effet, celui-ci implique des corrélations et des attributions chronologiques indues, la définition d'«étages» distincts à partir de dépôts appartenant à une même unité stratigraphique et ne tient pas compte de formations intercalées entre des «étages» successifs. A cause de tous ces problèmes, ce cadre chronologique doit être abandonné.

Mots-clés : Maroc, région de Casablanca, dépôts littoraux, lithostratigraphie, chronostratigraphie, dernier million d'années.

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INTRODUCTION

In the region of Casablanca (Morocco), the development of Quaternary littoral deposits has been exceptional. These deposits provide most of the stratotypes for the Maghreb sequence of Pleistocene marine «stages» (Biberson, 1961). The present study concerns a coastal fringe of 2-3 km wide and about 20 km long between the Anfa district (West of Casablanca) and the locality of Dar Bou Azza to the southwest (fig. 1). As a result of urban building work and quarrying in this area, it has been possible to determine precisely the nature and the configuration of the formations present and to observe, in most cases directly, their stratigraphic relationships. In this way, a reliable lithostratigraphic framework for the deposits attributed until now to the Maarifian, Anfatian, Amirian, Harounian, Tensiftian, Ouljian, Soltanian and Mellahian (Biberson, 1961) has been established. The period of time covered by these deposits has not been defined with any certainty. However, chronological markers (Geraads, 1994 and in press ; Rhodes *et al.*, 1994 ; Texier *et al.*, 1994) suggest that they cover about the last one million years.

PREVIOUS RESEARCH AND THE PROBLEMS RAISED

Lecointre (1916) first recognised the Quaternary age of certain of the consolidated littoral deposits of Morocco. In 1926, he defined five stages on the basis of altitude and palaeontology which he correlated with those identified around the Mediterranean (Sicilian, Milazzian, Tyrrhenian, Monastirian and Flandrian). This was followed in 1941 by Neuville and Ruhlman who carried out detailed stratigraphic research on the littoral formations of Casablanca. On the basis of this work, they defined four shorelines at similar heights to those recognised in Algeria and Southern Italy. Adopting Depéret's principle of altimetric correlation, they interpreted these as equivalent to the Mediterranean stages. However, this interpretation was heavily criticised by Bourcart (1943) who took the opposite view that Quaternary marine deposits consisted of a unique assemblage formed exclusively by transgression foreshore deposits followed by complete remodelling during the retreat of the sea. Bourcart later abandoned this extreme hypothesis and admitted with Choubert and Marçais that the Quaternary comprises «three distinct complexes, separated by erosions» (Bourcart *et al.*, 1949).

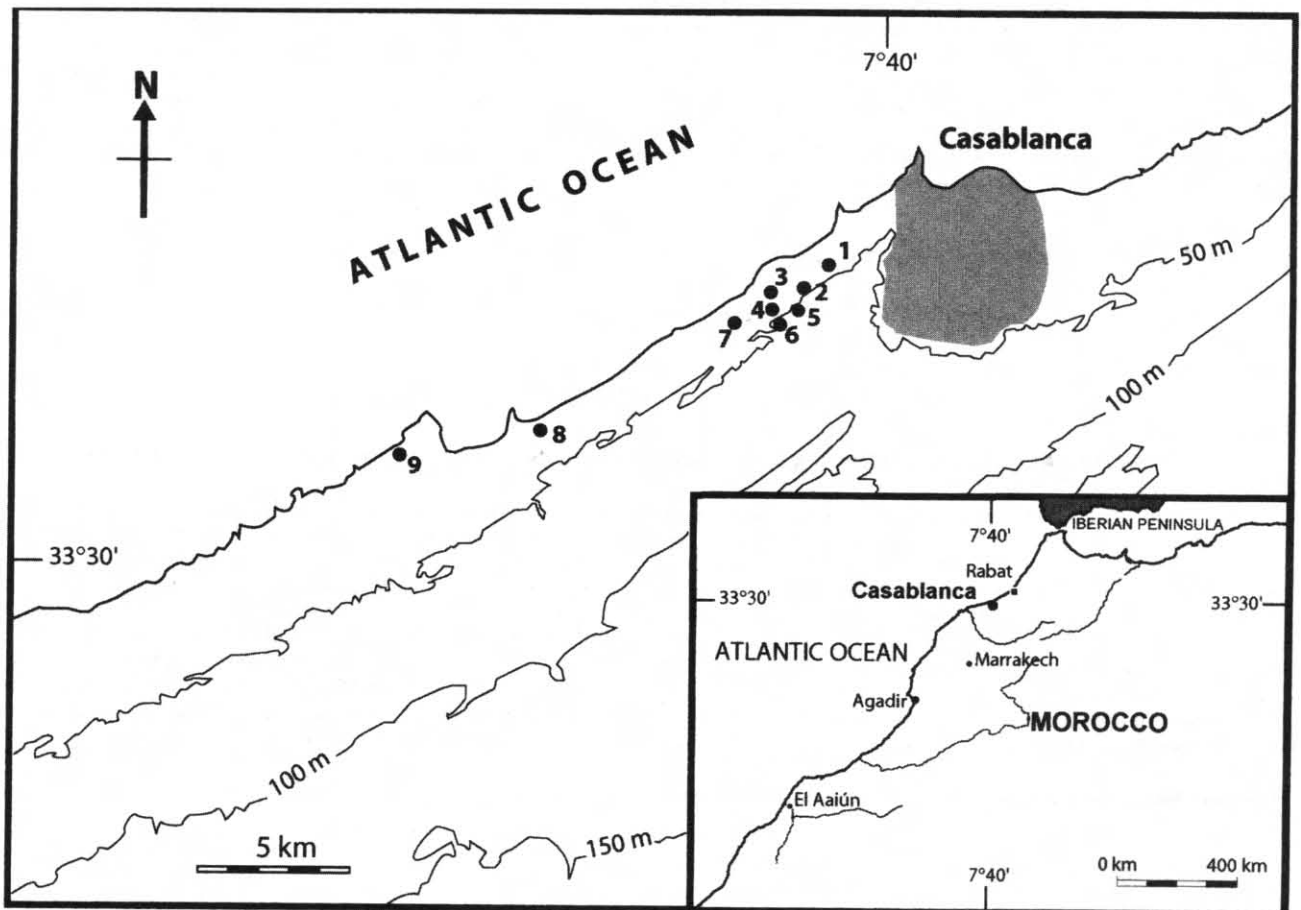


Fig. 1 : Geographical situation of the research area and the localities quoted in the text.

1 : La Cunette – 2 : Sidi-Abderrahmane Grande Exploitation – 3 : Sidi-Abderrahmane Extension – 4 : S.T.I.C. – 5 : Thomas I – 6 : Oulad Hamida – 7 : Kef El Haroun – 8 : Reddad Ben Ali – 9 : Dar Bou Azza.

Fig. 1 : Localisation géographique de la zone d'étude et des localités citées dans le texte.

1 : La Cunette – 2 : Sidi-Abderrahmane Grande Exploitation – 3 : Sidi-Abderrahmane Extension – 4 : S.T.I.C. – 5 : Thomas I – 6 : Oulad Hamida – 7 : Kef El Haroun – 8 : Reddad Ben Ali – 9 : Dar Bou Azza.

Recognising the existence of a series of «raised beaches» all along the Moroccan coast (*e.g.* Gigout, 1951 ; Lecointre, 1952 ; Dresch *et al.*, 1952), researchers subsequently began to take tectonic influences into account. It was recognised that the age of beaches decreased with decreasing altitude, but the latter could vary from one region to the other. Only the lowest shoreline was situated at a constant height of 5-8 m. Gigout (1949) designated this level as a «stage» and called it Ouljian.

After a few attempts to construct a coherent regional chronostratigraphic framework (Gigout, 1958 ; Gigout and Raynal, 1957), it was Biberson who, in 1961, established the basis of the scheme which came into widespread use for the Maghreb (Table 1). Biberson's work covered the same geographical area, south and west of Casablanca, as that studied by Neuville and Ruhlman in 1941. He defined several shorelines between 100 and 5-8 m and their relative age from the Lower to the Upper Pleistocene. Biberson interpreted each shoreline as a distinct Quaternary «stage» which he designated with local names. Dune and various terrestrial formations occurring between the marine stages were attributed to continental stages defined in other regions of Morocco (*e.g.* Choubert *et al.*, 1956).

More recently, in 1978, Stearns developed a mainly morphological and altimetric approach to studying this region, and he found three, possibly four, unidentified coastlines between the Maarifian and the Anfatian. Moreover, he tried to correlate all these stages with the oxygen isotopic stages from an estimate of the rate of uplift of Moroccan Meseta. More recently, taking into account all the new information obtained on the Atlantic coast of Morocco, Texier *et al.* (1985) attempted both to redefine the chronostratigraphic terminology and to correlate the revised framework thus established with the European stages.

The principal aim of all these exercises has been to establish a usable chronostratigraphic reference system for as broad a geographical base as possible. However, the data from which these schemes have been constructed are unsatisfactory for such an ambitious objective. Morpho-sedimentary responses to global climatic changes are infinitely variable from one region to another. Furthermore, recent tectonics, which has variable character and importance along the coast (*e.g.* Griboulard, 1980 and 1983 ; El Foughali and Griboulard, 1985), makes long distance correlations based simply on elevation illusory. These difficulties, as well as the problem of converging facies, cannot be at present overcome either by absolute datings or by faunal and archaeological associations. Indeed, the former are not numerous enough and their accuracy and potential are insufficient. Changes in the latter are not fast enough to characterise a formation or a specific level. Finally, it should be noted that the definition and characterisation of sedimentary environments have almost been entirely ignored in previous research.

All these considerations have led us to begin new basic research in a region which remains exceptional in the number of its recorded geological events and which is

| Marine stages | Continental stages |
|---------------|--------------------|
| | Rharbian |
| Mellahian | |
| | Soltanian |
| Ouljian | |
| | Tensiftian |
| Anfatian | |
| | Amirian |
| Maarifian | |
| | Saletian |
| Messaoudian | |
| | Villafranchian |

Table 1 : Chronostratigraphic framework of the Moroccan Quaternary according to Biberson (1961, modified).

Table 1 : Cadre chronostratigraphique du Quaternaire marocain selon Biberson (1961, modifié).

widely recognised as important for understanding human origins and prehistoric cultures. A first attempt to synthesize our results has been previously published (Texier *et al.*, 1994). Nevertheless, it has not been possible to set out all the arguments, explanations and implications in this preliminary note. Moreover, in this new proposal, new absolute dates are taken into account and a more important emphasis is put on cartographic criteria to define the formations (*sensu* Hedberg, 1976).

METHODS

The subdivisions and stratigraphic hierarchies proposed in this research conform to the international guidelines established by Hedberg (1976). The successions and associations of facies (*sensu* Walker, 1992) have been used to characterise the depositional environments, their evolution, and to infer the sea level changes. Along this part of the coast, this approach has been facilitated by the existence of huge sections which often extend several hundred meters laterally (sometimes more than a kilometre) and more than ten meters in height. The correlations and stratigraphic successions proposed here are based principally on direct observation of the contacts seen in exposures. Altimetric measurements have been made by theodolite and have been connected to the general contouring system for Morocco.

Microfacies studies (El Graoui, 1994) have provided specific information about diagenetic processes occurring during and after deposition. This analysis has been carried out from large thin sections (13,5 x 5,5 cm) cut in blocks of oriented sediments vacuum-impregnated with polyester resin, as in the technique devised by Guilloché (1980). The terminology used to describe these carbonated sediments is that of Dunham (1962) and the Elf-Aquitaine Group (1975 and 1977). Characterisation of the diagenetic environments has been based on widely acknowledged criteria (*e.g.* Purser, 1973, 1980, 1983 ; Sellwood, 1986). Finally, the terminology used to name calcareous continental crusts is adapted from that defined by Freydet and Verrecchia (1989) and by Vogt (1983).

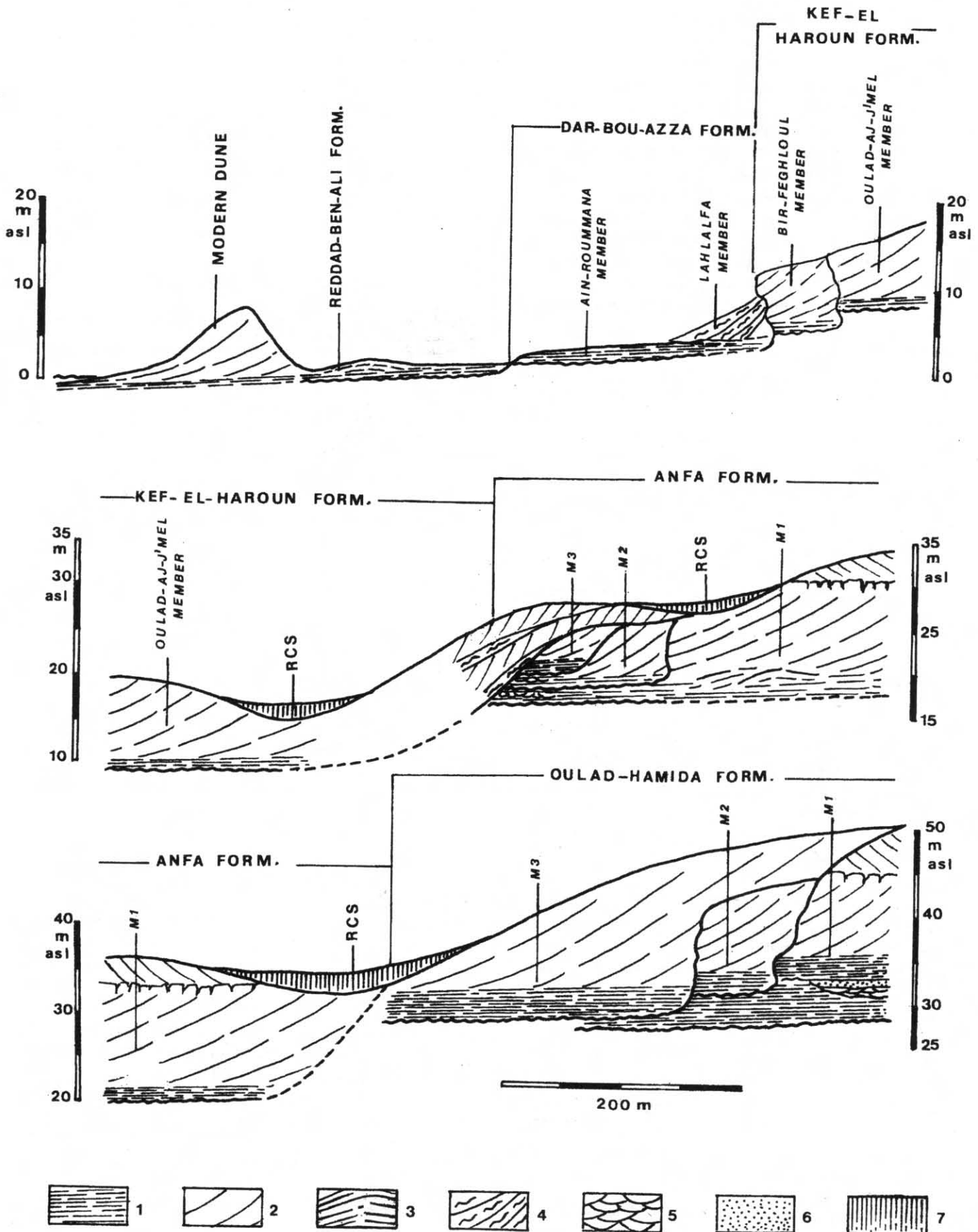


Fig. 2 : Morpho-stratigraphical scheme of Quaternary littoral deposits in the southwestern area of Casablanca.

1 : intertidal deposits - 2 : dune deposits - 3 : backshore deposits - 4 : slope deposits - 5 : cross-bedded deposits - 6 : massive calcarenite - 7 : red clayey sands.

Fig. 2 : Schéma morpho-stratigraphique des dépôts littoraux localisés au sud-ouest de Casablanca.

1 : dépôts intertidaux - 2 : dépôts dunaires - 3 : dépôts d'arrière plage - 4 : dépôts de pente - 5 : Dépôts à stratifications entrecroisées - 6 : calcarénite massive - 7 : «limons rouges».

RESULTS

The morphostratigraphic relationships between the different sedimentary units are shown schematically in figure 2. The deposits from the oldest to the most recent are described below.

THE OULAD HAMIDA FORMATION

This formation takes its name from the Oulad Hamida area, and it has been defined in Thomas Quarry 1. It consists of three inset, consolidated members named from the oldest to the youngest M1, M2 and M3, respectively.

Member M1 of the Oulad Hamida Formation

It is composed of the following beds from bottom to top respectively (fig. 3) :

- **Bed 1** : It consists of evenly parallel laminae of coarse bioclastic sands gently dipping toward the sea. They are deposited in a foreshore environment and rest on a cretaceous limestone bedrock. Their thickness varies from 2 to 3 m and they are situated between 32 and 35 m elevation. At the microscopic scale, the different kinds of cement and the processes of dissolution observed in this grainstone indicate a regressive diagenetic sequence. This begins with an early phase of lithification in sub- to intertidal conditions as indicated by iso- and anisopaque fringes of acicular microsparite around certain bioclasts (fig. 4). There is then a phase of cementation under continental phreatic conditions as shown by the equant calcite which fills the intergranular voids (fig. 4). Finally, a phase of dissolution of carbonates and deposition of ferruginous coatings occurs in a continental vadose environment.

- **Bed 2** : The lower part of this unit (2 to 3 m of thickness) consists of fine to coarse locally trough cross-bedded sands and calcareous mudstone. This material forms sequences into little inset channels orientated parallel to the coastline. In the upper part of these channels are seen features due to hydration-desiccation alternations (platy structure levels), to exundation (thin laminar calcareous crusts), to drying phenomena (fissural polygonal network emphasized by ferric oxides) and to bioturbation (rootlet marks associated to ferric coatings). These deposits are interpreted as evidence of an intermittently flowing braided stream.

At the upper part of this bed, there are 1.5-3 m of bioclastic sands more or less bioturbated, partially decarbonated and cemented. These have a mainly massive or nodular structure and incorporate numerous land snails and root traces. They probably represent aeolian deposits which accumulated in damp vegetated depressions. The microfacies corroborate this interpretation. Indeed, the constituents elements are well sorted and rounded ; moreover, as is usual in an aeolian deposit (Purser, 1980 ; 1983), the limestone fragments are markedly broken down and micritised.

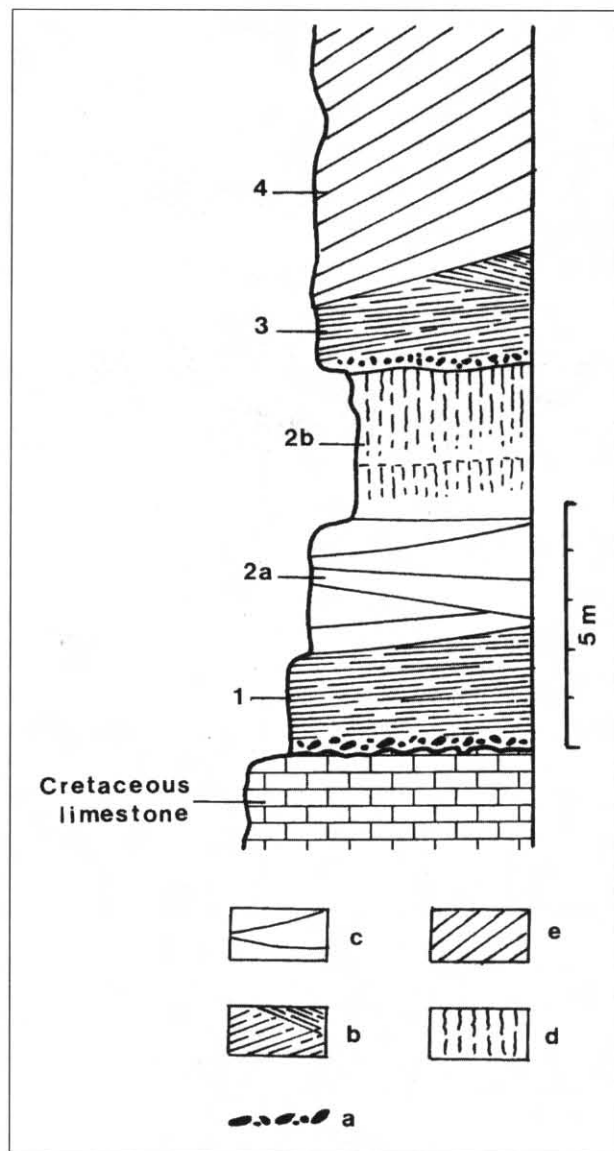


Fig. 3 : M1 Member of the Oulad Hamida Formation : stratigraphic log (1, 2, 3 and 4 correspond to the different beds observed in this stratigraphic unit ; 2a and 2b are the lower and the upper parts of Bed 2 respectively).

a : conglomeratic deposits - b : bioclastic sands showing seaward- or landward-dipping plane laminations - c : deposits showing large-scale trough cross bedding - d : bioturbated and concreted sands - e : bioclastic sands with large-scale cross bedding.

Fig. 3 : Membre M1 de la Formation d'Oulad Hamida : log stratigraphique (1, 2, 3 et 4 désignent les différents niveaux observés dans cette unité stratigraphique ; 2a et 2b désignent respectivement les parties inférieure et supérieure du niveau 2).

a : conglomérat - b : sables bioclastiques à lamines planes inclinées vers la mer ou vers l'intérieur - c : dépôts à stratifications entrecroisées de grande dimension - d : sables bioturbés et concrétionnés - e : sables bioclastiques à grandes stratifications entrecroisées.

Bed 2 has yielded an abundant early Acheulean industry (Raynal and Texier, 1989 ; Raynal *et al.*, in press) associated with numerous mammalian remains (Geraads, in press). It displays a reverse polarity (Sen, *in litteris*) and has yielded four OSL dates : $1,380 \pm 390$ Ky ; 804 ± 227 ky ; 747 ± 390 ky and 989 ± 208 Ky (Rhodes, *in litteris*).

- **Bed 3** : This unit consists of evenly bedded coarse bioclastic sands, gently sloping seaward or, locally and

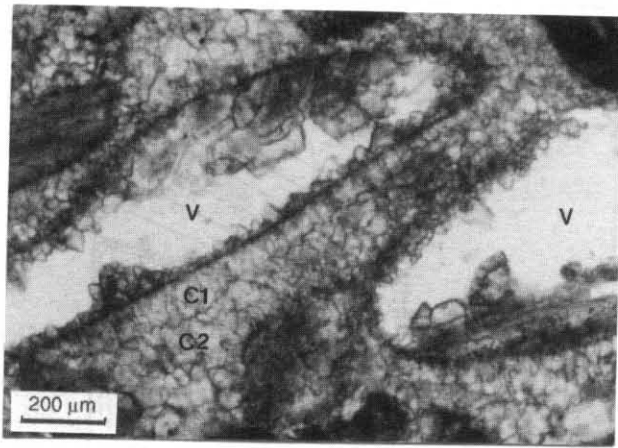


Fig. 4 : M1 Member of the Oulad Hamida Formation. Microfacies of Bed 1 (PPL).

The bioclasts are partially dissolved and recrystallised. Their original forms are underlined by a micritic envelope. The early cement (C1) consists of fibrous crystals with a microstalactitic arrangement ; it formed in vadose marine conditions. A later cement (C2) composed of equant calcite probably formed in a freshwater phreatic environment (V : voids).

Fig. 4 : Membre M1 de la Formation d'Oulad Hamida. Microfaciès du niveau 1 (LN).

Les bioclastes sont partiellement dissous et recrystallisés. Leurs formes sont soulignées par une enveloppe micritique. Le ciment précoce (C1), constitué de cristaux fibreux en microstalactites, s'est formé en contexte marin vadose. Un ciment plus tardif (C2), représenté par des cristaux sparitiques isogranulaires, enregistre un environnement phréatique d'eau douce (V : vides).

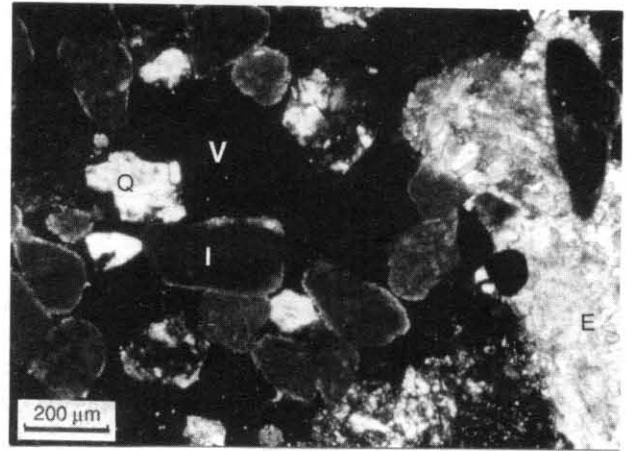


Fig. 6 : M3 Member of the Oulad Hamida Formation. Microfacies of the aeolian deposits (XPL).

The porosity (V) is highly developed. The intergranular cement remains only in the places where echinoderm fragments (E) exist. The isoclasts (I) have been preserved from dissolution. They show recrystallised edges and plane intergrain contacts. The quartz grains (Q) are corroded.

Fig. 6 : Membre M3 de la Formation d'Oulad Hamida. Microfaciès des dépôts éoliens (LP).

La porosité (V) est importante. Le ciment intergranulaire n'est conservé qu'aux endroits où subsistent des fragments d'échinodermes (E). Les isoclastes (I) ont été préservés de la dissolution. Leurs bords sont recrystallisés et les contacts intergrains sont de type plan. Les grains de quartz (Q) sont corrodés.

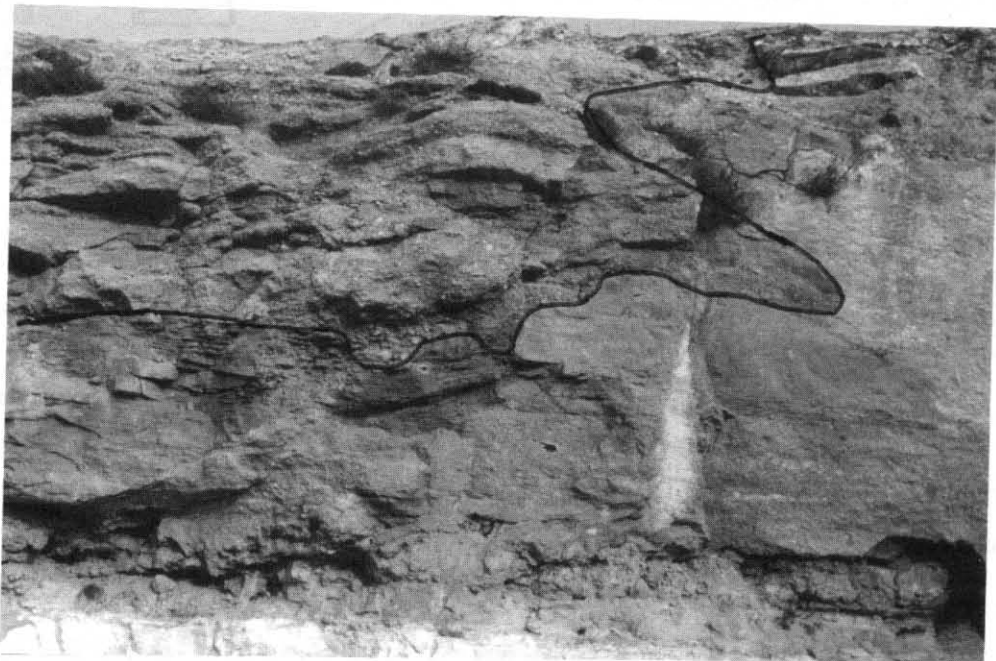


Fig. 5 : Oulad Hamida Formation : M3 shoreline (outlined) is cut into M1 and M2 Members.
Fig. 5 : Formation d'Oulad Hamida : la ligne de rivage de M3 (soulignée) est découpée dans les membres M1 et M2.

in more inner situations, landward. They are 1-2 m thick and at their base incorporate pebbles and blocks derived from underlying beds. Observed at between 31-35 m altitude, these deposits are considered to be intertidal and supratidal. They record an early phase of cementation in a marine vadose environment (formation of anisopaque fringes of acicular microsparite around the clasts),

then the lithification continues under continental vadose conditions (partial filling of the voids by a microsparite mosaic).

- **Bed 4 :** This comprises coarse bioclastic sands, 10 m thick, with large-scale cross bedding characteristic of dune deposits. As in the upper part of Bed 2, the car-

bonated constituents are markedly disrupted and micritised. They are cemented by microsparite formed under continental vadose conditions. Towards the summit, in conjunction with superficial pedogenesis, dissolution is significant and ferruginous coatings have been noted in the voids.

Member M2 of the Oulad Hamida Formation

This member fits into Member 1 in which it cuts a shoreline (fig. 2). It was correlated with the "Anfatian" of La Cunette at Sidi-Abderrahmane by Biberson (1961) on the basis of its molluscan fauna (Table 2 and *infra*).

Resting on a marine erosion platform, it comprises :

- a conglomerate of pebbles and large blocks at the base,

- 1 to 1,5 m of coarse bioclastic sands interstratified with gravelly layers and showing plane bedding of intertidal character,

- and, at the upper part, 2 to 3 m of calcarenites with a finer texture and large-scale cross bedding characteristic of aeolian deposition.

The intertidal deposits occur at an altitude of between 32 and 35 m.

They were affected by an early cementation in a vadose marine environment (anisopaque fringe of acicular calcite crystals around some bioclasts) and by dissolution-precipitation phenomena developed under continental vadose conditions (dissolution voids more or less infilled by a microsparitic cement). The lithification of the dune deposits is characterised by an early micritic cement coating the clasts. This particular type of cement, perhaps biochemical in origin, has been observed to the north in the biocalcarenes of the Rabat region and has been connected with the presence of an herbaceous vegetation cover (Akil et Gayet, 1984). A later phase of cementation is also present. It is characterised by a micritic cement related to the circulation of vadose meteoric waters.

Member M3 of the Oulad Hamida Formation

It is associated with a shoreline cut into Members M1 and M2 (fig. 2 and 5). It consists of medium sands less bioclastic than those of M2. These sediments are organised as follows :

- at the bottom, in parallel beds slightly dipping seaward and locally showing load structures (2 m thick),

- at the upper part, in large-scale planar cross beddings (about 10 m thick).

This member corresponds to foreshore deposits passing without disconformity into dune accumulation. The former lies between 29 and 32 m elevation.

On a microscopic level, M3 is distinguished from the previous members by the sandy grains which are characterised by an abundance of quartz and isoclasts (pellets and micritised bioclasts) as well as a scarcity of recognisable bioclasts. These characteristics indicate sediments which have been reworked for a long time by littoral currents (Purser, 1980, 1983). These deposits have undergone a diagenesis in a continental vadose context. This is expressed in the intertidal deposits by a microsparitic

cement developed in the intergranular voids and, in the dune deposits, by more or less complex dissolution-precipitation phenomena with formation of microsparitic cements, development of voids and plane intergranular contacts (fig. 6).

THE ANFA FORMATION

Fitted about 10 m into the Oulad Hamida Formation, the Anfa Formation has been described from the deposits exposed in the Sidi-Abderrahmane quarries (Cunette and Grande-Exploitation) situated in the Anfa district of Casablanca (fig. 1). It has also been partly recorded in the neighbouring quarry formerly known as S.T.I.C. quarry. It includes three distinct members named M1, M2 and M3 from the oldest to the youngest respectively (fig. 2).

Member M1 of the Anfa Formation

It comprises deposits previously attributed to the «Maarifian and Amirian stages» (Biberson, 1961). This formation rests on Cretaceous limestone or Cambrian quartzites on an erosion surface associated with a marine conglomerate. At present, the following sequence may be observed from bottom to top (fig. 7) :

- Strongly consolidated coarse bioclastic deposits locally including pebbles. Their thickness varies from 1 to 3 m and their elevation is between 17 and 20 m. The sedimentary structures include trough cross bedding (fig. 8) and plane parallel bedding sloping seaward or, locally, landward. Their lateral and vertical succession indicate upper shoreface, foreshore and back-shore environments.
- Then, without disconformity, biocalcarenic dune deposits with large-scale cross bedding overlie the preceding layer. They are 15 m thick and are less coarse than the earlier. They comprise two superimposed units separated by a slight disconformity. A flowstone from a karst cavity situated at the base of the dunes has been dated to 409 ± 88 Ky by the U/Th method (Schwarcz, *in litteris*). The dune deposits have an OSL age of 577 ± 73 Ky (Rhodes, *in litteris*).

The diagenetic processes ascertained by micromorphological work are complex. They consist of phases of cementation occasionally associated with recrystallisation phenomena, alternating with more or less marked episodes of dissolution. The most noteworthy processes to be pointed out are :

- an early phase of cementation affecting the base of the deposits and occurring in phreatic and vadose marine conditions as indicated by fibrous calcite fringes around the clasts (fig. 9) ;

- a phase of cementation and recrystallisation throughout most of the formation caused by phreatic freshwater (intergranular voids filled by a mosaic of equant calcite crystals) (fig. 10) ;

- and several phases of cementation under freshwater vadose conditions as shown by the deposition of a meniscus microsparitic cement and by ferruginous coatings formed at a later stage in dissolution voids (fig. 10).

| LITHOSTRATIGRAPHIC UNITS | | CHRONOLOGICAL DATA | ¹⁸ O STAGES | CLASSIC CHRONO-STRATIGRAPHIC ATTRIBUTIONS (Biberson, 1961) |
|--------------------------|--|--|------------------------|--|
| Reddad Ben Ali Formation | | 1.29 ± 0.27 Ky to 4.72 ± 1.17 Ky (1) | 1 | Mellahian |
| Dar Bou Azza Formation | - Lahalfa Member | Aterian Industries (20 to 40 Ky) | 2 to 4 | Unidentified |
| | - Aïn Roummana Member | Aminogroup O (2) | 5 | Ouljian |
| Kef El Harour Formation | - Dune deposits Bir Feghloul Member | 164 ± 36 Ky (3) | 7 (?) | Unidentified |
| | - Tidal deposits | | | |
| | - Dune deposits Oulad Aj J'mel Member | 324 ± 112 Ky (3) 394 ± 276 Ky (3) | 9 or 11 (?) | Anfatian |
| | - Tidal deposits | 355 ± 121 Ky (3) | | |
| Anfa Formation | - Upper Bed Member 3 | | 10 (?) | Presoltanian & Tensiftian |
| | - Lower Bed | | | Anfatian |
| | Member 2 | | to | Unidentified |
| | - Dune deposits Member 1 | 577 ± 73 Ky (3) > 409 ± 88 Ky (4) | 18 (?) | Amirian Maarifian |
| Oulad Hamida Formation | Member 3 | | 18 (?) | Unidentified |
| | Member 2 | | | Anfatian |
| | - Bed 4 | | to | Unidentified |
| | - Bed 3 | Reverse Polarity (5) 1,380 ± 390 Ky (3) | | |
| | Member 1 - Bed 2 | 989 ± 208 Ky (3) | | Amirian |
| - Bed 1 | 804 ± 227 Ky (3) 747 ± 390 Ky (3) | 22 (at least) | Maarifian | |

- (1) OSL datings (Rhodes, this issue) and ¹⁴C datings (Occhietti *et al.*, 1993)
- (2) From Occhietti *et al.*, 1993
- (3) OSR datings (Rhodes, *in litteris*)
- (4) U/Th dating (Schwarcz, *in litteris*)
- (5) Sen, *in litteris*

Table 2 : Lithostratigraphical units defined in the Casablanca Region : chronological data, correlations with marine isotope stages and previous chronostratigraphical attributions (from Biberson, 1961).

Table 2 : Unités lithostratigraphiques définies dans la région de Casablanca : données chronologiques, corrélations avec les stades isotopiques de l'oxygène et précédentes attributions chronologiques de Biberson (1961).

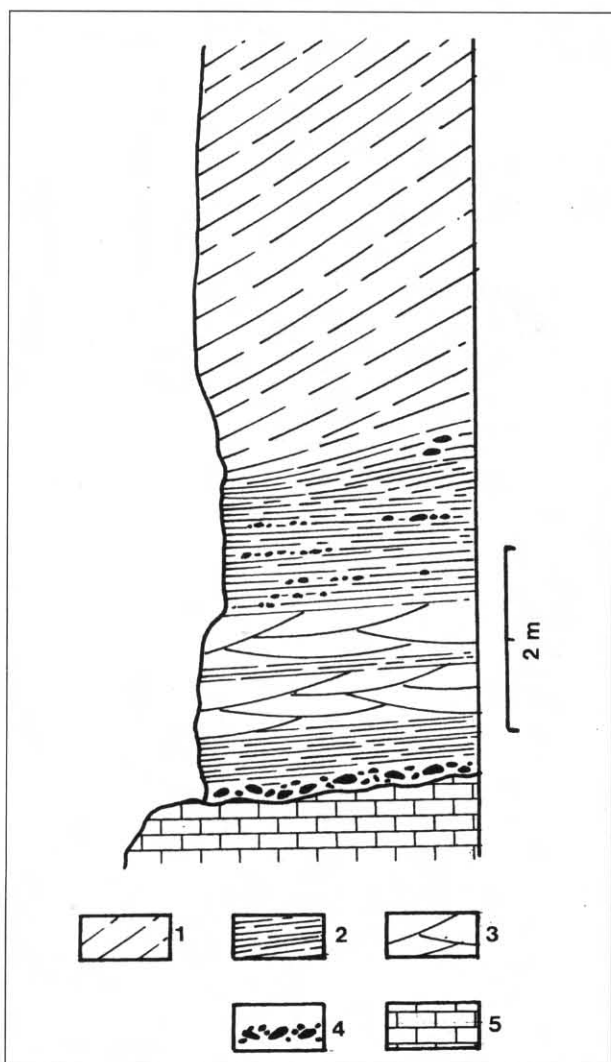


Fig. 7 : Stratigraphic log of M1 Member of the Anfa Formation. 1 : bioclastic sands with large-scale cross bedding. 2 : bioclastic sands showing seaward-dipping even laminations. 3 : trough cross-bedded bioclastic sands. 4 : gravels and pebbles. 5 : Cretaceous limestone.

Fig. 7 : Log stratigraphique du Membre M1 de la Formation d'Anfa. 1 : sables bioclastiques à grandes stratifications entrecroisées. 2 : sables bioclastiques à lamines régulières inclinées vers la mer. 3 : sables bioclastiques à stratifications en auges. 4 : granules et graviers. 5 : calcaire crétacé.

It is necessary to stress that, in the SW part of the Sidi-Abderrahmane quarry (Grande Exploitation), Neuville and Ruhlman (1941) observed a succession of levels (their levels K, L, M, N, O) which were intercalated between the substratum and the above-described deposits. As a result of the continuation of quarry's working, these levels were destroyed and never found again. From bottom to top, they comprised strand deposits (levels M, N and O) then, deposits probably of estuarine or lagoonal type (considering the malacofauna yielded by the level L) and finally a 15 cm thick sandy deposits (level K).

Member M2 of the Anfa Formation

It cuts a shoreline into M1. Its base is marked by an erosional surface situated between 18 and 20 m elevation. It consists of medium to coarse sands less bioclastic than

those of M1. Thickness varies from several decimeters to 3 m. A sequence of subtidal, intertidal and dune deposits may be recognised. They are characterised by trough cross bedding, parallel plane bedding sloping seaward and large-scale cross bedding, respectively.

At the microscopic scale, the composition of the sand grains appears quite similar to that of Member 3 of the Oulad Hamida Formation. This material consists mainly of markedly micritised bioclasts, pellets and quartz (fig. 11), suggesting that it was probably subjected to a long and intense phase of reworking prior to deposition. Early diagenetic changes on intertidal deposits took place in a vadose marine environment, whereas those on the dunes occurred in vadose continental conditions.

Member M3 of the Anfa Formation

This member includes the two beds described below.

The Lower Bed was previously described as the stratotype of the "Anfatian stage" (Biberson, 1961). It butts up against a coastline (fig. 12) formed in Members M1 and M2 and rests at an altitude of between 20 and 23 m. It is mainly composed of siliceous gravels and coarse cemented bioclastic sands organised in plane, parallel seaward sloping beds which often display a reverse grading (fig. 13). They were probably laid down in an intertidal zone close to the mouth of a wadi which supplied abundant gravelly material. The reverse-graded beds (fig. 13) show the same characteristics as the "traction carpets" described by Lowe (1982) for coarse-grained sandy high-density flows in which dispersive pressure and sieve effect play an important role. The same diagenetic processes as those observed in M2 have affected these deposits. The transition to the Upper Member is gradual.

The Upper Bed consists of bioclastic sands with large-scale cross bedding. It has a variable component of coarse elements : calcarenitic rock debris derived from M1, and siliceous gravels from the Lower Bed. These rock-debris and gravels are either dispersed throughout the deposits, or sometimes occur as distinct layers several meters wide. This Upper Member is interpreted as a climbing dune laid against the coastline associated with the Lower Bed. Rockfall processes as well as run-off processes (stone layers) have likely interfered with the aeolian process itself.

Weathering has affected these deposits. It may concern their whole thickness (4-5 m) and sometimes extends down to the top of the Lower Bed. Moreover, a succession of calcaric horizons develop from the top to the bottom of the unit : at the top, a laminar crust several centimeters thick ; then a massive and nodular calcrete 0,5-0,75 m thick ; lower down a laminated and nodular calcrete of 1-1,5 m thickness ; finally, a discontinuous nodular crust about 1,5 m thick.

This stratigraphic unit was attributed to the «Tensifian» and to the «Pre-Soltanian» by Biberson (1961) (table 2). It incorporates abundant artefacts of Upper and Final Acheulean industries, as well as faunal remains (Biberson, *op. cit.*).

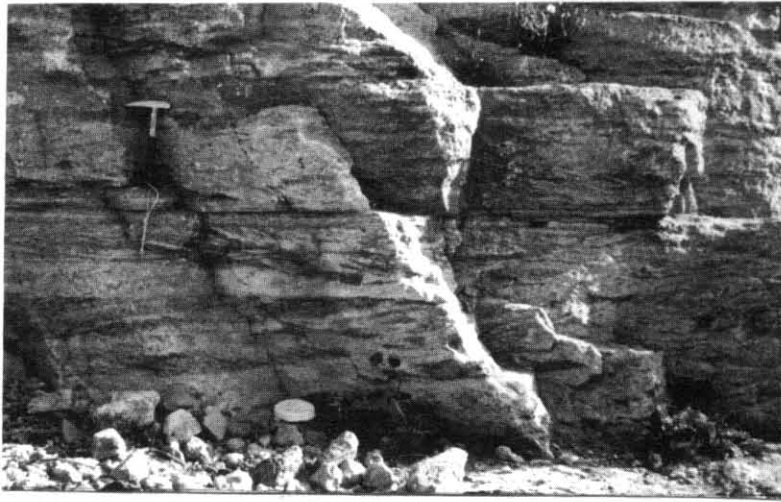


Fig. 8 : Subtidal deposits of M1 Member of the Anfa Formation (Hammer : 28 cm).
Fig. 8 : Dépôts subtidaux du Membre M1 de la Formation d'Anfa (Marteau : 28 cm).

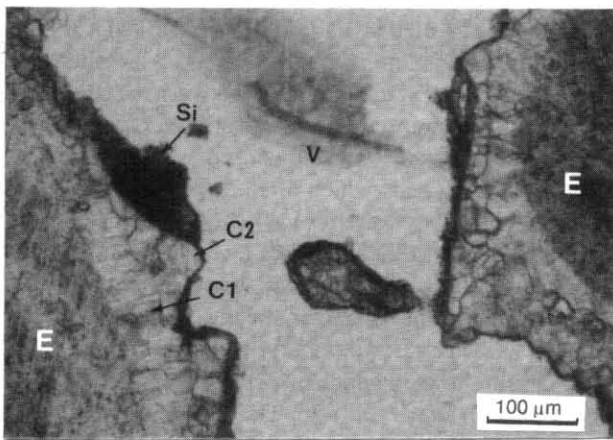


Fig. 9 : M1 Member of the Anfa Formation. Microfacies of the intertidal deposits (PPL).

The early cement consists of an isopaque fringe of fibrous crystals formed in a phreatic marine environment (C1). It has been preferentially preserved around fragments of echinoderm (E). The phase of cementation (C2) which took place in vadose freshwater conditions is here only locally preserved. Late dissolution provides vughs and chambers (V) coated with a ferruginous deposit (Si).

Fig. 9 : Membre M1 de la Formation d'Anfa. Microfaciès des dépôts intertidaux (LN).

Le ciment précoce est représenté par des revêtements isopaques de cristaux fibreux formés en contexte marin phréatique (C1). Il a été conservé préférentiellement autour des fragments d'échinoderme (E). La phase de cimentation (C2) qui se produit en milieu vadose d'eau douce, n'est ici visible que localement. Une phase de dissolution tardive a occasionné de grands vides (V) de type «vugh» et «chambers» revêtus par un dépôt ferrugineux (Si).

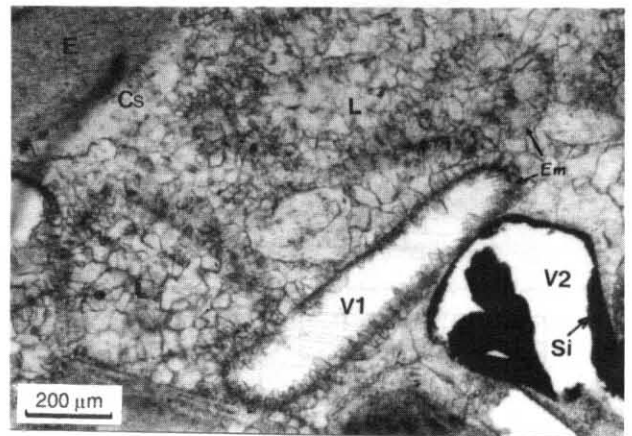
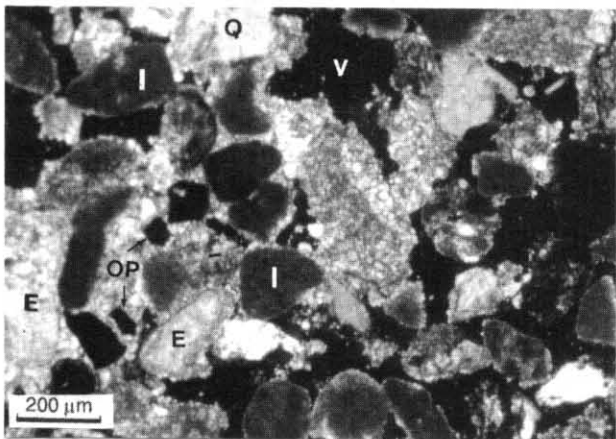


Fig. 10 : M1 Member of the Anfa Formation. Microfacies of the intertidal deposits (PPL).

Fragments of lamellibranchia have been dissolved (V1) or recrystallised (L). Their original form is stressed by a partially preserved micritic envelope (Em). The intergranular cement consists of an equant calcite formed in phreatic freshwater conditions. A syntaxitic calcite (Cs) has developed around the echinoderm fragments (E). Dissolution provides vughs (V2) coated by ferruginous deposits (Si) formed during a late diagenetic phase.

Fig. 10 : Membre M1 de la Formation d'Anfa. Microfaciès des dépôts intertidaux (LN).

Les fragments de lamellibranches ont été dissous (V1) ou recristallisés (L). Leur forme originelle est soulignée par une enveloppe micritique (Em) partiellement conservée. Le ciment intergranulaire est constitué par de la calcite isogranulaire formée en contexte phréatique. Des cristaux syntaxiques de calcite (Cs) se sont développés autour des fragments d'échinodermes (E). Une phase de dissolution tardive a occasionné des vides (V2) revêtus par des dépôts ferrugineux (Si).



← Fig. 11 : M2 Member of the Anfa Formation. Microfacies of the intertidal deposits (XPL).

The deposits consist of a grainstone rich in isoclasts (I), quartz grains (Q) and opaque minerals (OP). Bioclasts (B) are rare. The cement comprises a mosaic of microsparitic crystals which partially fill the intergranular voids.

Fig. 11 : Membre M2 de la Formation d'Anfa. Microfaciès des dépôts intertidaux (LP).

Les dépôts sont de type grainstone, riches en isoclastes (I), grains de quartz (Q) et minéraux opaques (OP). Les bioclastes (B) sont rares. Le ciment est constitué par une mosaïque de cristaux microsparitiques qui remplissent partiellement les vides intergranulaires.

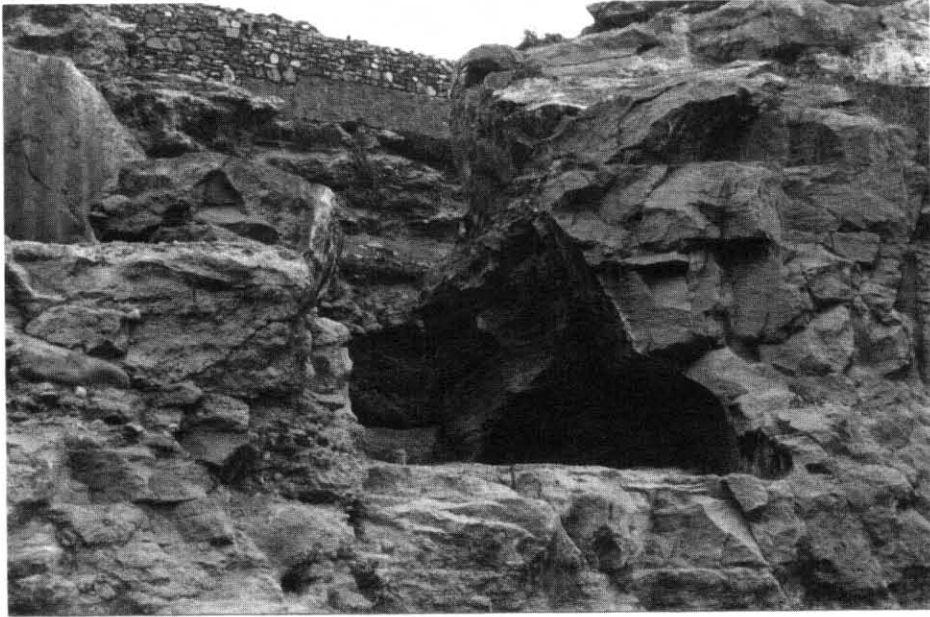


Fig. 12 : The M3 shoreline (about 6 m high) cut into M1 of the Anfa Formation at Cap Chatelier.

Fig. 12 : Ligne de rivage de M3 (environ 6 m de haut) inscrite à l'intérieur de M1 de la Formation d'Anfa au Cap Chatelier.

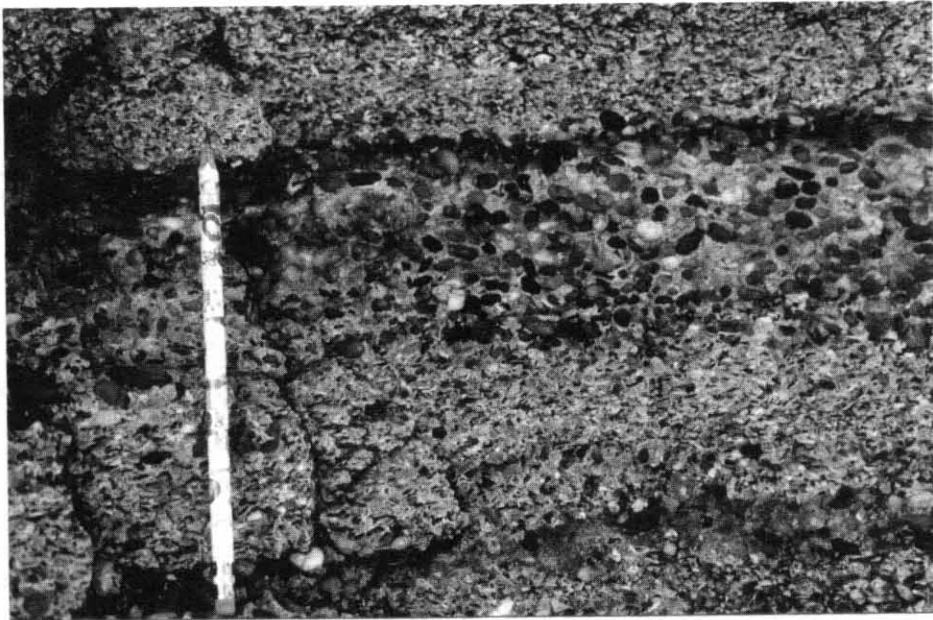


Fig. 13 : Member M3 of the Anfa Formation : example of reverse graded layers (Pencil : 17 cm).

Fig. 13 : Membre M3 de la Formation d'Anfa : exemple de lits à granoclassement inverse (Crayon : 17 cm).

THE KEF EL HAROUN FORMATION

This formation has been described from sections located in the Kef El Haroun area (fig. 1). It is embedded about 10 m into the Anfa Formation (fig. 2) and rests on Cambrian quartzites. It comprises two distinct members named Oulad Aj J'mel Member and Bir Feghloul Member from the oldest to the youngest respectively.

The Oulad Aj J'mel Member

At the type locality, it comprises a basal marine conglomerate overlain by 1 to 2 m of coarse evenly laminated bioclastic sands deposited in a foreshore environment

and, at the top, 10 m of calcarenite with large-scale cross bedding of dune type. The tidal deposits are positioned between 9 and 11 m elevation and has an OSL age of 355 ± 121 ky (Rhodes, *in litteris*). The superimposed aeolian deposits has been dated to 324 ± 112 Ky by the same method (Rhodes, *in litteris*).

The diagenetic transformations vary from bottom to top of the Oulad Aj J'mel deposits. At the base of the intertidal sediments, they are related at first to a phreatic marine environment (isopaque fringes of fibrous calcite crystals), then to a phreatic fresh water context (equant calcite cement). At the top of these foreshore deposits, cementation phenomena imply vadose marine then vadose continental conditions. Finally, dune deposits

record processes of carbonate redistribution in connection with circulation of vadose meteoric waters (dissolution of some bioclasts, development of a meniscus microsparitic cement).

In the Sidi-Abderrahmane quarry, are visible deposits which are superimposed on Members 1, 2 and 3 of the Anfa Formation and which can be correlated with the Oulaj Aj J'mel Member. It consists of beds (0,5-1,50 m thick) of large-scale cross-bedded bioclastic sands alternating with layers of 0,75 cm thickness composed of heterometric rock-fragments and various calcrete debris in pink sands. These sediments represent a succession of aeolian episodes separated by periods of alteration and erosion during the course of which the coarsest stripping products occur as residual deposits at the bottom of gullies. They have been attributed to the beginning of the «Soltanian» (Table 2) by Biberson (1961). Nevertheless, the aeolian horizon situated at the bottom of this continental series has an OSL age of 394 ± 276 Ky (Rhodes, *in litteris*).

The lithification of aeolian sediments has taken place under vadose continental conditions. At first, it occurs as an early micritic cement which coats the sand grains and which is perhaps associated with a herbaceous vegetation cover (Akil and Gayet, 1984). Later, microsparitic cement of irregular thickness developed in the voids.

The Bir Feghloul Member

The Bir Feghloul Member is fitted into the former member and comprises the same stratigraphic succession : foreshore bioclastic sands including more or less pebbles and passing upward into a sandy aeolianite. The foreshore deposits are situated at an altitude of 7-8 m (fig. 2). They yield mollusc assemblages that include numerous *Patella* and *Thaïs haemastoma*. The dune deposits have been dated to 164 ± 36 ky by the OSL method (Rhodes, *in litteris*).

THE DAR BOU AZZA FORMATION

It has been defined in the commune of Dar Bou Azza (fig. 1) but can be found throughout the research area as far Sidi Abderrahmane. It consists of two lithostratigraphic units : the Ain Roummana Member and the Lahlalfa Member (fig. 2).

The Ain Roummana Member

This comprises consolidated foreshore deposits 1,5 m thick showing significant facies variability as follows : evenly laminated coarse bioclastic sands dipping seaward, similarly bedded sorted gravels, large flattened blocks locally imbricated lying in a coarse bioclastic matrix with some complete shells (fig. 14). At Dar Bou Azza, the upper part of the unit is composed of openwork imbricated blocks inclined seaward. By comparison with the local modern coastal deposits, these blocks are interpreted as backshore deposits. The presence of *Mytilus*, *Patella* and *Thaïs haemastoma* is notable in the mollus-

can faunal assemblage. This stratigraphic unit is situated at between 2 and 6 m altitude and it fits into a shoreline fashioned out of the Kef el Haroun Formation (fig. 15). Often obscured by the continental deposits of the Lahlalfa Member, this shoreline can be followed along the entire length of the study zone. It is attributed to the Ouljian Stage (Biberson, 1961).

The Lahlalfa Member

This unit consists of red clayey-sand slope deposits containing heterometric calcarenite and calcrete fragments floating in the matrix. There is evidence of bioturbation, and numerous terrestrial gastropods occur throughout the thickness of the deposit. Typically subdivided into three sub-units by laminar calcareous crusts, it systematically overlies the previous member. The upper part of the two lower sub-units is enriched in carbonates which occur in form of nodules and tuffaceous crust (fig. 16). The intermediate unit has yielded an Aterian archaeological assemblage which developed in Morocco between 20 and 40,000 years B.P. (Debénath *et al.*, 1986 ; Texier *et al.*, 1988).

The processes by which these sediments were deposited are not yet clearly understood. However, run-off, mud-flows and debris-flows are probably the main transportation agents. The sedimentary material is essentially derived from soils. The laminar calcareous crusts which interrupt these deposits probably represent phases of relative morphological stability associated at least locally with an increase in aridity (Freytet and Verrecchia, 1989 ; Vogt, 1989 ; Verrecchia, 1994).

THE REDDAD BEN ALI FORMATION

The Reddad Ben Ali Formation extends along the present day coastline. It comprises a basal conglomerate which rests at an altitude of 3 m on an erosion platform cut into Cambrian quartzites. At the type locality (fig. 1), a long trench (several hundred meters long) dug perpendicularly to the present shoreline permitted a detailed study of the lateral and vertical succession of lithofacies to be made (fig. 17). This formation comprises 1 to 3 m of uncemented coarse deposits including pebbles, pebbly sands and coarse bioclastic sands. The sedimentary structures (landward- and seaward-dipping laminations) indicate backshore then foreshore environments. Granulometry also records these environmental variations. Indeed, from land to sea, there is a lateral transition from large imbricated openwork pebbles to smaller openwork pebbles then to less and less coarse bioclastic sands locally associated with small pebbles. This succession can also be found on the present coast and is characteristic of supratidal, then more and more outer intertidal environment. A same vertical section exhibits a coarsening-upward sequence (fig. 17) as the result of the marine retreat. A coherent series of radiocarbon and OSL dates has been obtained from shells and quartz grains coming from this sedimentary sequence (Occhietti *et al.*, 1993 and in press ; Lefèvre *et al.*, 1994 ; Rhodes, *in litteris*).



Fig. 14 : Ain Roummana Member (about 2 m thick) of the Dar Bou Azza Formation resting on Cambrian quartzites.
Fig. 14 : Membre d'Aïn Roummana (environ 2 m d'épaisseur) de la Formation de Dar Bou Azza reposant sur des quartzites cambriens.



Fig. 15 : The «Ouljian» shoreline.
Fig. 15 : La ligne de rivage «ouljienne».

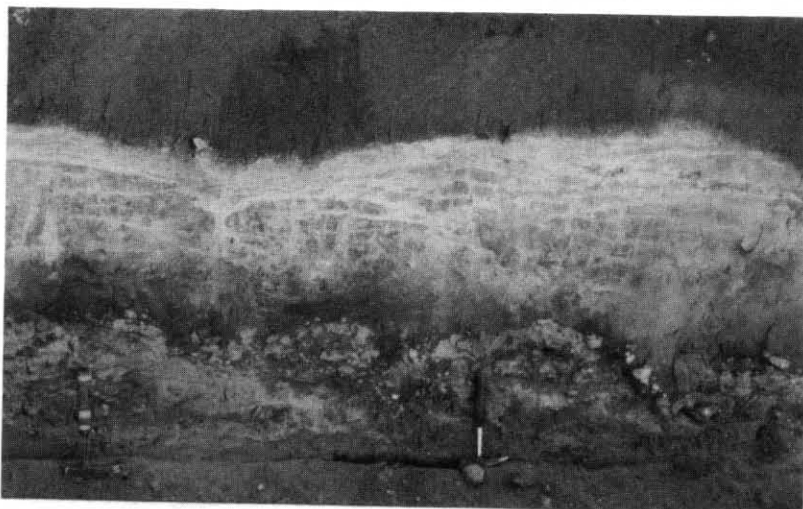


Fig. 16 : The Lahlalfa Member of the Dar Bou Azza formation (Hammer : 28 cm).
Fig. 16 : Le Membre de Lahlalfa de la Formation de Dar Bou Azza (Marteau : 28 cm).

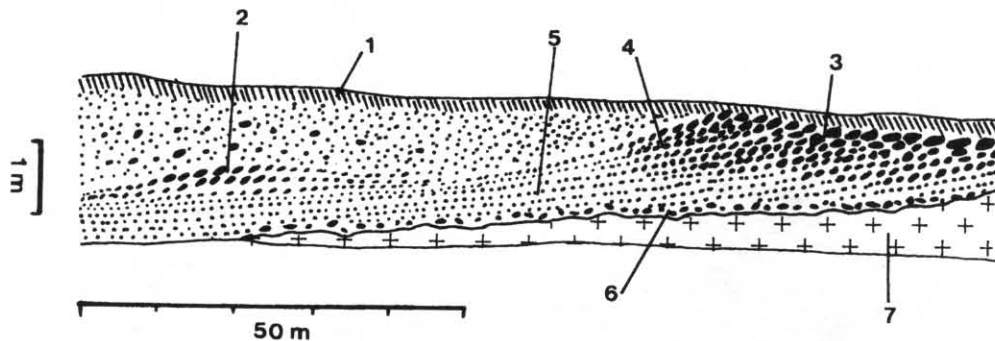


Fig. 17 : Reddad-Ben Ali Formation - Section perpendicular to the shoreline showing the organisation of the deposits behind the present coastal dune ridge. These deposits record both a regressive movement of the sea and a morphological evolution of the coastline. Indeed, the equivalent to deposits 3, 4 and 5 are now observed near rocky capes, whereas deposits analogous to deposits 2 are located in embayments.

1 : organic soil - 2 : pebble lines and pebbles in massive bioclastic sands (backshore deposits) - 3 : openwork imbricated big pebbles and cobbles (supratidal deposits) - 4 : openwork imbricated pebbles (upper part of the foreshore) - 5 : evenly laminated bioclastic sands and granules (median and lower parts of the foreshore) - 6 : abrasion platform and associated conglomerate - 7 : Cambrian Quartzites.

Fig. 17 : Formation de Reddad Ben Ali - Coupe perpendiculaire au rivage montrant l'organisation des dépôts en arrière du cordon dunaire actuel. Ces dépôts enregistrent un mouvement régressif de la mer ainsi qu'une évolution morphologique du littoral. En effet, l'équivalent des dépôts 3, 4 et 5 s'observe actuellement près des caps rocheux tandis que l'équivalent des dépôts 2 sont localisés dans les baies.

1 : sol organique - 2 : lignes de galets et galets dispersés dans des sables bioclastiques massifs (dépôts d'arrière plage) - 3 : gros galets et blocs imbriqués à structure ouverte (dépôts supratidaux) - 4 : galets imbriqués à structure ouverte (partie supérieure de l'estran) - 5 : sables bioclastiques et graviers organisés en lits plans réguliers (parties moyenne et inférieure de l'estran) - 6 : plate-forme d'abrasion et conglomérat associé - 7 : quartzites cambriens.

They suggest that it occurred between ca 1.29 ± 0.27 and 4.72 ± 1.17 Ky BP. The Reddad Ben Ali Formation passes laterally into modern beach and dune deposits.

Apart from the different sedimentary units described above for which the morpho-stratigraphic relationships are clear, **red clayey sands** (RCS) are mainly found in depressions (fig. 2). These deposits vary in thickness from several decimeters to 2-3 m and are widespread in northwest Morocco. Known under the name of «Limon rouges», they were attributed to the Soltanian by previous authors like Biberson (1961). In fact, their genesis is very complex and can take place throughout the Quaternary. It involves various types of pedogenesis and erosion processes like run-off, mud-flow or deflation (Raynal et Texier, 1984 ; Raynal *et al.*, 1985 ; Texier and Raynal, 1989 ; Texier *et al.*, 1992). In the study area, these deposits often incorporate various prehistoric industries including Acheulian, Aterian and Iberomaurusian, and it is not possible to define precisely their stratigraphic position in relation with the others stratigraphic units.

DISCUSSION

Ten or twelve (*cf. infra*) successive marine episodes have been recorded in this part of the Moroccan coast. The maximum advances of these marine episodes are almost always marked by sea cliffs cut into older deposits. However, those connected with Member 1 of the Oulad Hamida Formation, with Member 1 of the Anfa Formation and with the Oulad Aj J'mel Formation have not been observed. Nevertheless, we may infer that the sea responsible for these deposits has not passed by much the studied sections. In effect, sedimentary structures, as well as the early diagenetic phenomena identified within these deposits, give evidence of intertidal or, sometimes, subtidal environments but never deeper conditions.

Each of these marine episodes is expressed by a

sequence resting on an erosional surface and including successively subtidal or intertidal deposits, then supratidal and dune deposits. However, Member 1 of the Oulad Hamida Formation suggests a little more complex evolution with advances and retreats of the shoreline. The main episodes of this evolution are illustrated in figure 18. They do not imply global or even regional changes but just local adjustments of the littoral morphology in connection with the building and the disruption of a coastal dune ridge. The succession of the levels K, L, M, N and O of Neuville and Ruhlman (1941) and the deposits constituting the Member 1 of the Anfa Formation could be explained in the same manner. However, two of us (DL and JPR) think that each of these stratigraphic series (*i.e.* Member 1 of the Oulad Hamida Formation and Member 1 of the Anfa Formation plus the levels K, L, M, N, and O of Neuville and Ruhlman) represents two major distinct marine episodes.

In any case, these different sequences are linked to an increase in accommodation rate (Cross, 1988) and conform to the definition given by Van Wagoner *et al.* (1990) for the parasequences : «a relatively conformable succession of genetically related beds or bedsets bounded by marine-flooding surfaces or their correlative surfaces». Moreover, as most of these sequence types, they are progradational and are related to a basinward migration of the coastline (Van Wagoner *et al.*, *op. cit.*). Three different mechanisms have been put forward to explain parasequence genesis : 1) compaction of prodelta mudstone in a delta lobe, 2) subsidence along tectonically active faults and 3) eustasy (Van Wagoner *et al.*, *op. cit.*). In the study case, the first and the second mechanisms can be ruled out. Indeed, the geological setting is not that of a delta lobe and the Casablanca Region corresponds to an anticlinorium which displayed an uplift trend throughout all the Quaternary Period (Griboulard, 1980 and 1983). Therefore, the observed littoral sequences can mainly be regarded as responses to glacio-eustatic events. As a

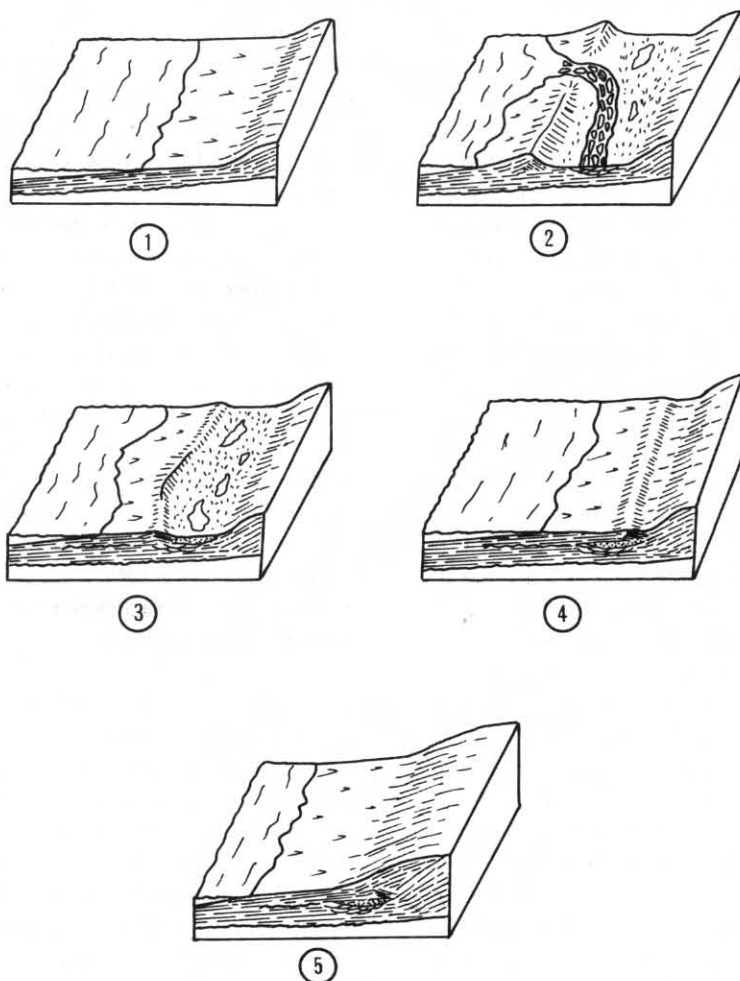


Fig. 18 : Palaeogeographic evolution recorded in Member M1 of the Oulad Hamida Formation.

1 - High sea level. Deposition of Bed 1. 2 - Formation of a littoral barrier and, behind the latter, of a depression drained by an intermittently flowing braided stream which deposits the lower part of Bed 2. This stream line attracts fauna and prehistoric people. Presence of ponds and sparse vegetation is likely. 3 - The littoral barrier is partially broken up. Aeolian sands (upper part of Bed 2) are laid down in the depression where the outflow is inhibited. Ponds and sparse vegetation persist. 4 - Deposition of Bed 3. The palaeogeographic situation is approximately the same as during the deposition of Bed 1. A beach ridge is built up on the backshore. 5 - Regression of the sea and formation of a littoral dune (Bed 4) which is superimposed on deposits of the Beds 1, 2 and 3.

Fig. 18 : Evolution paléogéographique enregistrée dans le Membre 1 de la Formation d'Oulad Hamida.

1 - Haut niveau marin. Dépôt de l'assise 1. 2 - Formation d'une barrière littorale et, en arrière de celle-ci, d'une dépression drainée par un cours à chenaux tressés à écoulement intermittent (partie inférieure de l'assise 2). Ce cours d'eau constitue un point d'attraction pour la faune et les hommes préhistoriques. Présence vraisemblable de marigots et d'une végétation clairsemée. 3 - La barrière littorale est partiellement rompue. Des sables éoliens (partie supérieure de l'assise 2) se déposent dans la dépression et inhibent l'écoulement vers la mer du cours d'eau. Des marigots et une végétation clairsemée persistent. 4 - Dépôts de l'assise 3. La situation paléogéographique est approximativement la même que lors du dépôt de l'assise 1. Une levée s'édifie en haut de plage. 5 - Régression de la mer et formation d'une dune littorale (assise 4) qui se surimpose aux assises 1, 2 et 3.

matter of fact, dates (*cf. supra* and table 2) attributed to the two most recent marine episodes (Reddad Ben Ali Formation and Aïn Roummana Member) show that they are contemporaneous with MIS 1 and 5. Therefore, it is tempting to correlate each of the identified sea level highstands with a major «temperate» isotopic stage. This though process allows to ascribe the oldest regional sequence (Member 1 of The Oulad Hamida Formation) to MIS 21 or 23 and does not basically disagree with the available chronological markers (table 2).

Nevertheless, several observations lead to strongly qualify this chronologic approach. First, $\delta^{18}\text{O}$ measurements made on deep sea cores show that the interglacials are not all equivalent (Shackleton, 1987). For example, the amount of ^{18}O obtained for MIS 7, 13, 15, 17 and 19 is less than that found in the Holocene, and it is possible

that high sea levels contemporary with these periods would not have reach the modern level (Shackleton, *op. cit.*). By contrast, it seems that the sea level highstand related to MI sub-stage 5e was 3 to 7 m higher than the present sea level (Chappell and Shackleton, 1986 ; Bard *et al.*, 1990 ; Dumas and Raffy, 1993 ; Dumas *et al.*, 1998). It also needs to be emphasized that the recording of parasequences strongly depends on the sedimentation supply (Van Wagoner *et al.*, 1990). Furthermore, it is unlikely that the regional uplift rate would have remained constant over the time period considered here. All these factors (tectonic, glacio-eustatic, sedimentary) may have combined in different ways to have a positive or negative influence on accomodation rate. This would explain the fitted or the stepped arrangement of the sequences (fig. 2) and might have led both to the non-

recording of some glacio-eustatic maxima or to the recording of some secondary glacio-eustatic events (*i.e.* events with short return periods). This last situation has been observed in several other coastal areas. For example, numerous dates obtained on the raised beaches of Southern and Northern Morocco (Stearns and Thurber, 1965 ; Weisrock, 1986, 1987), of Southern Spain (Hillaire-Marcel *et al.*, 1986 ; Zazo *et al.*, 1999), of Tunisia (Paskoff and Sanlaville, 1980), or of Egypt (Plaziat *et al.*, 1998) show that distinct levels were formed at different times within MIS 5, or even within MI sub-stage 5e. Moreover, some investigators have stressed that Heinrich events could be responsible for more than 10 m sea-level rises (Labeyrie and Jouzel, 1999) and for the formation of marine terraces (Bond *et al.*, 1993 ; Dumas *et al.*, 2000). The great confidence intervals linked to numerical ages concerning the stratigraphic units predating the Last Interglacial (table 2) do not permit this problem to be solved. In the same manner, the fact, as indicated by erosional structures (*e.g.* sea cliffs), that the consolidation of regional littoral deposits has occurred between two successive transgressions and regressions of the sea does not completely overcome this chronological uncertainty. Indeed, although our own observations on the Moroccan Atlantic coast show that the lithification of intertidal and dune deposits built up from ca. 4700 BP at Reddad Ben Ali (see above) and from 4550 BP at Skhirat, south of Rabat (Daugas *et al.*, 1989) is rather slight, the rate of consolidation of bioclastic sands deposited in sub-, inter- or supratidal environments may be rapid (Shinn, 1969 ; Taylor and Illing, 1969 ; Evans *et al.*, 1973 ; Purser, 1980). Nevertheless, two of us (DL and JPR) think that each of the marine level identified corresponds to a major glacioeustatic event, namely an interglacial episode. At present, the available chronological markers lead to propose the following correlations : The Kef el Haroun Formation could be contemporaneous with MIS 7 (Bir Feghloul Member) and MIS 9 or 11 (Oulad Aj J'mel Member) ; the Anfa Formation could have formed between MIS 10 and 18 and the Oulad Hamida Formation between MIS 18 and 22 (at least).

In any case, the sequences we identified are related to fourth- and fifth-order marine cycles (Vail *et al.*, 1977 ; Van Wagoner *et al.*, 1990) and are not very useful for long distance correlations (Van Wagoner *et al.*, *op. cit.*). Nevertheless, it is important to stress that the Casablanca Region is a very favourable one for the recording of high-resolution sequences which are, in this region, many more numerous than in the other coastal Moroccan areas (*e.g.* Aberkan, 1989 ; Alouane, 2001 ; Ouadia, 1998 ; Weisrock, 1980).

At the rear of the different palaeoshorelines, pedogenetic and reworking processes have occurred. Evidences of these phenomena can be noticed in the pedogenesis observed on the Upper Bed of Member 3 of the Anfa Formation, in the coarse detritic layers intercalated in the upper part of Oulad Aj J'mel Member (Sidi-Abderrahmane quarry), in the superficial red clayey sands (RCS) and in the continental deposits of the Lahlalfa Member of the Dar Bou Azza Formation. The latter were formed during a period of low sea level contemporary with the

Last Glaciation. Indeed, they are more recent than the Ain Roummana Member built up during the penultimate high sea level and they contain an industry dated between 20 and 40,000 BP (Debénath *et al.*, 1986 ; Texier *et al.*, 1988).

This kind of deposit may have occurred between the other marine formations. However, they have then completely dismantled and eroded by further marine advances. Indeed, we note that the continental levels preserved in this stratigraphic series lie above the height achieved by the high sea level that followed their deposition. The superficial red clayey sands located in more inner position may have recorded evidence of these morphogenetic phases, but their textural homogeneity and the absence of chronological markers prevent confirmation of this.

Furthermore, the climatic signal contained in the continental deposits interfingering in this stratigraphic series (Lahlalfa Member of the Dar Bou Azza Formation, coarse detritic levels intercalated in the deposits of the Oulad Aj J'mel Member) is rather slight. In effect, the conditions favourable for their development include a more or less discontinuous vegetation cover, a dry season and high-intensity rainfalls. These may occur together, at least locally, within a relatively broad range of climates : from the sub-humid climate of the Rabat region to sub-arid climate like those of the Tiznit and Souss regions, passing into the modern semi-arid conditions of the Casablanca region. Therefore, it is impossible to assign them to a particular situation within the Pleistocene climatic cycles, and they could equally be contemporary with a «temperate» or a «cold» stage.

Finally, the lithostratigraphic framework presented here does not agree with that which has served as basis for the chronological subdivisions of the Moroccan Quaternary (Biberson, 1961 ; table 2). We would note in particular that previously unidentified stratigraphic units are interstratified between successive «stages» from the earlier sequence (*e.g.* Member 2 of the Anfa Formation intercalated between the «Anfatian» and the «Amirian» of Biberson) while deposits attributed to different «stages» now indisputably appear to be from the same unit (*e.g.* Member 1 of the Anfa Formation which includes the «Amirian» and the «Maarifian» of Biberson). Moreover, correlations made previously (*ibid.*) between certain deposits from the Anfa and the Oulad Hamida Formations cannot now be retained. This particularly concerns Beds 1 and 2 of the Oulad Hamida Formation which have been correlated with aeolian deposits of Member 1 of the Anfa Formation dated to the «Amirian» and the upper part of the Oulad Aj J'mel Member dated to the «Soltanian» considered equivalent to the Last Glaciation (*Ibid.*). In the same manner, the chronological framework the authors more recently proposed (Texier *et al.*, 1985) appears too theoretical. It could be a source of confusion with the earlier nomenclature and should be abandoned in favour of the lithostratigraphy proposed here.

CONCLUSIONS

The stratigraphical sequences studied here represents an exceptional record of geological events since about one million years. Ten (or possibly twelve) distinct,

inset and leveled parasequences (*sensu* Van Wagoner *et al.*, 1990) have been identified on this part of the Moroccan coast. They are progradational and correspond to a basinward migration of the coastline. Each of them is composed of associations and successions of facies characteristic of subtidal (Members 1 and 2 of the Anfa Formation), intertidal, supratidal and aeolian dune environments. In most cases, they provide evidence of a relatively straightforward history with an abrupt rising followed by a gradual falling of the sea level.

The microfacies confirm these interpretations and show that diagenetic processes operating on these deposits generally occurred in vadose marine or vadose continental conditions. Lithification produced in phreatic marine or continental environments is relatively unusual and has been identified only in Bed 1 of Member 1 of the Oulad Hamida Formation, in Member 1 of the Anfa Group, and in the Oulad Aj J'mel Formation.

Slope deposits interfingering between the littoral formations (Lahlalfa Member of the Dar Bou Azza Formation, stony levels of the Oulad Aj J'mel Member) were probably formed by runoff and mud- or debris-flow processes under more or less arid and unvegetated conditions.

Only the last two formations can be placed accurately in relation to MIS: the Reddad Ben Ali Formation is contemporaneous with MIS 1 and the Dar Bou Azza Formation with MIS 5 (Ain Roummana Member) and MIS 2 to 4 (Lahlalfa Member) (table 2). Because the confidence intervals of available dates are great, and because it is difficult to know if the different marine sequences we identified correspond only to glacio-eustatic maxima or also to short return glacio-eustatic events, the chronological situation of the other stratigraphic units is more uncertain. They probably formed between MIS 7 and 22 at least (table 2).

Moreover, the results indicate that the Quaternary «stages» defined in this area by previous authors (Biberson, 1961) are built on an unreliable basis. The classic chronostratigraphical framework used until now in the Maghreb should be abandoned in favour of regional lithostratigraphies established on basis similar to those proposed here. Correlations between different regions should be done subsequently and must be based on as many and varied chronological markers as possible.

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