Microfacies of the Late Jurassic to Early Cretaceous carbonate platform at the Mazagan Escarpment (Morocco)

Microfacies
Continental margin
Jurassic
Paleoenvironment
Carbonate platform

Microfaciès
Marge continentale
Jurassique
Paléoenvironnement
Plateforme carbonatée

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ABSTRACT

The Jurassic and Lower Cretaceous carbonate platform of the Mazagan submarine plateau is composed of 3 main facies units: Facies A comprises neritic shallow marine lithologies of the Oxfordian to Kimmeridgian carbonate ramp and the beginning of the Tithonian carbonate platform. Crustose stromatolitic limestones (MF 1) and lagoonal as well as oolitic sediments (MF 2 and 3) are predominant. Their composition indicates sponge and coral growth on the Jurassic slope of early Mazagan Escarpment. Facies B contains hemipelagic sediments which are the result of platform defacing processes mixed with pelagic influx. Pelagic components are remains of *Saccocoma* and calpionellids. The observed facies types are hemipelagic micritic limestones with calpionellids (MF 4) and bioclastic, oolitic limestones with calpionellid-bearing lithoclasts (MF 5). Facies C is composed of intertidal to shallow subtidal sediments, deposited on the top of the platform. The calcareous sediments are oolitic and intraclastic micritic limestones (MF 6), and fenestral limestones (MF 7). The dolomitic facies is represented by dolomicrites (MF 6.3). Deposits with increased terrigenous influx are located at the northern slope of the El Jadida Canyon. They are calcareous, quartz-bearing packstones (MF 8). Composite types and transitional types of facies demonstrate short distance changes of lithologies in certain areas. The depositional history of the carbonate platform is strongly influenced by blockfaulting and sea level changes. During the formation of the Mazagan Escarpment subsiding marginal blocks developed a steep slope composed of numerous steps of different vertical and horizontal extension. From the outer to the inner platform the lateral sequence of facies types ranges from periplatform clastics (facies B) to platform stabilizing lithologies (facies A) and shallow water platform sediments (facies C). Sea level changes and increasing subsidence rates were responsible for two transgressive events: a minor transgression between Late Tithonian and Early Berriasian. During this phase the calpionellid facies merged landward onto the platform. These sediments were reworked in a Late Berriasian to Valanginian regression. Indications of emergence and vadose diagenesis are present. New rapid subsidence started in the Lated Valanginian, and the entire Mazagan plateau was drowned to the recent depth of 2 000 m in several pulses during the Cretaceous and the Cenozoic (von Rad *et al.*, this vol.).

Oceanol. Acta, **1984.** Submersible Cyana studies of the Mazagan Escarpment (Moroccan continental margin), CYAMAZ cruise 1982, 111-126.

RÉSUMÉ

Microfaciès de la plate-forme carbonatée du Jurassique Supérieur au Crétacé Inférieur, escarpement de Mazagan (Maroc)

La plate-forme carbonatée du Jurassique et du Crétacé inférieur du plateau sous-marin de Mazagan est composée de trois principales unités de faciès : le faciès A comprend les lithologies marines néritiques et peu profondes de la pente carbonatée de l'Oxfordien au Kimméridgien, ainsi que le début de la plate-forme carbonatée du

Tithonique. Les calcaires stromatolitiques encroûtés (MF1) ainsi que les sédiments lagunaires et oolithiques (MF2 et 3) sont prédominants. Leur composition indique la croissance d'éponges et de coraux sur la pente jurassique de l'escarpement inférieur de Mazagan. Le faciès B contient des sédiments hémipélagiques qui sont le résultat de processus de dégradation de la plate-forme combinés avec des dépôts pélagiques. Les composants pélagiques sont des restes de Saccocoma et de calpionelles. Les types de faciès observés sont des calcaires micritiques hémipélagiques à calpionelles (MF4) et des calcaires oolithiques bioclastiques à lithoclasts à calpionelles (MF5). Le faciès C est composé de sédiments intertidaux à subtidaux superficiels, déposés au sommet de la plate-forme. Les sédiments calcaires sont des calcaires micritiques oolithiques et intraclastiques (MF6) et des calcaires « fenestral » (MF7).
Le faciès dolomitique est représenté par des dolomicrites (MF6.3). Les dépôts à apports terrigènes accrus sont situés sur la pente nord du Canyon de El Jadida. Ce sont des packstones calcaires à quartz (MF8). Des types de faciès composites ainsi que transitionnels rappellent de courts changements de lithologie dans certaines zones. L'histoire des dépôts de la plate-forme carbonatée est fortement influencée par des effondrements et des variations du niveau de la mer. Pendant la formation de l'escarpement de Mazagan, des blocs marginaux affaissés ont contribué à la formation d'une pente abrupte composée de nombreuses marches, d'extension verticale et horizontale variable. Si l'on va de la plate-forme extérieure à la plate-forme intérieure, la séquence latérale de types de faciès s'étend des bioclastes de la périplate-forme (faciès B) jusqu'aux lithologies de stabilisation de la plate-forme (faciès A) et sédiments de plate-forme en eau peu profonde (faciès C). Les variations du niveau de la mer et l'accroissement des taux de subsidence ont entraîné deux événements transgressifs : une transgression mineure entre le Tithonique supérieur et le Berriasien inférieur. Pendant cette phase, le faciès à calpionelles a fusionné avec la plate-forme du côté de la terre. Ces sédiments ont été remaniés lors d'une régression du Berriasien supérieur au Valanginien. Nous pouvons constater la présence d'indicateurs d'une diagénèse d'émersion et « vadose ». Le Valanginien supérieur a été marqué par une nouvelle subsidence rapide et tout le plateau de Mazagan a été immergé jusqu'à la profondeur actuelle de 2 000 m. Ce phénomène s'est déroulé en plusieurs étapes durant le Crétacé et le Cénozoïque (von Rad *et al.*, ce vol.).

Oceanol. Acta, **1984.** Études par le submersible Cyana de l'escarpement de Mazagan (marge continentale marocaine), campagne CYAMAZ 1982, 111-126.

INTRODUCTION AND GEOLOGICAL SETTING

The Mazagan Plateau is located at the passive Moroccan continental margin 200 km west of Casablanca and 100 km west of El Jadida (Mazagan). The plateau represents an Upper Jurassic to Lower Cretaceous shallow marin carbonate platform which was drowned during the Cretaceous and the Tertiary by rapid subsidence. The recent depth of the Mazagan Plateau is 1 000-2 000 m. Its margins are characterized by almost vertical exposures of massive Jurassic limestones, which were first observed and sampled by VEMA and METEOR (Renz *et al.*, 1975, Wissmann, von Rad, 1979). Prior to the CYAMAZ project this areas was intensely studied by geophysical investigations (Hinz *et al.*, 1982 ; Seazagan, Auzende *et al.*, 1983) and drilling (DSDP Legs 41/50, site 370/46 s, Schlager, 1981 ; Lancelot, Winterer, 1980 ; DSDP Leg 79, sites 544-547, Hinz, Winterer, in press ; Bernoulli, 1984 ; Steiger, Jansa, 1984 ; Jansa *et al.*, 1984). The purposes for the deep diving campaign were :

1) to complete the results of the deep sea drilling by direct observation ;

2) to help comparing the intensely investigated margin of the Mazagan Plateau with onshore Morocco (Ager, 1974 ; Michard, 1976 ; Adams *et al.*, 1980 ; Jansa, Wiedmann, 1982). The geology of the central Mazagan Plateau is nearly unknown. This large lateral gap was planned to be closed by dives on top of the plateau.

The diving profiles were located with the help of multichannel echosounder map which was made by the French research vessel Jean Charcot (SEAZAGAN, Auzende *et al.*, 1983) and under water acoustic transponder navigation. The Mazagan Plateau can be split into 3 research areas : A northern part, which has been investigated by drilling and dredging. Here, the plateau is divided into an outer, hemipelagic and an inner shallow-marine platform. The outer platform is a seamount-like structure since the Upper Jurassic. This area is characterised by condensed calcareous red limestones of Late Jurassic age (Steiger, Jansa, 1984). The transition to the inner platform is covered by Cretaceous and Cenozoic pelagic sediments. The slope is less steep than further south (Fig. 1).

Diving was proposed for the southern part of the Mazagan Plateau, where the El Jadida Canyon reaches the abyssal depths of the Atlantic Ocean, and for the western part, where the slope was expected to be steep enough to find exposures of hard limestones.

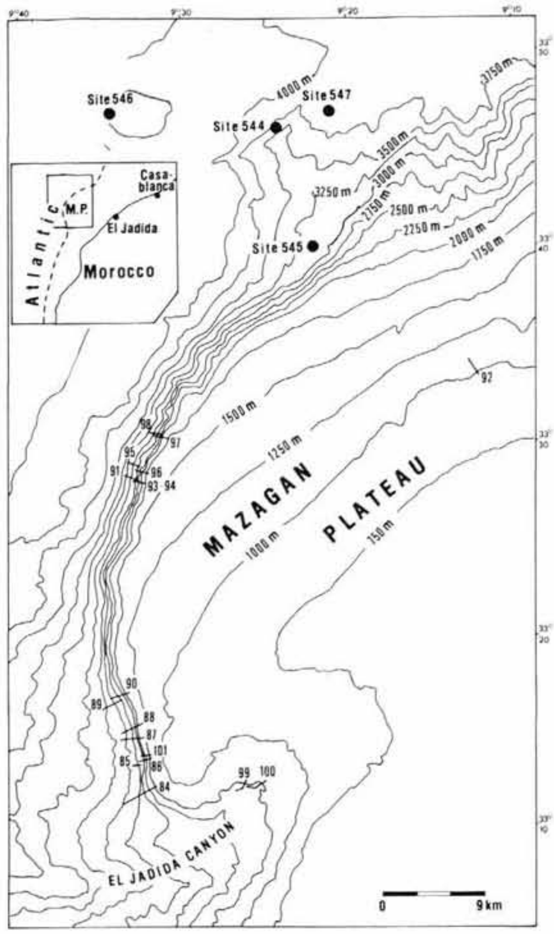


Figure 1

Bathymetric map (after Seazagan seabeam map, Auzende et al., 1983) showing the locations of the CYAMAZ dives and the DSDP Leg 79 drilling sites on the Mazagan Plateau.

The geological setting of the Mazagan Plateau is characterized by the sedimentological development of a starved passive continental margin (Lancelot, Winterer, 1980 ; Seibold, 1982 ; Hinz, Winterer, 1984). The Jurassic and Lower Cretaceous sediments contain Tethyan elements (Bernoulli, 1972 ; Bernoulli, Kaelin, 1984). The Mazagan Plateau is the seaward margin of the stable continental block of the Moroccan Meseta. This margin is divided into rhomblike segments which are limited by variscan faults (Michard, 1976 ; Hinz. *et al.*, 1982 ; Stets, Wurster, 1982).

Each block has individual subsidence and indiviual facies evolution. Facies differences resulting from biogenic activity first occur in the Oxfordian (Steiger, Jansa, 1984). The basinal facies of the northern part of the Mazagan Plateau reflects fluctuating borders of the carbonate ramp in this time. This is documented by proximal slope breccias, which contain remains of siliceous sponges, by hard-ground cycles and by pelmicritic crusts.

The aims of the microfacies studies of the limestones recovered by CYANA were :

— to specify the age of the formation of the Mazagan Escarpment.

— to find out the degree of facies differentiation at the transition between the inner and the outer Jurassic to Lower Cretaceous carbonate platform.

— to investigate the reasons of these facies differentiations either by tectonics or biogenic activity.

— to follow the vertical lithologic sequence at the Escarpment in order to reconstruct the sea level history during the Late Jurassic and the Earliest Cretaceous.

— to fix the time of final drowning of the Mazagan shallow-marine platform (comp. von Rad et al., this vol).

THE FACIES UNITS AT THE MAZAGAN ESCARPMENT AND THEIR MICROFACIES TYPES

In the Table an overview of the Upper Jurassic and Lowermost Cretaceous facies units and their microfacies types is given. Their numbers are related to the facies numbers used by von Rad (this vol).

DESCRIPTION OF THE MICROFACIES TYPES AND INTERPRETATION OF THEIR DEPOSITIONAL ENVIRONMENTS

The description of the Upper Jurassic to Lower Cretaceous limestones recovered at the Mazagan Plateau is based on the classifications of Dunham (1962), Embry and Klovan (1972) and Folk (1959). The charts of Bacelle and Bosellini (1965) were used for quantitative particle analysis. Flügel's textbook (1978 ; 1982) was used for the description and interpretation of the paleoenvironment of the platform limestones.

Facies A : neritic shallow-water facies (platform slope)

Facies unit A includes all carbonate sediments which were sampled at the steep exposures of massive limestone at the Mazagan Escarpment. It partly still corresponds to the paleoslope of the margin of the Jurassic carbonate platform.

Microfacies 1 : neritic columnar stromatolitic peloidal packstone (Plate 1 : Fig. 1-3 ; Plate 2)

Most of the Jurassic limestone samples (23) belong to this facies. They were taken from massive to thick-bedded limestones, which form the alpine morphology of the exposures at the Mazagan Escarpment. In thin-section the sediment consists of small arenitic particles. The most frequent components are peloids which accumulate in thinly laminated crusts. Lamination is irregular and the crusts are interlayered by grainstones which are composed of different components. Such components are bioclasts : small benthic foraminifera (*Protopeneroplis striata* Weynschenk, *Nautiloculina oolithica* Mohler, *Gaudryina* sp., *Textularia* sp.), debris of encrusting algae (*Thaumatoporella parvovesiculifera* Raineri, *Tubiphytes* sp.), ostracods, fragments of bivalve shells and echinoderm remains.

Table

The main facies units, the microfacies types, and composite and transitional sediments recovered at the Mazagan Escarpment.

Facies-type	Lithology	von Rad *et al.* (this vol.)	Samples CZ	Plates, Figures
Facies A	Stromatolitic peloidal facies			
Microfacies 1	Columnar stromatolitic peloidal packstone	MF 3	85-5 ; 87-4, 6, 8 ; 88-4, 5 ; 89-1, 4 ; 91-1, 3, 6, 7 ; 94-1, 2, 4 ; 95-3, 7 ; 96-4, 7 ; 98-5, 6, 7 ;	Pl. 1 : Fig. 1 ; Pl. 2 ;
Microfacies 2	Neritic intraclastic, bioclastic, and oolitic facies			
Subtype 2.1	Neritic bioclastic grainstone	MF 4, MF 4.1 MF 4.3	85-1 ; 88-1, 6, 9 ; 89-3 ; 91-2 ; 94-9 ; 101-1 ;	Pl. 3 : Fig. 2 ;
Subtype 2.2	Neritic oolitic grainstone	MF 5.2	94-6 ;	Pl. 3 : Fig. 3 ;
Microfacies 3	Neritic algal bindstone facies			
Subtype 3.1	Neritic algal bindstone with coral debris	MF 3	87-1 ;	Pl. 3 : Fig. 1 ;
Subtype 3.2	Neritic algal bindstone with oolites	MF 5.1	85-6 ; 96-9 ;	Pl. 3 : Fig. 4 ;
Facies B	Hemipelagic facies with calpionellids			
Microfacies 4	Hemipelagic packstone with calpionellids	MF 1 ;	85-4 ; 87-2, 3 ; 89-2 ;	Pl. 4 : Fig. 1 ;
Microfacies 5	Bioclastic, oolitic grainstone with calpionellid-bearing lithoclasts	MF 2 ;	98-4 ;	Pl. 4 : Fig. 2 ;
Facies C	Neritic micritic and quartz-bearing facies			
Microfacies 6	Neritic mudstone, wackestone and packstone			
Subtype 6.1	Oolitic bioclastic packstone	MF 5.3	98-9 ;	Pl. 5 : Fig. 3 ;
Subtype 6.2	Intraclastic wackestone	MF 7.1	86-7 ;	Pl. 5 : Fig. 1 ;
Subtype 6.3	Dolomicrite	MF 7.2	92-1 ;	
Microfacies 7	Micritic fenestral facies			
Subtype 7.1	Fenestral peloidal wackestone	MF 6.2	101-3 ;	Pl. 6 : Fig. 1 ;
Subtype 7.2	Laminated fenestral peloidal packstone	MF 6.4, MF 4.5	86-6 ; 101-8 ;	Pl. 6 : Fig. 2 ;
Microfacies 8	Micritic quartz-bearing intraclastic packstone with Clypeina jurassica debris	MF 8.1	101-9 ;	Pl. 5 : Fig. 2 ;
Transitional and composite types of facies				
Composite type : microfacies 1 and microfacies subtype 2.1			86-5 ; 94-3 ; 95-6 ; 96-1, 6 ;	
Composite type : microfacies 1 and microfacies subtype 3.1			87-1 ;	
Composite type : microfacies 1 and microfacies subtype 7.1			98-1 ;	
Transitional type : microfacies subtype 2.1 and microfacies subtype 3.1			101-2 ;	

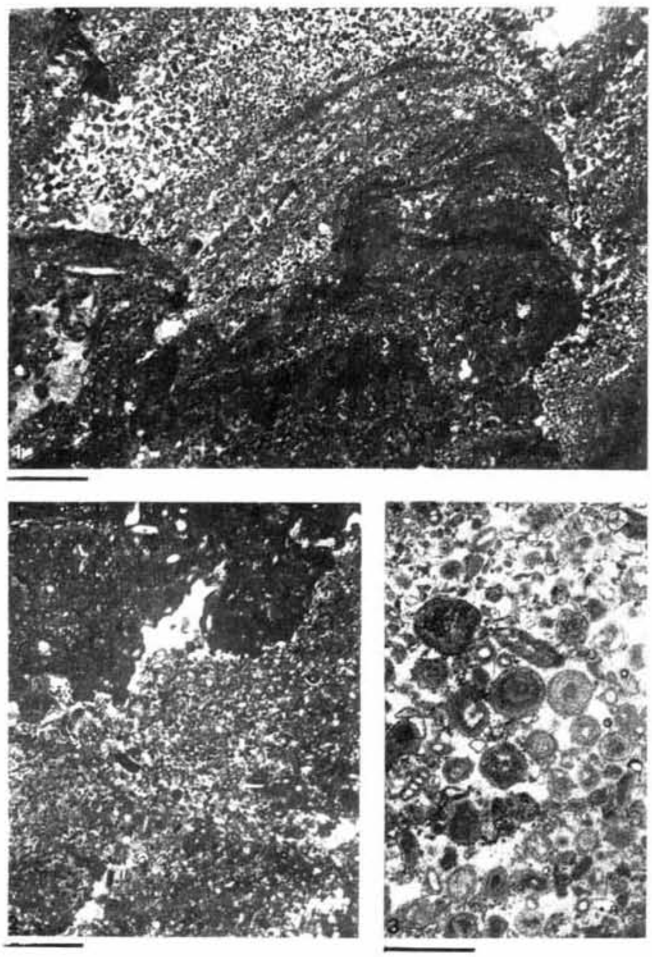


Plate 1

Facies A : Microfacies types from the margin of the Upper Jurassic Mazagan carbonate platform.

Figure 1

Microfacies 1 : columnar stromatolitic peloidal packstone. Domal irregularly layered peloidal crusts, are overlain by bioclastic grainstone (grading into type 2.1). Sample CZ 91-1, 11 x.

Figure 2

Microfacies 1 : Bioclastic grainstone overlain by pelmicrite. The pelmicrite is the lower portion of the domal structure shown in Figure 1. Cavities are visible between the micritic limestone and the bioclastic grainstone. This suggests differential lithification, i.e. early lithification of the pelmicritic crusts and later cementation of the grainstones or later infill of the grainstones into a cavity system below the peloidal crusts. Sample CZ 91-1, 11 x.

Figure 3

Microfacies 1 : ooids with irregular outlines. These components occur within peloidal crustose structures. Sample CZ 91-6, 25 x.

2

1

Plate 2

Facies A : Microfacies types from the margin of the Upper Jurassic Mazagan carbonate platform.

Figure 1

Polished slab of sample CZ 89-1. Microfacies 1 and subtype 2.1. Columnar stromatolitic peloidal packstones with bioclastic grainstones. The layered pelmicritic crusts (dark gray) are clearly distinguished from a « pipe » filled with coarser bioclastic material. Below the laminated peloidal limestone areas and at the top of the grainstone pipe residual porosity occurs. 1,2 x (photo by U. von Rad).

Figure 2

Thin-section of sample CZ 89-1. The peloidal crusts are thinly laminated (1). In the upper right they alternate with coarse bioclastic sediment. Sharp contacts and cavities (2) below the pelmicritic layers suggest *secondary infill of the bioclastic material into a leached cavity system or simple grain compaction of uncemented grains beneath the early lithified peloidal crusts. In the middle left a shell of an oyster is embedded into bioclastic sediment (3). Below elongate bivalve shells sheltered cavities are developed (4). In the lower right (5) a calcite-filled mold of a hexactinellid siliceous sponge is encrusted by micrite and sessile foraminifera. 3,5 x (photomicrograph by U. von Rad).*

Other particles are non-skeletal, such as small intraclasts and ooids. The ooids are mainly superficial ooids. Some are tangential ooids which, in contrast to normal ooids, have no sharp boundaries between the individual crystal layers and have irregular contour. The stromatolitic peloidal facies also contains large biomorpha : calcitized hexactinellid and lithistid siliceous sponges (Lang, Steiger, this vol.).

The rock matrix is calcite spar. Cementation commences by a rim of « dog-tooth » crystals upon the particle boundaries. This first rim is about 10 micron thick. The remaining pores are occluded by blocky calcite spar. Micrite is minor distributed and restricted to the densely packed peloidal areas. Occasionally the laminated, micritic, peloidal crusts appear upon bioclastic sediment with sharp contacts. In advanced developmental stages the domes and columns have irregular growth forms, which expand laterally. In some cases the micritic surfaces of the crusts are extremely convex and their boundaries to the detrital sediment are almost vertical. Bioclastic sediment clearly laps on pelmicritic crusts. This suggests that the peloidal crusts were hard. The encrusted parts of the columnar stromatolitic peloidal packstone are often bored, and the grainstone areas are bioturbated.

Due to the development of peloidal crusts the microfacies types in MF1 vary from peloidal packstone in the crustose parts (also bacterial bindstone, when bacterial lithification of the sediment is supposed) to bioclastic and peloidal grainstone. Many of the samples of facies 1 are composite or show transitions between both sediments.

A similar depositional fabric has been recognized in the Central European Upper Jurassic sponge reef environments. Here, the peloidal packstones occur in Kimmeridgian deposits just below coral-bearing reef limestones (Meyer, 1977). These sediments contrast with the micritic sponge-crust-boundstone facies (Flügel, Steiger, 1982) which is also characterized by peloidal crusts (aphanostromata crusts ; Nitzopoulos, 1974). Such crusts seem to be bound to the existence of decaying siliceous sponges : the sponge is entirely surrounded by micritic crusts and then capped by large domes of peloidal crusts which grow geopetally (Wagenplast, 1972). At the Mazagan Escarpment, however, the siliceous sponges occurring in the columnar stromatolitic peloidal packstones show only minor overgrowth by peloidal crusts. The sediment itself is encrusted and the formation of the crusts seems not to be bound to any particular organism.

Microfacies 2 : neritic intraclastic, bioclastic and oolitic facies

The neritic intraclastic, bioclastic and oolitic facies is closely associated with the columnar peloidal packstone facies (*cf.* " composite and transitional types "),

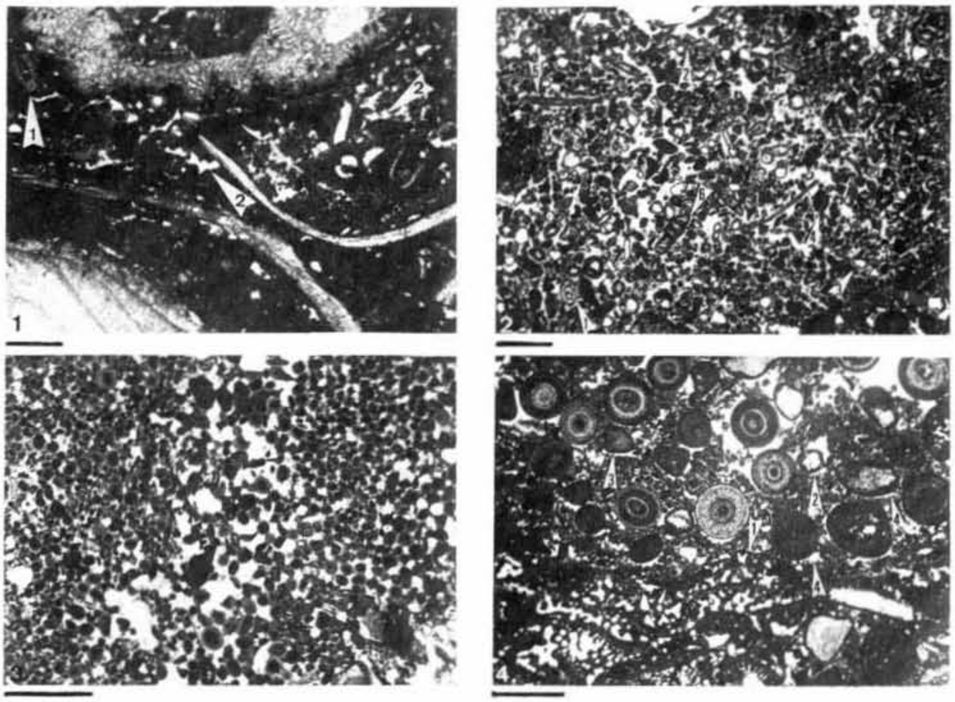


Plate 3

Facies A : Microfacies types from the margin of the Upper Jurassic Mazagan carbonate platform.

Figure 1

Microfacies 3.1 : Neritic algal bindstone with coral debris. Ruditic coral fragments, bivalve shells, coated grains, debris of Salpingoporella pygmaea *Gümbel (1) are encrusted by peloidal micrite. Fenestral fabric (2) occurs in the peloidal sediment. CZ 87-1, 6,9 x.*

Figure 3

Microfacies 2.2 : Neritic oolitic grainstone. Superficial ooids and small concentrically layered ooids compose most of the thin-section. Other components are tiny mollusk shells and benthic textulariid foraminifera. Subangular intraclasts are embedded in the coarse fraction in the center of the photo. This facies interfingers with the crustose peloidal facies (MF 1). CZ 94-6, 11 x.

Figure 2

Microfacies 2.1 : Neritic bioclastic grainstone composed of coated grains. The particles are remains of dasycladacean algae (Salpingoporella pygmaea *(Gümbel) (1),* Salpingoporella annulata *Carozzi (2)), foraminifera* [Trocholina alpina *(Leupold) (3)]*, Nautiloculina oolithica *Mohler (4)), echinoderm remains (5), coral fragments (6) and intraclasts. This composition indicates a general " back-reef" depositional environment. CZ 91-2, 7 x.*

Figure 4

Microfacies 3.2 : Neritic algal bindstone with oolites. This sediment, which is characterized by large ooids, is intensely encrusted by calcareous algae Lithocodium aggregatum *Elliott (1)). Other components are echinoderm remains, foraminifera* (Ammobaculites *sp.* (2)), *and encrusted fragments of* Thaumatoporella parvovesiculifera *Raineri (3). The pore spaces are filled th peloidal material. Fenestral porosity is irregularly developed (4). Depositional environment of the sediment is oolite bars in shallow subtidal to intertidal zones above the stromatolitic peloidal facies. CZ 85-6, 9 x.*
All scale bars are 2 mm long.

but also interfingers with near reef bioclastic deposits. Two microfacies subtypes are distinguished :

Microfacies subtype 2.1 : Neritic bioclastic grainstone (Plate 3 : Fig. 2). This facies is characterized by skeletal grainstones and rudstones which are mostly composed of coated bioclastic grains. The bioclasts are remains of : calcareous algae (*Teutloporella* sp., *Salpingoporella pygmaea* (Gümbel), *Salpingoporella annulata* Carozzi, *Clypeina jurassica* Favre and Richard, *Lithocodium morikawai* Endo, *Bačinella irregularis* Radoicic, *Thaumatoporella parvovesiculifera* Raineri, *Cayeuxia* sp. and others (*cf.* Jaffrezo, this volume)), benthic foraminifera (*Nautiloculina oolithica* Mohler, *Conicospirillina basiliensis* Mohler, *Pseudocyclammnina* sp., *Trocholina alpina* (Leupold), *Trocholina elongata* (Leupold), *Protopeneroplis striata* Weynschenk, species of *Ammobaculites*, *Coscinophragma*, *Textularia*, ataxophragmiids, *Ophthalmidium*, *Quinqueloculina*, *Lenticulina*), gastropods, corals, bryozoans, serpulids, echinoderms and *Tubiphytes* sp. Non-skeletal particles are intraclasts, peloids and rare ooids. The components are cemented by sparry calcite. Quantities are about 35 % bioclasts, 15 % intraclasts, 5 % peloids and 40 % cement. Grain sizes range from arenite (60 %) to rudite (40 %). Former porosity is about 40 % and is divided into interparticle porosity (35 %) and into moldic porosity (5 %).

Microfacies subtype 2.2 : Neritic oolitic grainstone (Plate 3 : Fig. 3). Concentrically layered ooids, peloids, micritized intraclasts, grapestones and skeletal debris (fragments of dasycladacean algae, bivalve shells, and foraminifera (*Nautiloculina*, textulariids)) are the constituents of this facies type. Particle quantities are 90 % ooids, 5 % intraclasts (up to rudite grain size) and 5 % skeletal grains. Matrix of the rock is sparry calcite.

Occasionally, the interparticle pores are filled with black ferromanganese oxides. Together with blocky calcite they take part in the occlusion of the pores after the first cement rims were formed.

Microfacies 3 : neritic algal bindstone facies

This microfacies is characterized by traces of sediment binding cyanobacteria and encrusting algae. Two microfacies subtypes can be recognized :

Microfacies subtype 3.1 : Neritic algal bindstone with coral debris (Plate 3 : Fig. 1). This sediment is composed of skeletal debris which is derived from coral-bearing environments : remains of corals, calcareous sponges, *Cladocoropsis mirabilis* Felix, *Lithophyllum* sp., *Nipponophycus* sp., gastropods, serpulids, sessile foraminifera (*Placopsilina*, *Thurammina*, *Tolypammina*, *Nubeculinella*). Non-skeletal particles are intraclasts. The matrix of the rock is pelmicrite. Birds-eyes structures indicate that cyanobacteria have probably bound rapidly the sediment. Although composed of detrital material, this limestone must be regarded as a bindstone because of the early lithification of sediment-binding cyanobacteria. The occurrence of frame-builders of considerable size indicate deposition very close to a reef environment. True coral boundstones, however, were never recovered. This could be due to the fact, that sampling was rather selective, limited by the hardness of the massive limestone which possibly could also yield reef facies.

Microfacies subtype 3.2 : Neritic algal bindstone with ooids (Plate 3 : Fig. 4). This type contains ooids and minor skeletal debris. The particles are bound by encrusting algae : *Bacinella irregularis* Radoicic and *Lithocodium aggregatum* Elliott. Other components are *Cladocoropsis mirabilis* Felix, dasycladacean algae [*Salpingoporella pygmaea* (Gümbel)], lituolid foraminifera, *Nautiloculina oolithica* Mohler, remains of echinoderms and corals. The cement of the rock is sparry calcite bound to *Bačinella irregularis*. Particle quantities are 25 % ooids, 20 % skeletal material, 10 % peloids, 40 % *Bacinella irregularis* and *Lithocodium aggregatum*. 5 % of the section is open porosity. Unusually large ooids characterize this type of limestone. We interprete them to be allochthonous, transported into lagoonal basins between oolite bars and platform patch-reefs. Coral debris and *Bacinella irregularis* indicate near reef position (Fenninger and Holzer, 1972). In fact encrusting algae such as *Bačinella irregularis*, *Lithocodium*, and *Thaumatoporella parvovesiculifera* (comp. microfacies 2.1) frequently consolidate the sediment for further coral growth (Flügel, 1964 ; Steiger, Wurm, 1980).

Facies B : hemipelagic facies with calpionellids

Hemipelagic sediments occur in deeper, but not in the deepest, seaward areas of the central Mazagan Escarpment. Two microfacies types reflect normal deposition of fine-grained bioclastic sediments mixed with pelagic biota, as well as coarse clastic fore slope sedimentation due to reworking during the Berriasian regression.

Microfacies 4 : Hemipelagic packstone with calpionellids (Plate 4 : Fig. 1)

The main facies type of hemipelagic limestone in front of the Mazagan plateau is a microbioclastic packstone which is composed of calpionellids (mostly *Calpionella*

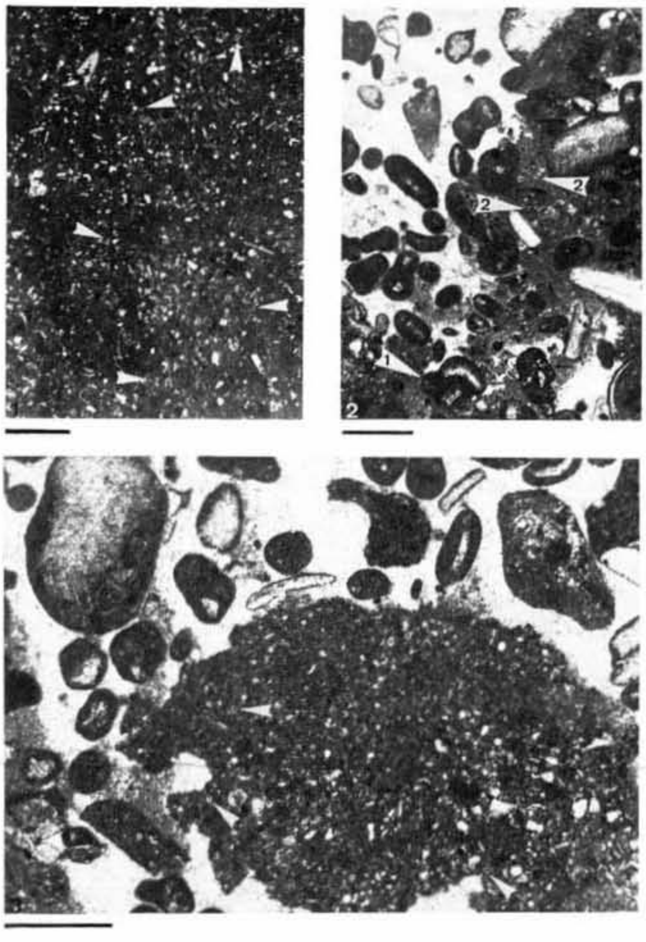


Plate 4

Facies B : Hemipelagic limestones with calpionellids from the seaward edge of the Upper Jurassic to Lower Cretaceous Mazagan carbonate platform.

Figure 1

Microfacies 4 : Bioclastic, pelmicritic packstone to wackestone with calpionellids. Bioclasts are echinoderm remains, nodosariid foraminifera, bivalve shells and ostracods. In the micritic matrix micrite intraclasts occur. The calpionellids are mostly Calpionella alpina *Lorenz (arrows). CZ 85-4, 17 x.*

Figure 2

Microfacies 5 : Bioclastic, oolitic grainstone with calpionellid-bearing matrix. The ooids are micritized and frequently lumped together (1). Matrix of the rock is sparite and minor micrite. The micrite has a patchy distribution and contains calpionellids (2). CZ 98-4, 19 x.

Figure 3

Microfacies 5 : Bioclastic, oolitic grainstone with calpionellid-bearing lithoclasts. Most of the particles are coated grains. Their nuclei have indistinct particle boundaries. The intraclast is a bioclastic, pelmicritic packstone with calpionellids (arrows). The irregular contour of the intraclast indicates short distance of transport. CZ 98-4, 28 x.

alpina Lorenz, *see* Jaffrezo *et al.*, this vol. ; *comp.* also Azéma, Jaffrezo, 1984), hexactinellid and lithistid siliceous sponges which are preserved in place or semi-in place (Lang, Steiger, this vol.), and of skeletal debris derived from the platform slope (solitary corals, bryozoans, shells of brachiopods, and echinoderm remains). Other pelagic biota are rare debris of *Saccocoma*, ammonites, debris of aptychi and thin shells of pelagic bivalves. Small benthic foraminifera also occur (*Trocholina*, *Textularia*, *Lenticulina*). Single ostracod valves are frequent. Non-skeletal particles are peloids and small intraclasts. The sediment also contains angular quartz grains (averaging 50 microns in diameter) of varying quantities (up to 1 %). The quantities of the other particles are : 50 % biota (10 % echinoderm remains, 2 % calpionellids), 15 % peloids, 10 % intraclasts and 25 % micritic matrix.

The described facies is restricted to a very narrow belt subparallel to the Mazagan Escarpment. It is located between the above stromatolitic peloidal facies (facies A) and the below periplatform talus which is expected from about 3 000 m to 4 000 m. The outcrops of hemipelagic calpionellid limestone are probably limited to individual tectonic blocks which have subsided rapidly in the external areas of the Upper Jurassic to lowermost Cretaceous paleoslope.

Microfacies 5 : bioclastic, oolitic grainstone with calpionellid-bearing lithoclasts (Plate 4 : Fig. 2 and 3)

In dive 98 one sample of limestone was recovered which contains reworked calpionellids. The sediment is a lithoclastic to oolitic grainstone. Bioclasts are echinoderm remains, calcite-cemented molds of siliceous sponges (hexactinellid and lithistid types), gastropods, bivalves, ammonites, bryozoans, fragments of *Tubiphytes* sp., and foraminifera (*Ammobaculites* and *Lenticulina*). Non-skeletal particles are ooids, cyanobacterial oncoids, and intraclasts. The intraclasts are composed of cyanooncoid wackestone and peloidal packstone. Many of the lithoclasts contain calpionellids. In the intra-skeletal pores of the siliceous sponges calpionellids also occur. Matrix of the rock consists of 60 % sparry calcite and 40 % micrite. The micrite shows patchy distribution and contains calpionellids.

Obviously the rock is the result of reworking of outer platform limestones. Their original depositional environment is the sponge-cyanooncoid facies which is known from DSDP Site 544 and Miocene gravity flows (mostly composed of Jurassic material) from DSDP Site 545 (Steiger, Jansa, 1984). Cements indicate sedimentation of the bioclastic and oolitic grainstone with calpionellid-bearing lithoclasts in a shallow marine environment. This is also indicated by the presence of shallow-water ooids. We assume that reworking and redeposition happened during the Berriasian to Valanginian regressive period.

Facies C : neritic micritic and quartz-bearing facies

On the top of the Mazagan Plateau muddy calcareous and dolomitic sediments and algal bindstones were deposited in shallow marine environments. Here, such environments occurred during Kimmeridgian as well as during Berriasian to Valanginian regressive phases (*cf.* microfacies 5). Calcareous and dolomitic sediments were found in the center of the plateau (central and western area). The southern part near the El Jadida canyon is made up of quartz-bearing sediments, mixed with lagoonal calcareous components. Two microfacies types were distinguished :

Microfacies 6 : neritic mudstones, wackestones and packstones

Neritic mudstones, wackestones and packstones of facies C are mainly composed of shallow-marine skeletal and non-skeletal debris normally embedded into micritic matrix. These lithologies are derived from intra- to shallow subtidal mudflats and low energy lagoons. They developed both during the carbonate ramp stage and during the carbonate platform stage of the Mazagan platform evolution (Jansa *et al.*, 1984). Three microfacies subtypes can be recognized.

Microfacies subtype 6.1 : oolithic bioclastic packstone (Plate 5 : Fig. 3)

Major components of the calcarenite are concentric ooids. Other particles are intraclasts, peloids, foraminifera (*Textularia*, miliolids, *Protopeneroplis striata* Weynschenk, *Trocholina alpina* Leupold), debris of dasycladacean algae (*Salpingoporella annulata* Carozzi, *Campbelliella striata* (Carozzi)), echinoderm remains, fragments of bivalve and gastropod shells. Amongst the particles 80 % are ooids, 15 % skeletal debris and 5 % intraclasts (up to rudite grain size). The rock is cemented by sparry calcite. Two generations of cement are present :

a) a first rim of isopachous fibrous palisade cement which partly grades into dog-tooth cement ;

b) a second cementation phase characterized by blocky crystals which occlude the pores.

The boundary between the first and the second phase of cementation is marked by a dark layer of detrital material. One pendant rim of micro-stalactitic palisade cement could be observed. This possibly is a phase of vadose diagenesis (Milliman, 1974 ; Müller, 1971).

Microfacies subtype 6.2 : intraclastic wackestone (Plate 5 : Fig. 1)

This microfacies subtype is characterized by the occurrence of large diagenetic idiomorphic calcite crystals and overgrowth of calcite upon particles, which in part cannot be identified. Also numerous very small rhomb-like calcite crystals are widely distributed in the sedimentary matrix. Some particles are intensely micritized and coated by micrite. As far as determinable, they are intraclasts, rare ooids, bivalve shells, gastropod shells, foraminifera *(Textularia, Ammobaculites)*, and debris of the dasycladacean alga *Salpingoporella annulata* Carozzi. The particles are embedded in micritic matrix, occasionally they are lumped together to form " aggregates " with an irregular shape. These aggregates are not cemented like grapestones and do not show micritic encrustations like algal lumps (*cf.* Flügel, 1982). Possibly they are due to reworking, *i.e.* true intraclasts (Folk, 1959), however they also could be burrow fillings. This latter interpretation is supported by the fact that the micritic matrix shows mottling of dense micrite, patches of microsparite and concentrations of particles.

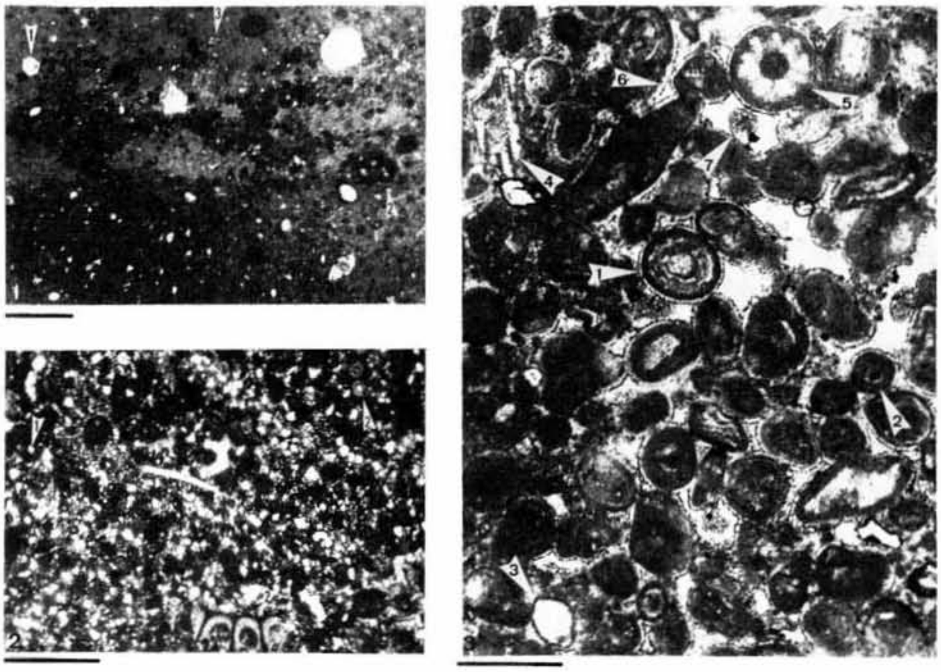


Plate 5

Facies C : Upper Jurassic and Lower Cretaceous microfacies types from the top of the Mazagan carbonate platform.

Figure 1

Microfacies 6.2 : Intraclastic wackestone composed of syntaxially overgrown echinoderm remains (1), gastropods (2), coated bioclasts (note Salpingoporella annulata *(3)), intraclasts and peloids. The sediment is layered and slightly bioturbated. CZ 86-7, 9 x.*

Figure 2

Microfacies 8.1 : Micritic quartz-bearing, intraclastic packstone with debris of Clypeina jurassica. *Well rounded intraclasts, angular quartz grains and bioclastic material of lagoonal origin are the major constituents of this microfacies type. Within the intraclasts and at particle boundaries dolomite rhombs are developed (1). The* Clypeina *fragments (2) are strongly abraded. The sample comes from at the northern slope of the El Jadida canyon in the southern part of the Mazagan carbonate platform CZ 101-9, 50 x (photomicrograph by U. von Rad).*

Figure 3

Microfacies 6.1 : Oolitic, bioclastic grainstone/packstone. Major constituents are concentrically layered ooids (1) which are frequently micritized (2). Other particles are benthic foraminifera (Trocholina *sp. (3)), echinoderm remains (4) and debris of dasycladacean algae* (Salpingoporella annulata *Carozzi (5)). At the left the components are lumped, bound by micrite. At the right particles are cemented by an even-rim cement. The cement rim consists of fibrous palisades of calcite (6) with some dog-tooth crystals growing into the interior of the pore space. The fibrous rim is covered by a dark layer of micritic material. In the centers of the remaining pore spaces the cements around particles below or above the section were cut tangentially (7). CZ 98-9, 55 x.*

The idiomorphic calcite crystals probably represent overgrown echinoderm remains. Some of them show neomorphically a structured center which is surrounded by clear calcite replacing micritic rock matrix.

Microfacies subtype 6.3 : dolomicrite

The top of the Mazagan Plateau (dive 92) is mostly composed of pelagic Upper Late Cretaceous to Paleocene peloidal foraminiferal packstones (Jaffrezo *et al.*, this vol.). However, the basal lithologies of this profile are slightly laminated dolomicrites of probably Late Jurassic to Earliest Cretaceous age. Such dolomites are known from onshore Morocco (Immouzzer Formation, Jansa, Wiedmann, 1982 ; Hüssner, 1985 ; Schmitz, pers. comm., Feb. 84). Here, they are regarded as Jurassic and Lower Cretaceous landward evaporitic deposits. As the dolomicrites from the base of dive 92 are clearly distinguished from the above Upper Cretaceous to Paleocene beds, we assume that they represent the uppermost deposits of the Mazagan shallow-marine platform.

Microfacies 7 : micritic fenestral facies

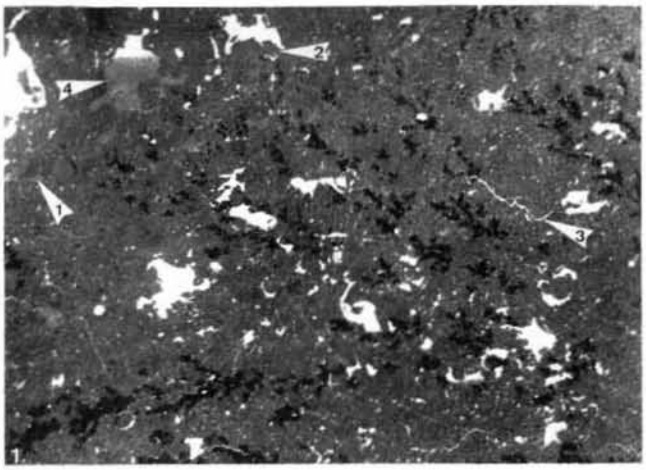
The second calcareous lithology of facies C are fenestral limestones. Peloidal and intraclastic sediments are particularly associated with birds-eyes structures and stromatactis.

Microfacies subtype 7.1 : fenestral peloidal wackestone (Plate 6 : Fig. 1)

This facies consists of disturbed pelmicrite (dismicrite, Folk, 1959) which is characterized by irregularly developed cavities and fissures. The cavities contain angular to rounded micritic intraclasts. The fissures indicate that the rock may be completely composed of micritic intraclasts. Some of the cavities are geopetally filled with microcrystalline calcareous material. Such internal sediments is interpreted as crystal silt (Dunham, 1969), and the fenestral porosity as a result of leaching in the vadose zone (Scholle, 1978).

Microfacies subtype 7.2

Laminated fenestral peloidal and intraclastic pack-



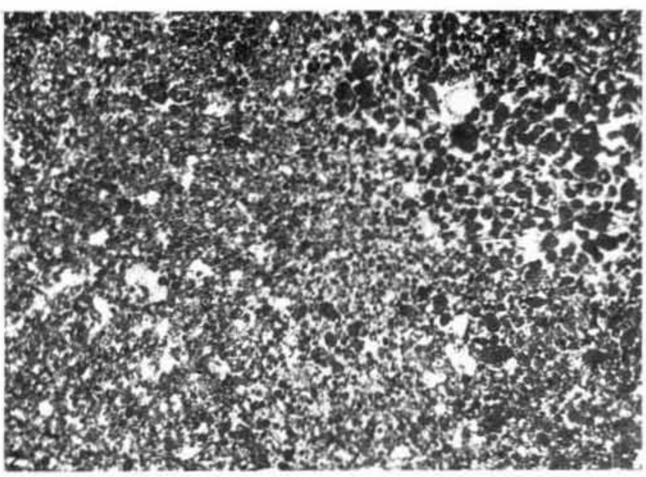


Plate 6

Facies C : Upper Jurassic and Lower Cretaceous microfacies types from the top of the Mazagan carbonate platform.

Figure 1

Microfacies 7.1 : Fenestral intraclastic, peloidal wackestone to dismicrite. The sediment is composed of micritic intraclasts, visible in the pelmicritic matrix (1) and in cavities (2). The depositional fabric is disturbed by phosphatized fissures (3). The irregularly contoured cavities are geopetally filled with calcareous silt (4). This type of fenestral porosity is interpreted to be of vadose origin (see description chapter 3.3). *CZ 101-3, 13 x.*

Figure 2

Microfacies 7.2 : Intraclastic peloidal packstone composed of subangular to well rounded quartz-bearing micritic intraclasts. Other components are foraminifera, mollusk fragments, and echinoderm remains. Larger pores on the left represent fenestral porosity which is cut parallel to bedding. In hand specimen the rock is thinly layered. This microfacies type reflects the beginning of the change from pure calcareous sedimentation into sandy post-platform sedimentation. CZ 101-8, 13 x.

stone (Plate 6 : Fig. 2). Intraclasts and peloids are the main constituents of this microfacies subtype. Further components are echinoderm remains, textulariids and other agglutinating foraminifera, and gastropods. The particles are cemented by sparry calcite. The depositional fabric is characterized by laminations in vertical section and by larger pore spaces which are oriented subparallel to the laminated structure. We interprete the large pores as birds-eyes structures. In horizontal section they have an irregular shape and are irregularly scattered through the rock.

Microfacies 8 : micritic quartz-bearing intraclastic packstone with Clypeina jurassica debris (Plate 5 : Fig. 2)

The entire upper sequence of the southern slope of the Mazagan Plateau consists of calcareous quartz-bearing sediments. These well-bedded deposits occur close to the El Jadida canyon, which seems to have been an area of rapid siliciclastic and calcareous sedimentation with high accumulation rates during the Earliest Cretaceous (von Rad, this vol.). The facies of these sediments ranges from micritic quartz-bearing intraclastic packstones to sandy echinoderm packstones (*see* MF-types 8.1-8.4 ; von Rad, this vol.).

Sample CZ 101-9 (1 207 m) contains debris of the dasycladacean alga *Clypeina jurassica* Favre and Richard (up to 1 %). Other components are round (possibly rounded) and angular micritic intraclasts. Peloids are present. Angular sand-sized quartz grains are common (30 %). The micritic intraclasts also contain rare quartz grains. Diagenetic minerals are dolomite rhombs which have grown in interparticle pores as well as within the micritic intraclasts.

The *Clypeina* segments are abraded. In connection with the rounded intraclasts this suggests transport of calcareous lagoonal material into the siliciclastic environment of the El Jadida Canyon. The fact that the micritic intraclasts contain quartz grains indicates a transition zone from pure calcareous sediments on the top of the platform to siliciclastic sandstones in the canyon. We assume a gentle slope between the platform top and the canyon area which occasionally could be affected by erosional currents. *Clypeina jurassica* and micritic sediment were reworked by these currents and transported into the canyon. It is unlikely that *Clypeina jurassica* lived in the siliciclastic environments.

We assume that the canyon is a very old structure developed in the time of platform growth and filled during the first phase of drowning. The valley subsequently was intensely eroded and outcrops of wellbedded sandstones were formed.

Transitional and composite facies types

Large thin-section include the possibility to observe several microfacies types and their transitions. At the margin of the Mazagan carbonate platform microfacies types strongly interfinger. Most of the transitional types occur in contact with the columnar stromatolitic peloidal packstones. This facies is frequently interbedded with coarser bioclastic grainstones (microfacies 2.1). Such detrital sediments accumulated around domal crustose peloidal structures. Occasionally they are graded and contain coral debris up to rudite grain size. The stromatolitic peloidal facies also interfingers with algal bindstones (microfacies 3.1) and with intraclastic wackestones (microfacies 7.1). In numerous thin-sections composite lithologies of bioclastic grainstones and algal bindstones (encrusting algae and fenestral fabric) occur.

The observed composite facies types reflect the very heterogenous sedimentary and hydrologic conditions at the platform margin. The sea floor, exposed to currents along the outer margin of the platform, obviously had an irregular relief as a result of rapid bacterial lithification of the peloidal material, erosion and resedimentation in oceanward position exposed to currents.

BIOSTRATIGRAPHIC PROBLEMS

The reconstruction of the lithologic evolution of the Mazagan carbonate platform, interpreted from the CYAMAZ diving results, is hampered by the difficulty to establish a vertical succession of microfacies types.

Geometric criteria

The platform limestones of the Mazagan Escarpment underwent tectonic extension in a W-E direction during different phases of block-faulting, accompanied by rapid and differential subsidence of the western blocks. This is indicated by the occurrence of shallow-marine stromatolitic limestones (MF 1) from 1 700 to 3 000 m depth. It is therefore impossible to reconstruct a stratigraphic succession from the present position of the rock samples recovered by CYANA.

Biostratigraphic criteria

The biostratigraphic data are also insufficient to establish a stratigraphic succession of the microfacies types. The best dated microfacies type is the calpionellid limestone (MF 4) of Late Tithonian to Berriasian age (Jaffrezo *et al.*, this vol.). Parts of the stromatolitic peloidal facies dated by siliceous sponges (Lang, Steiger, this vol.), are of Oxfordian to Kimmeridgian age. Most of the neritic limestones contain Late Jurassic to earliest Cretaceous microfossils. The biostratigraphic value of these microfossils, however, is not sufficient to distinguish between Late Jurassic and earliest Cretaceous. A few of the neritic microfacies types are clearly of Cretaceous age (intraclastic wackestone MF 6.2 and fenestral intraclastic packstone MF 7.2). They are probably younger than the stromatolitic peloidal limestones and their lateral equivalents (facies A, MF 1-3).

Sedimentologic criteria

Due to the existence of transitional microfacies types it is possible to observe the facies passages between the stromatolitic peloidal limestones (MF 1) and the neritic bioclastic grainstones (MF 2.1) as well as the neritic algal bindstone (MF 3.1). The stromatolitic peloidal facies is also interlayered with neritic fenestral peloidal wackestones (MF 7.1). Bioclastic grainstones of type 2.1 are consolidated by encrusting algae (neritic algal bindstone MF 3.1). All these facies types are more or less synchronous.

Comparison with the lithologies of the High Atlas

Jaffrezo (this vol.) shows that in the western High Atlas platform carbonates are surrounded by a fringe of calpionellid limestone layer. This lithology is comparable with the calpionellid limestones found in the CYAMAZ samples. It is therefore likely, that during a Late Jurassic to Berriasian transgressive event the calpionellid limestones (facies B, MF 4) were deposited on top of the carbonate platform or that they at least lap on the stromatolitic peloidal limestones and their lateral equivalents (facies A, MF 1-3) along the platform margin.

The limestones with calpionellid-bearing intraclasts and shallow water ooids recovered in sample CZ 98-4 (MF 5) also demonstrate that deeper marine sediments were reworked in a subsequent regressive period. Therefore, the age of the stromatolitic peloidal facies overlain by Upper Tithonian to Berriasian calpionellid facies is probably Oxfordian to Middle Tithonian.

Comparison with DSDP Leg 79

DSDP Leg 79 was concerned with geological and structural research in the northern, seaward part of the Mazagan Plateau. Detailed facies descriptions and paleoenvironmental interpretations are given by Jansa *et al.*, 1984, Bernoulli, Kaelin, 1984 ; and Steiger, Jansa, 1984. Numerous lithologies are comparable with those recovered by Cyana (Fig. 2 ; *cf.* also CYAMAZ Group, 1984).

— Calpionellid facies occurred in the uppermost section of the Jurassic to Lowermost Cretaceous limestone sequence of Site 547 B (Azema, Jaffrezo, 1984). Calpionellids associated with siliceous sponges (MF 4 and 5 in this paper) were found in Miocene gravity flow deposits (site 545) which are mainly composed of Upper Jurassic material. This suggests that sponge growth in a near-pelagic environment was widely distributed on the platform slope, more than found during CYAMAZ.

— Stromatolitic peloidal facies comparable with MF 1 of CYAMAZ was drilled in site 547 B. This facies was about 1 m thick, in contrast to the thickness in excess of 200 m at the Mazagan Escarpment (lateral distance 4.5 km) The in-situ stromatolitic peloidal facies of site 547 B was overlain by 9 m of coarse breccias consisting of sponge-crust limestone lithoclasts. These breccias indicate subsidence of the distal blocks after a short period of in place organic deposi-

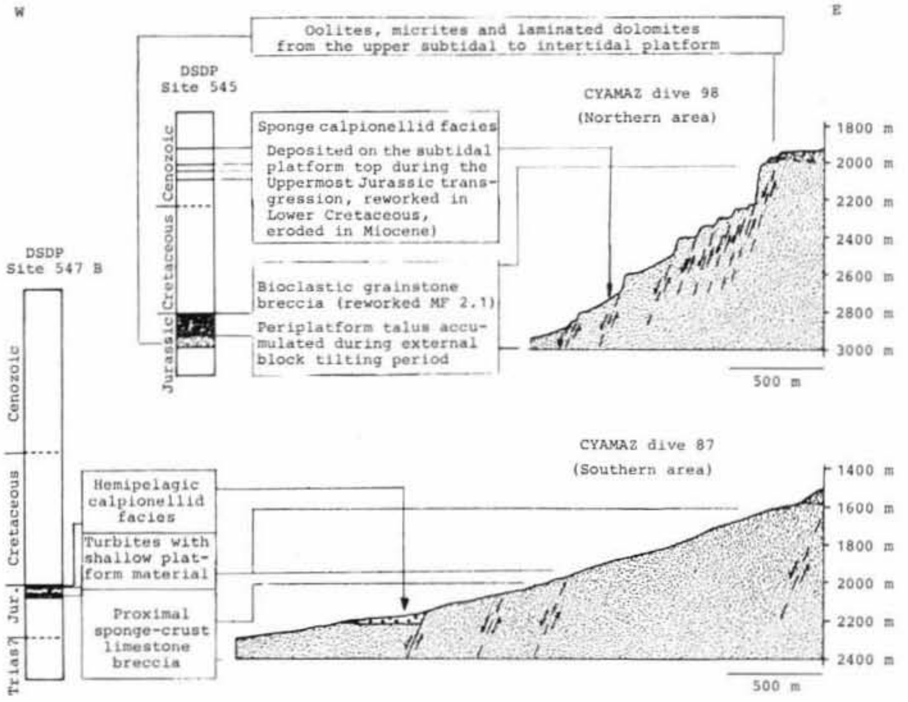


Figure 2

The Upper Jurassic to Lowermost Cretaceous sediments of the Mazagan Escarpment compared with the DSDP sites of Leg 79. Except for stromatolitic peloidal limestones found in site 547 B and platform micrites and dolomites found in site 545 all Upper Jurassic to Lower Cretaceous lithologies recovered at these Sites were allochthonous (periplatform talus with proximal slope breccias, calcareous turbidites and gravity flow deposits) or pelagic. The vertical scale of the DSDP sites is exaggerated 1 : 2. Arrows mark direction of sediment transport. No arrows : autochthonous deposition.

tion (largest extension of the carbonate ramp, Steiger, Jansa, 1984).

The site 547 B stromatolitic peloidal and sponge limestones were found 11 m below the Kimmeridgian Saccocoma facies. They occur 9 m above red quartz-bearing Dogger breccias. Therefore they probably are of Oxfordian age.

— Bioclastic grainstones particularly rich in dasycladacean algae and foraminifera *(Trocholina, Protopeneroplis)* were found in site 545. They accumulated as a periplatform talus on top of a relatively slowly subsiding block between the horst of site 544 and the margin of the inner carbonate platform (present Mazagan Escarpment). The age of these limestones is Late Jurassic to Earliest Cretaceous.

— Oolites were drilled at site 545 below the periplatform talus. They are interlayered with calcareous and dolomitic stromatolites and micrites. They probably correspond to the oolites and fenestral limestones from the top of the inner platform recovered by CYANA. In this case the bioclastic grainstone breccias of the above periplatform talus would be of Early Cretaceous age.

Lithostratigraphic consequences

Following the described lithological relationships it is necessary to distinguish three facies units :

Facies A : the massive stromatolitic peloidal limestone which represents the rigid core of the Mazagan Platform margin.

Facies B : the hemipelagic calpionellid limestones which were deposited in the deeper zones of the Late Jurassic to earliest Cretaceous slope. They probably overlie massive stromatolitic peloidal limestones of facies A.

Facies C : mainly lagoonal micrites and fenestral limestones which possibly also overlie stromatolitic peloidal limestones of Oxfordian to Middle Tithonian age.

The possible ages of all three facies units are shown in Figure 4.

INTERPRETATION OF THE LITHOLOGIC EVOLUTION OF THE CARBONATE PLATFORM

The lithologies and their depositional environments

Figure 3 summarizes the facies distribution of the Mazagan Escarpment. The horizontal zonation is : outer platform in the west, inner platform in the east. The vertical succession at the slope is upper subtidal at the base, represented by stromatolitic peloidal limestones, to upper bathyal on the top, represented by hemipelagic calpionellid limestones. The platform top is characterized by sediments, most probably deposited in the intertidal zone, occasionally affected by vadose diagenesis (pendant microstalactitic palisade cements, crystal silt).

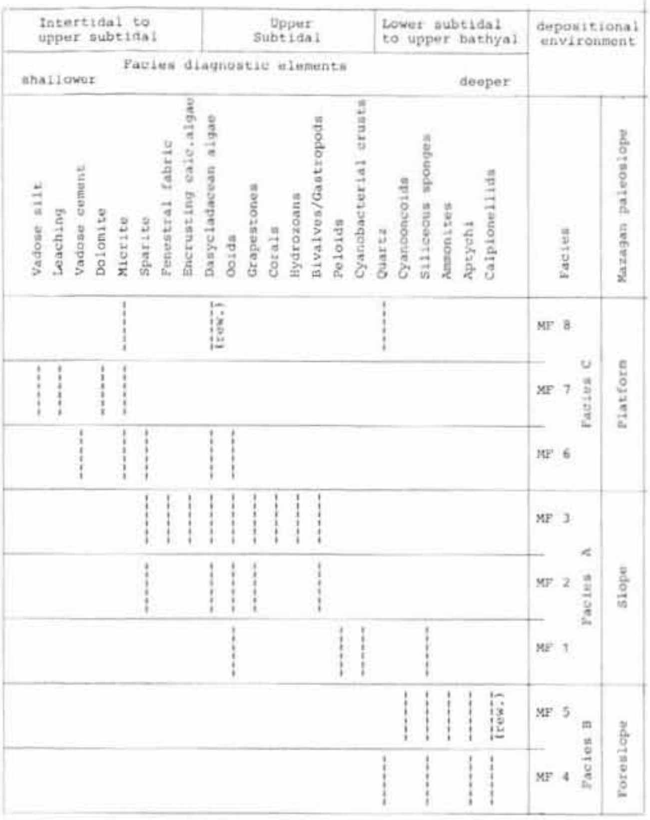


Figure 3

Facies diagnostic elements (biota, components and fabric) and their occurrence in the facies types of the Upper Jurassic and Lowermost Cretaceous sediments from the Mazagan Escarpment.

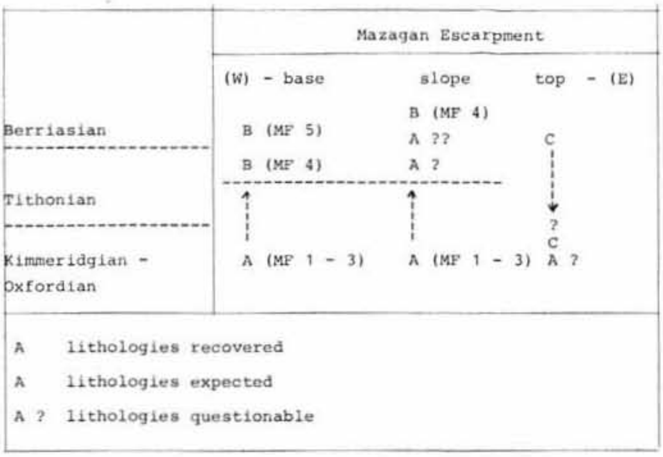


Figure 4

The age ranges of the facies units of the Upper Jurassic to Lowermost Cretaceous sediments from the Mazagan Escarpment.

Sampling was concentrated to the recent slope of the Mazagan Escarpment. Most of the CYAMAZ samples belong to facies A. Although the massive stromatolitic peloidal limestones are tectonically repeated along the slope and simulate much larger thicknesses along the recent escarpment than deposited, it is possible that even in Late Jurassic times the slope was convex due to rapid bacterial lithification and high accumulation rates of the sediment. This is suggested by special faunal associations characteristic for certain depth intervals: siliceous sponges and associated faunas (expected to live in depths below 50 m, occasionally mixed with calpionellids) were found at the deeper escarpment, whereas corals and calcareous green algae (bound to the photic zone above 50 m) were predominantly found at its upper part.

The lithologies and " relative sea level changes "

The biostratigraphic data and the interpretation of the depositional environment of the limestones recovered from the Mazagan Escarpment indicate the following " relative sea level changes " (Fig. 5):

1) During the Kimmeridgian to Tithonian the stromatolitic peloidal limestones were deposited. Water

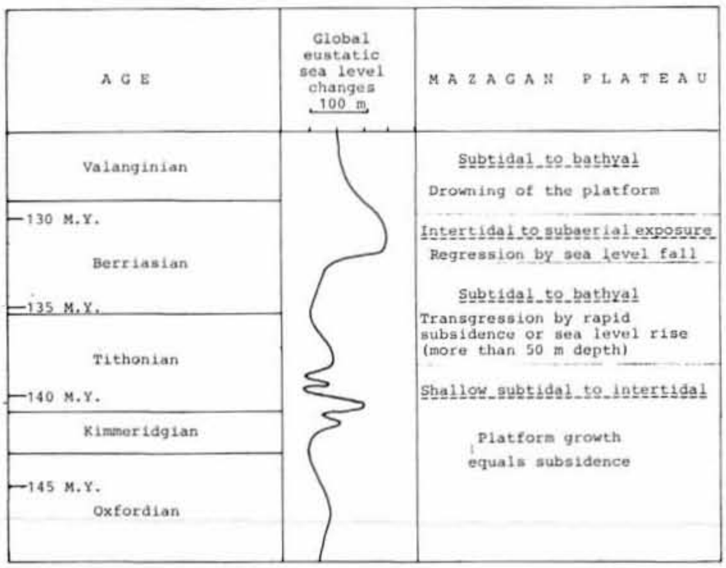


Figure 5

Global sea level changes (Vail, Todd, 1981) compared with the lithologic evolution of the Mazagan Plateau during the Upper Jurassic and Lower Cretaceous.

depth did not change because the upper subtidal to intertidal sedimentation was balancing the subsidence of the underlying tectonic blocks and possible changes in sea level.

2) The calpionellid limestones restricted to the external blocks of the Mazagan Escarpment are the result of rapid subsidence rather than a transgression by a sea level rise.

3) However, the neritic grainstones (MF 5) which contain calpionellid bearing lithoclasts indicate that micritic calpionellid deposits were eroded and reworked during a short regressive phase. This phase represents a " relative sea level low " before the final transgression in the Early to Middle Cretaceous. Sedimentologic and diagenetic criteria suggest vadose conditions and possibly occasional subareal exposure of the central platform area. Also the irregular contact between the intraclastic quartz-bearing packstones (MF8) and the underlying platform limestones marks an " erosional surface ". The regressive phenomena observed at the Mazagan Escarpment can be correlated with the " global Berriasian regression " (Vail, Todd, 1981 ; Vail *et al.*, in press ; Hüssner, 1985).

The lithologic evolution of the carbonate platform

The development of the Mazagan carbonate platform consists of three stages (Fig. 6) :

Kimmeridgian to Middle Tithonian

The major facies of the Mazagan Escarpment is the stromatolitic peloidal limestone. These massive limestones could probably stabilize the platform margin due to early bacterial lithification and rapid cementation. Back-tilting of the individual tectonic blocks probably led to an accentuated morphology with cemented limestones exposed, forming ridges in front of lagoonal basins. The lagoons were filled with neritic grainstones (MF 2) and neritic algal bindstones (MF 3). Transitional types indicate intricate interfingering of the marginal facies types. From the Kimmeridgian to the Middle Tithonian sedimentation rates increased and the shallow-marine carbonate platform was formed. In the internal areas of the platform intertidal micrites accumulated (MF 7). The bathymetric conditions remained stable during the Kimmeridgian and the Tithonian as sedimentation rates kept pace with subsidence and eustatic sea level changes.

Late Tithonian to Berriasian

The major sedimentary event of the Late Tithonian to Berriasian is the deposition of calpionellid limestones in subtidal to upper bathyal environments. In the Recent escarpment their occurrence is limited to deeper areas along the western slope. They are completely absent in the more landward and southern parts of the Mazagan Plateau.

The absence of this facies in the east can be due to

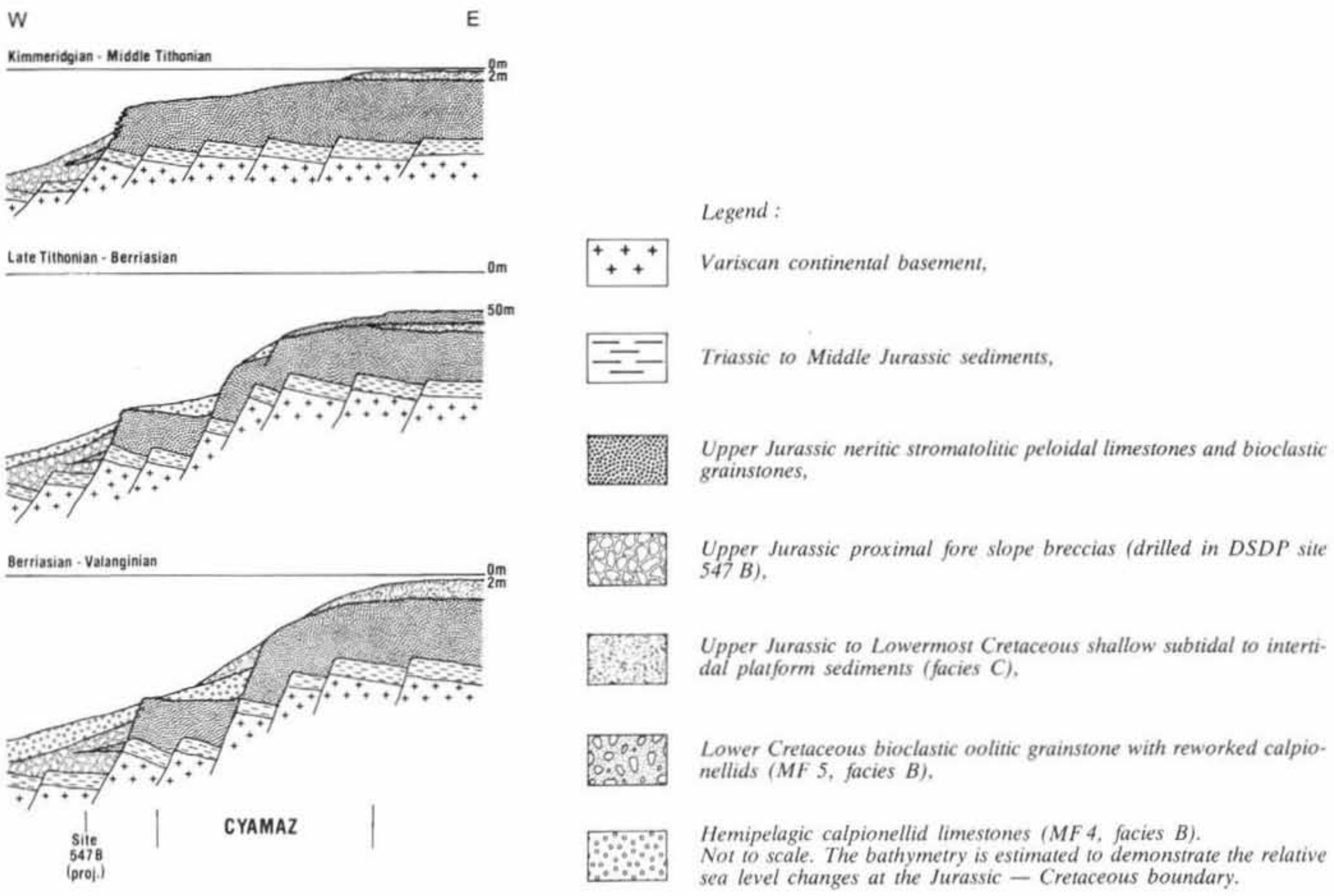


Figure 6

Scheme of the lithologic evolution of the margin of the Mazagan carbonate platform during the Late Jurassic and Early Cretaceous from the results of the CYAMAZ diving project.

non-deposition in remaining shallow-water environments or can be due to an erosional gap. In this case the platform would habe been drowned completely as a result of subsidence or a sea level rise.

We favour a synchronous lateral succession of facies B, deposited in the west, facies A (youngest portion of the stromatolitic peloidal sediments) in the central area of the margin, with local occurrences of facies C in the east. This indicates that facies evolution is tectonically controlled. According to the general tectonic pattern of the passive NW-African continental margin the platform is divided into individual blocks which rapidly subside in the distal and more slowly subside in the proximal part of the margin. The individual blocks are tilted to the east (Lancelot, Winterer, 1980) and the calpionellid facies tends to be deposited geometrically upon the external blocks having sharp facies limits.

Berriasian to Valanginian

The first post-platform sediments are echinoderm packstones (*comp.* von Rad, this vol.). In the east they overly micritic shallow-water deposits (facies C) of Early Cretaceous age.

Along the " steepened " Mazagan Escarpment reworked calpionellids were embedded into shallow water oolites. We assume

— that the crinoidal packstones are in part as old as the oolitic bioclastic grainstones which contain calpionellid limestone fragments (MF 5) ;

— that the echinoderm packstone as well as the oolitic bioclastic grainstones with reworked calpionellids result from a short regressive phase which is also responsible for the erosional surface on top of the platform limestone sequence.

This " relative sea level low " probably is more eustatic than tectonic. It is the last event before the final drowning of the platform during the Lower Cretaceous.

CONCLUSIONS

The main results of the sedimentological analysis of the deposits exposed at the Mazagan Escarpment are :

1) The steep slope of the Mazagan Escarpment facies units ranging from the Oxfordian to the Berriasian are exposed.

2) The present-day distribution of the Jurassic-Cretaceous facies pattern still reflects the environmental configuration of the Late Jurassic paleoslope. The neritic stromatolitic peloidal limestone is the major facies of this slope constituting the substrate for various associations of organisms in different water-depths : siliceous sponges in the deeper zones (possibly below 50 m), coralliferous environments in the shallower zones (possibly above 50 m).

3) With the formation of the Mazagan Escarpment, a facies differentiation developed during the Late Jurassic with hemipelagic calpionellid-bearing facies (facies B) in the distal margin, neritic stromatolitic peloidal facies along the central escarpment (facies A), and calcareous micritic and dolomitic shallow platform deposits (facies C) in the proximal margin.

4) Facies correlations with DSDP Leg 79 sites indicate that there was a carbonate ramp (distally steepened ramp ; Read, 1985) during the Oxfordian and a carbonate platform during the Kimmeridgian to Tithonian. The lithologies stabilizing the platform are rapidly cemented stromatolitic peloidal limestones (facies A) which were tectonically exposed by block-faulting.

5) Facies development and distributional patterns of lithology were controlled not only by tectonism and subsidence, but also by sea level changes. This is indicated by the Lower Cretaceous regressive sediments. At that time the Late Jurassic-Earliest Cretaceous transgressive period was terminated by a sea level fall and calpionellid-bearing facies were reworked in shallow marine environments.

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