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Facies Patterns within a Lower Jurassic Upper Slope to Inner Platform Transect (Jbel Bou Dahar, Morocco)

Christian **Scheibner** and John J.G. **Reijmer**, Kiel

KEYWORDS: FACIES ANALYSIS – CARBONATE PLATFORM – UPPER SLOPE – PLATFORM MARGIN – HIGH ATLAS (MOROCCO) – LOWER JURASSIC

CONTENTS

SUMMARY

This study concentrates on the description of a platform edge of a Lower Jurassic carbonate platform in the High Atlas of Morocco. The Jbel Bou Dahar displays a well-preserved platform to basin morphology with no major tectonic disturbance.

A clear separation in facies belts could be made for the upper slope to platform interior environment. At the transition from the upper slope to the inner platform no prominent reef can be observed. Only a small zone exists with *Lithiotis* mud-mounds and some corals, probably associated with sponges. It separates the ooid shoals of the platform interior from the upper-slope environment with its characteristic boulder beds. The angle of repose within the upper slope ranges from 23° to 35°, at the platform edge between 6° to 10° (*Lithiotis* mud-mounds zone), and within the platform interior from 1° to 4°. Nine microfacies types could be distinguished. These microfacies types include i.e. laminated pelmicrites, biopelsparites, and boundstones. Facies analysis showed that the sediments were deposited in facies belts 4 (slope of the platform) to 7 (open platform areas) after WILSON (1975).

1 INTRODUCTION

The High Atlas mountain chain bordering the north-western margin of Africa has been a prominent structural boundary since the Late Palaeozoic (Fig. 1; JACOBSHAGEN, 1988). The polyphase orogenic history of the Atlas Mountains includes Hercynian deformation, Mesozoic wrench-rift tectonics, and alpine inversion. In the Triassic rifting started, which accelerated during the Liassic (Early Jurassic). This process occurred in response to the opening of the North Atlantic and the separation of Africa and Europe.

The southern High Atlas mountains of Morocco offer exposures of relatively intact Lower and Middle Jurassic carbonate platforms which developed in an tectonically active rift-basin setting (WARME, 1988; CREVELLO, 1990; KENTER & CAMPBELL, 1991).

Models proposed for the tectonic formation of the Jurassic High Atlas seaway centre around a rifted basin setting with pull-apart and fault stepping over tectonics, fault-bounded rifting or a strong transtensional component (JACOBSHAGEN 1988). Depositional facies and synrift depositional models incorporate oblique extension to strike-slip compression for platform and basin strata in the High Atlas (e.g. LEE & BURGESS, 1978; JENNY et al., 1981; JOSSEN, 1987). The rift zones were marine seaways during the middle Liassic (DU DRESNAY, 1979). These narrow seaways terminated with shorelines near the structural high of the Tichka Massif, along the Moroccan Meseta, and along the southern border with the Saharan Meseta (Fig. 1). The seaways approximate the region of main subsidence within the rifts, which were filled with deep-water limestone and marl, whereas at the margins shallow-water carbonates developed (WARME, 1988). The Jurassic seaways and the carbonate platform margins bordering the axial, deep-water limestones were extensively described by AGARD & DU DRESNAY (1965) and DU DRESNAY (1971, 1977, and 1979). DU DRESNAY (1979) distinguished two stages of platform development along the margin of the rift: (A) a

Addresses: Dipl. Geol. Chr. Scheibner, University of Bremen - FB 5, P.O. Box 330440, D-28334 Bremen, E-mail: scheibne@uni-bremen.de; Dr. J.J.G. Reijmer, GEOMAR Forschungszentrum für marine Geowissenschaften, Wischhofstr. 1-3, D-24148 Kiel, E-mail: jreijmer@geomar.de

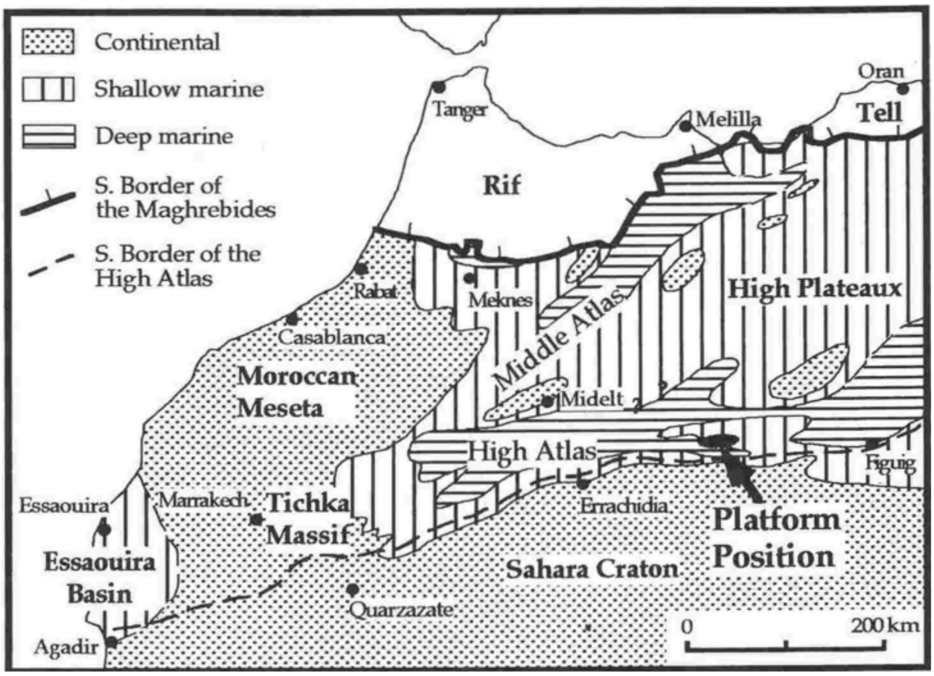


Fig. 1. Distribution of Jurassic sediments and location of the Jbel Bou Dahar carbonate platform within the High Atlas mountain chain.

Lower to Middle Liassic (Sinemurian to Domerian) lower carbonate platform complex and (B) an Upper Liassic to Lower Dogger (Aalenian to Bajocian) upper carbonate platform complex (Fig. 1).

The Jbel Bou Dahar platform developed on a fault block off the southern margin of the Central and Eastern High Atlas Rift of Morocco. In this mountain range a Lower to Middle Liassic carbonate platform is exposed (Fig. 2). The platform growth at the Jbel Bou Dahar was initiated during the Sinemurian and ended when the platform drowned between the end of the Domerian (Upper Pliensbachian) and the Middle Toarcian (CREVELLO, 1990; BLOMEIER & REIJMER, this volume). Toarcian shales and Aalenian lime mudstones progressively onlap the Domerian platform flanks and conformably overly the platform top indicating the abrupt cessation of platform evolution at the Domerian-Toarcian transition (CAMPBELL, 1992).

The Jbel Bou Dahar was first researched by AGARD & DU DRESNAY (1965). They show that this isolated platform was only moderately structurally disrupted. The original platform geometry has remained intact thus preserving a 500 m high carbonate platform structure (AGARD & DU DRESNAY, 1965; CREVELLO, 1990; KENTER & CAMPBELL, 1991). The presence of in situ facies belts, platform interior to basin, showing the original geometrical and stratigraphical relationships as well as geopetal fills in the reef and slope sediments, are evidence for a complete and undisturbed platform geometry. A variety of studies concentrated on the sedimentological character of the carbonate platform margins. CREVELLO (1990) developed the stratigraphic framework and overall evolution of the platform. CREVELLO (1991) analysed the sedimentary stacking patterns of the inner platform deposits and made a comparison with the cycles developed in the basin. The platform margin geometry was mapped by KENTER & CAMPBELL (1991). They observed minimal recrystallization and virtually no dolomitization of the platform sediments. Dolomitization of the Jbel Bou Dahar is restricted to the Sinemurian carbonates and was not observed in the Domerian rocks. CAMPBELL & STAFLEU (1992) used this platform for modelling studies of drowned carbonate platforms. The sedimentary development and sequence stratigraphic interpretation of the toe-of-slope deposits was studied by BLOMEIER (1997). GLÄSER (1996) focussed on the cycle stacking patterns of the slope sediments. SCHEIBNER (1995) mapped the upper slope and reef facies belts.

The main objective of this paper is (1) to map the edge of the Domerian platform and (2) to analyse facies variations at the upper slope to platform interior transition, including the reef environment. For the Early Jurassic a sharply reduced abundance of sphinctozoans, inozoans and stromatoporoids is described in literature (FAGERSTROM, 1987), thus limiting the development of reefs. Hettangian and Sinemurian reefs are relatively unknown and Pliensbachian reefs are only known from the Atlas Mountains in Morocco (STANLEY & BEAUVAIS, 1994). The Jbel Bou Dahar thus offers the unique opportunity to study reefs for this specific geologic time interval. It allows us to list what types of biota are present along the platform edge and what type of reef communities are present.

In the first part of this paper we describe the facies distribution pattern along the platform edge as found in a grid of 15 x 30 m rectangles that were laid out in the field along this part of the platform. The individual rectangles were mapped in great detail including the topography and facies distribution. Samples were taken for thin-section

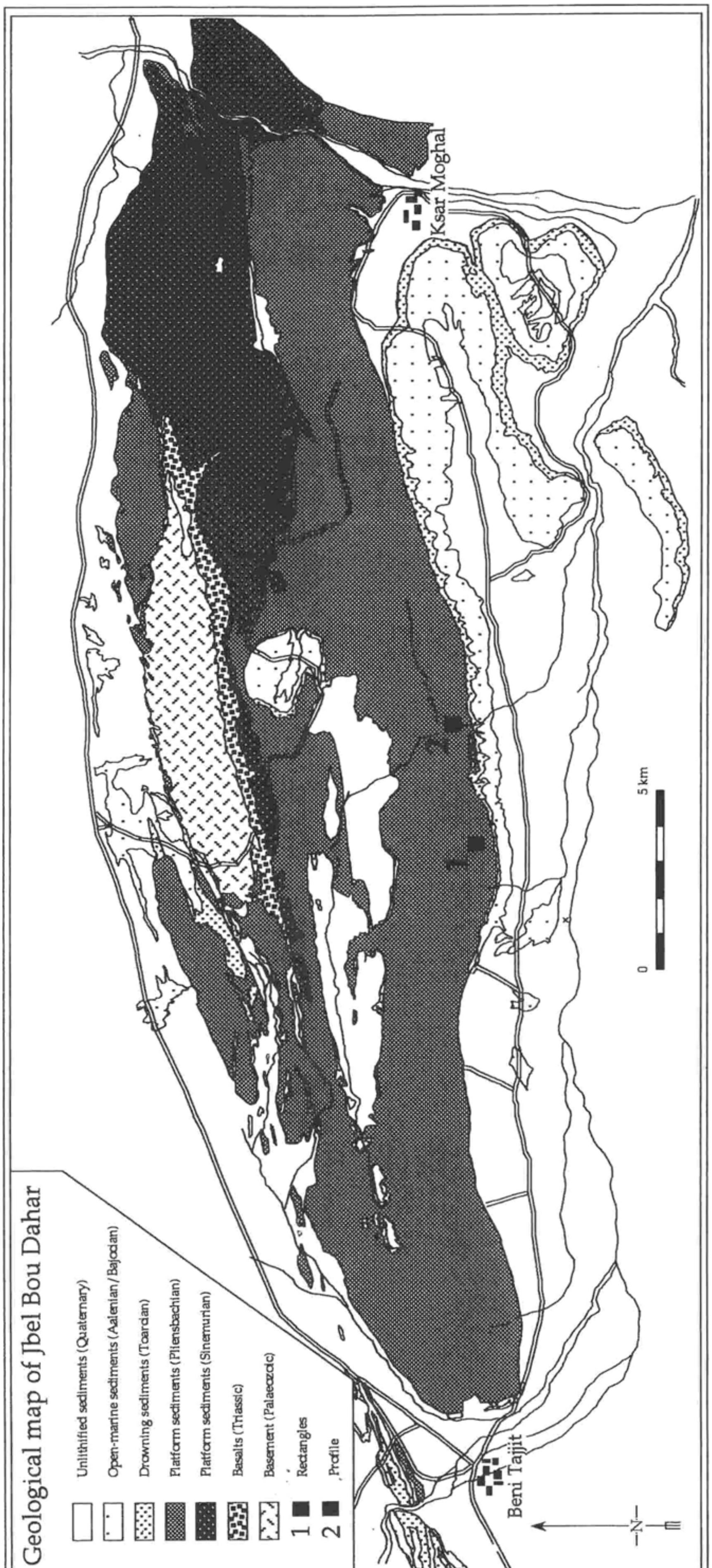


Fig. 2 for precise location.

analysis within these rectangles, characterising all facies types encountered.

In the second part a photographic profile is described of the upper slope deposits. Drawings were made to precisely document the outcrop and to analyse the vertical stack of the individual upper-slope facies types. Within this chapter a detailed analysis of the biota found will be given, followed by the sediment classification into 9 microfacies types.

2 METHODS

The sedimentological and facies variations in the transition zone from the upper slope towards the inner platform were analysed in detail by mapping 14 rectangles in total (Figs. 2 and 3; Chapter 3). The long side of the rectangles, 30 m, is orientated more or less parallel to the inclination of the slope. The short side, 15 m, runs parallel to strike. The relative altitude of the individual rectangles was measured using an altimeter; the inclination was documented using a standard clinometer (Figs. 3 & 4). The general orientation of the rectangles chain varies from NW/SE to N/S. The sediments within the rectangles were described in the field using a handlens. General facies-distribution was mapped within the individual rectangles. In total 454 samples were analysed in this part of the platform-to-slope transect, 110 samples were taken of the individual facies within the lower 5 rectangles. Due to outcrop changes the sampling and mapping procedure was adjusted for the upper 9 rectangles. Within these rectangles, 344 samples were taken, spaced 3 to 5 m apart, in order to characterise the broad facies belts present. The microfacies of all samples were described using the DUNHAM-classification.

One profile situated within a gully (Fig. 2; Chapter 4) was stud-

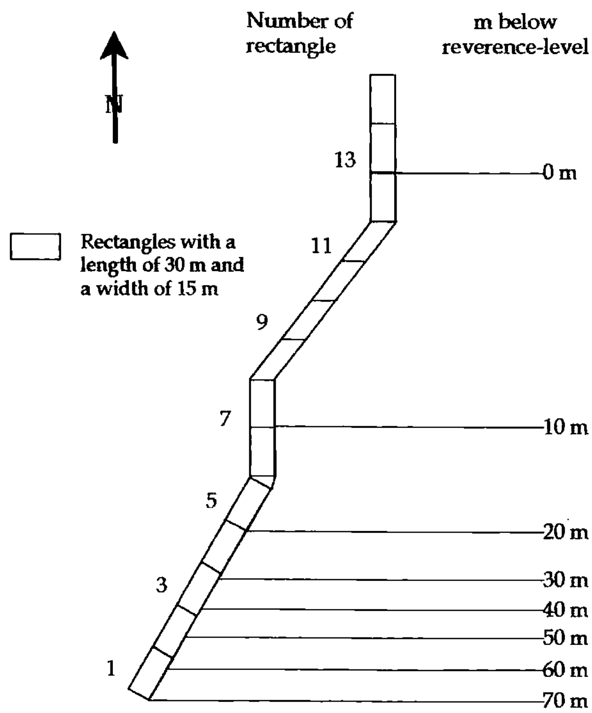


Fig. 3. Orientation of the rectangles across the platform edge. The facies maps of the individual rectangles are given in Figs. 5 and 6. See Fig. 2 for precise location.

ied to characterise the microfacies of the upper slope and to establish a general facies model for this part of the profile. This profile was researched using 80 thin-sections. The classification of the components was made in thin-sections and if possible the thin-sections were point-counted. The grain bulk method was used. It considers the inner voids of a component as part of the component. The outcome thus reflects the volume percentage of the components present in the thin-section. Two hundred points were counted. In total 9 microfacies types could be distinguished based on this thin-section analysis.

3 PART A: FACIES PATTERNS WITHIN THE RECTANGLES

The rectangles (Fig. 5) described in this chapter form part of a platform to slope transect (Fig. 3). Within these rectangles, fourteen in total, macrofacies- and microfacies-characteristics were studied semi-quantitatively. The facies types encountered fit well into the facies models of Wilson (1975) and Flügel (1978). The entire profile reflects their facies belts 4 to 7, upper slope to open areas of the platform. The following classification of the facies patterns present in the rectangles could be made (Figs. 6 and 7): (A) Rectangles 1 - 4: facies belt 4: platform slope (upper slope); (B) Rectangles 5 - 8: facies belt 5: reef or platform edge; (C) Rectangles 8 - 10: facies belt 6: platform edge sands; and (D) Rectangles 11 - 14: facies belt 7: open platform areas.

The following description starts with the deepest facies belt 4 (slope of the platform) and continues to facies belt 7 (open platform areas). The microfacies of rectangles 1 to 4 (facies belt 4) are described in greater detail in the second chapter of the paper (Part B: microfacies of the upper slope).

3.1 Description of the rectangles 1 to 14 (Fig. 5): Topography and large-scale variations

In the two lowermost rectangles (Figs. 5.1, 5.2) and in rectangle four (Fig. 5.4) two different morphologies are present: (1) Relative smooth areas with no significant unevenness and (2) areas with different sized boulders.
In the planar beds small-scale joints are present, which seem to run parallel to a neptunian dike present on the left side of the rectangles (not shown in the drawing). In some parts of the rectangles, the planar beds appear as finger-formed sediment-tongues that rise up to 40 cm above the underlying beds. No distinct elevation can be seen at the beginning of these tongues in the up-slope direction. These beds mostly consist of grainstones with predominantly biolithoclasts. A few beds hold 3 to 5 cm large intraclasts. In these areas the highest amount of colony building corals was observed, together with single corals and shells. The largest colony building coral found in this sedimentary environment measures 110 cm in length and 70 cm in width (Pl. 18/3). The surface of the planar beds is also characterised by round karstholes of about 20 cm in depth and 20 cm in width, as well as small karren.

A maximum height difference of 200 cm was measured at the transition from the planar beds to the boulder beds. However, in most areas no large topographic differences between the individual beds can be observed. Within the boulder areas, the size of the individual boulders is rather uniform. They usually are very small, up to 20 cm in diameter. The boulders consist of various rock types ranging from wackestones to packstones to grainstones. In contrast to the planar beds where macrofossils are rare, all boulders contain small fragments of colonial corals, head corals, shells, gastropods or *Lithiotis*. Authigenic quartz can only be found in the boulder areas, and is totally absent in the planar beds. The angle of repose within the first rectangle is 35° (Fig. 4).

Rectangle 2 (Fig. 5.2), with an angle of repose of 24°, contains an area with ochre-grey carbonates that are cut

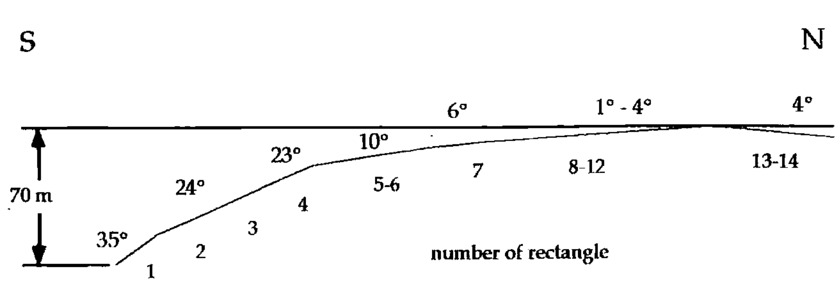
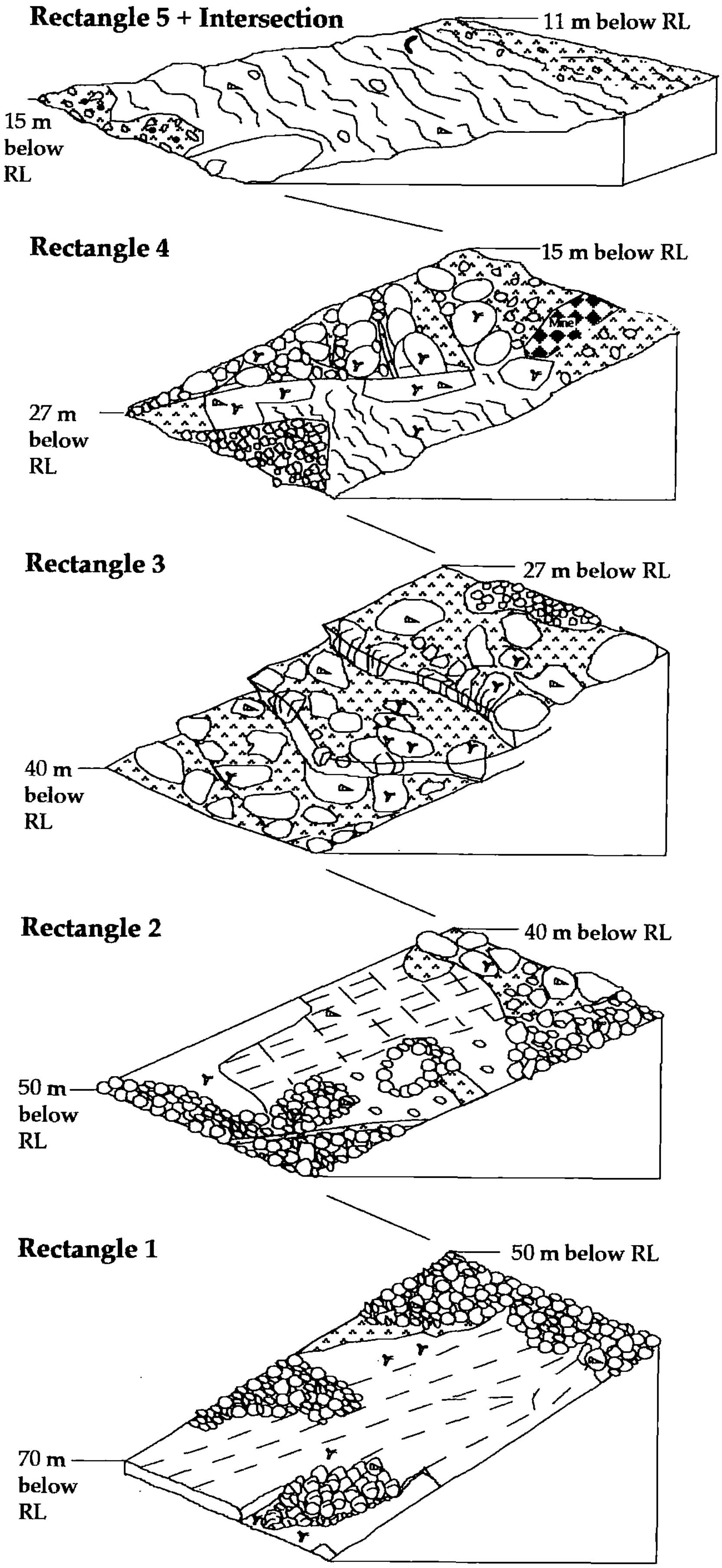


Fig. 4. Present day angle of repose along the rectangle profile. The present day angle probably represents the original slope angle. Vertical scale approx. 350 m.



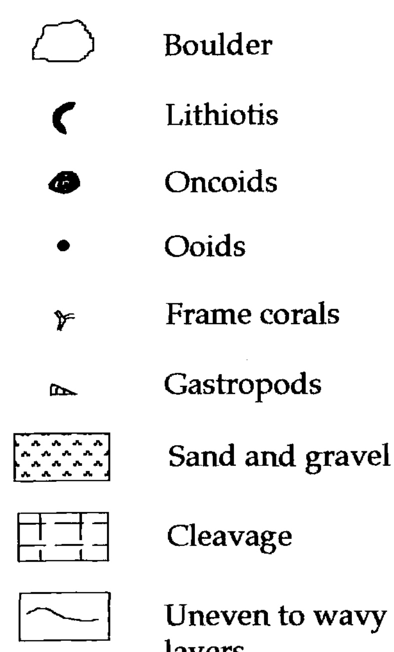


Fig. 5. Facies distribution within the individual rectangles ranging from the upper slope (rectangle 1) to the lagoon (rectangle 14). Rectangles 1 - 4 represent facies belt 4 the slope of the platform, They are characterised by high angles of repose (23° - 35° dipping to the south) and are dominated by boulder layers and rather planar parts. Rectangle 5 - 7 represent facies belt 5 the reef or edge of the platform. Medium angles of repose (6° - 10°) are found within these rectangles and they are dominated by boulder-like roundforms. The following three rectangles (8 - 10) represent facies belt 6, the platform edge sands, that are typified by more or less planar beds with low angles of repose (1° - 4°). The sediment contains high amounts of ooids and oncoids. The last four rectangles (11 - 14) represent facies belt 7 the open platform areas. They also show planar beds with low angles of repose (1° - 4°), that dip south and north.

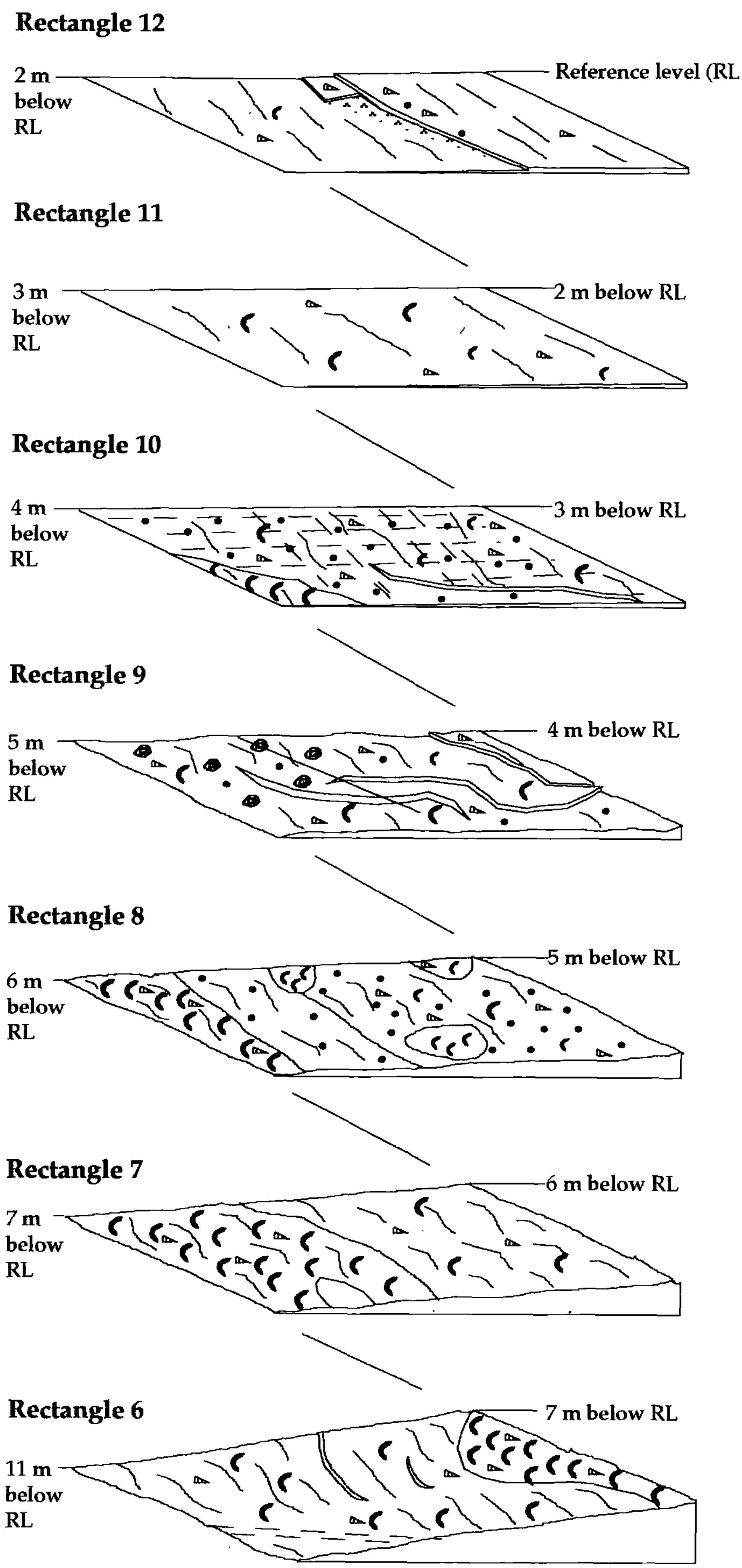
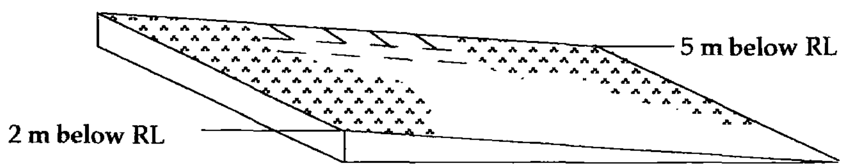


Fig. 5. continued. Facies distribution within the individual rectangles ranging from the upper slope (rectangle 1) to the lagoon (rectangle 14). Rectangles 1 - 4 represent facies belt 4 the slope of the platform, They are characterised by high angles of repose (23° - 35° dipping to the south) and are dominated by boulder layers and rather planar parts. Rectangle 5 - 7 represent facies belt 5 the reef or edge of the platform. Medium angles of repose (6 - 10°) are found within these rectangles and they are dominated by boulder-like roundforms. The following three rectangles (8 - 10) represent facies belt 6, the platform edge sands, that are typified by more or less planar beds with low angles of repose (1 - 4°). The sediment contains high amounts of ooids and oncoids. The last four rectangles (11 - 14) represent facies belt 7 the open platform areas. They also show planar beds with low angles of repose (1 - 4°), that dip south and north.

Rectangle 14



Rectangle 13

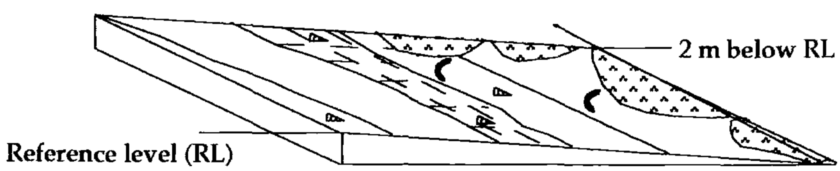


Fig. 5 continued. Facies distribution within the individual rectangles ranging from the upper slope (rectangle 1) to the lagoon (rectangle 14). The last four rectangles (11-14) represent facies belt 7 the open platform areas. They also show planar beds with low angles of repoşe (1°-4°).

vertically by numerous joints with a NE/SW orientation. The entire interval has a slightly wavy appearance and lies between planar beds and boulder areas. This bed mainly consists of grainstones with all types of macrofossils.

In all areas, within the lowermost two rectangles, caves (about 20 cm in diameter) are present that must have been open when active sedimentation took place on the slope. At present they are filled with different cement generations. Grey early cements occur clearly separated from white cements, that filled the rest of the pore space in a later stage.

Rectangle 3 is characterised by four boulder layers (Fig. 5.3). The transition from one layer to another is only shown by the differences in height of up to 120 cm. Lithologically there are no differences. Within the single boulder layers the height difference may exceed 100 cm. The diameter of the largest boulders found is 5 to 6 meters. In-between these large boulders, smaller-sized boulders, detritus and carbonate sand can be found. The boulders consist of wacke- to grainstone with a large variety of macrofossils, though colonial corals, single corals and gastropods occur more frequently. Two different types of colony building corals have been observed. One with up to 1 cm thick corallites and a second with thin corallites (3 to 4 mm). In this rectangle, small zones with dark, blue grey, micritic sediments are present showing thin mm-scale layering. The angle of repose is similar to the second rectangle, 24°.

The sedimentological and topographical features in rectangle 4 are similar to those within the first two rectangles, except for the presence of higher amounts of authigenic quartz (Fig. 5.4). Going from rectangle 4 to 5 a sharp reduction in the angle of repose occurs, from 23° to 10°.

Moving from rectangle 5 onwards in the up-slope direction (Fig. 5.5), it becomes very difficult to distinguish the individual layers. The first planar part is composed of oolitic pack- to grainstone, whereas the rest of this rectangle only shows small elevations or boulder-like roundforms. The latter consist of wacke- to packstone with the highest amount of authigenic quartz found in the transect. In the upper part of this rectangle the first scarce occurrences are found of up to 17 cm long *Lithiotis* shells.

Rectangle 6 is similar to the upper part of rectangle 5 (Fig. 5.6) and shows the same angle of repose, 10° (Fig. 4). Detritus and sand fills up the space between the boulder-like roundforms. The only higher elevation observed is a mud-mound with *Lithiotis* west of the rectangle studied. In the following rectangles *Lithiotis* does not occur as individual mounds, but appears spread out over large areas (Pl. 18/4). The *Lithiotis* and gastropods specimens reach lengths of up to 25 cm. This rectangle contains the last occurrence of colonial corals, whereas single corals are present up to rectangle 11.

From rectangle 7 onwards the boulder-like round-forms are not found anymore and the area is covered either by small 50 cm large blocks or by small planar areas (Fig. 5.7). While the topography changes and becomes progressively horizontal, the individual facies zones occupy large areas of the rectangles. The angle of repose is reduced to 7° (Fig. 4).

In rectangles 8 - 10, forming facies belt 6 after Wilson (1975; platform edge sands), three different microfacies types are present:

1) Oncosparite: This MFT is characterised by up to 3 cm large oncoids in a pelsparitic matrix. The oncoids mostly have a nucleus of a single component, like gastropods (Pl. 12/3).

2) Oosparite: This MFT is dominated by multiple layered ooids in a sparitic matrix (Pl. 12/9).

3) Echinodermsparite: Within this MFT echinoderms are the dominating particles. The matrix consists of syntaxial cement.

In rectangles 8 and 10 the amount of ooids is very high (Figs. 5.8, 5.10). Rectangles 8 and 9 are the only ones that contain oncoids (Pl. 12/3). In rectangle 8 small areas are covered by small *Lithiotis* shells (5 cm length). Within the rectangles 8 to 10 the angle of repose varies between 1° to 4°. In rectangle 9 individual layers are present with a maximum thickness of 15 to 20 cm (Fig. 5.9).

In the final 4 rectangles (11 - 14) forming facies belt 7 after WILSON (1975; open platform areas), the following 2 MFT are present: (1) Oosparite with birdseyes: In contrast to the oosparite within facies belt 6 the ooids are only single layered. Birdseyes with an irregular laminoidal fabric are present (Pl. 12/7). (2) Pelsparite: This MFT is dominated by peloids within a micritic to sparitic matrix. The biogenic components consist of calcareous algae (Pl. 12/4), foraminifers and microproblematica like *Thaumatoporella* sp. and *Bacinella* sp. Birdseyes with an irregular laminoidal fabric are also present (Pl. 12/2). Rectangle 11 does not display any remarkable features. In rectangle 12 three successive layers were present with heights of about 10 to 20 cm (Fig. 5.12). The second and part of the third layer consist of dark packstone with some ooids and a high amount of small gastropods (3 cm). Beds within this rectangle dip to the north whereas in the first 11 rectangles they incline southward.

From rectangle 13 onwards reddish sand and detritus cover large parts of the surface of the rectangles and no clear facies belts could be distinguished (Fig. 5.13). The angle of repose is 4° northward towards the lagoon.

Beyond the open platform areas of rectangle 14, towards the inner platform areas, the following microfacies types are found:

(1) Red pelsparite with birdseyes. This MFT is very similar to the MFT's in facies belt 7 with the exception of the red colour and the infill with vadose silt of the larger birdseyes. These two aspects are typical for areas with intermittent subaerial exposure (Pl. 12/5).

(2) Oncosparite with birdseyes. The oncoids of this MFT are not as typical as the oncoids in facies belt 6. They consist of peloids that are covered by cyanobacterial micritic layers. Within the sediment birdseyes with an irregular laminoidal fabric are present. Authigenic quartz is rare but it can reach 6 mm in length and 2 mm in width (Pl. 12/1).

(3) Pelmicrite: This MFT is characterised by the absence of sparite. The dominant components are peloids with rare to abundant oncoids, foraminifers, and calcareous algae.

(4) Algal laminations: Within this MFT only an alternation of sparitic and micritic to peloidal layers is present, whereas biogenic components are missing. The sparitic layers have a planar bottom whereas the top is wavy or irregular formed. These sparitic layers represent the algal mats that were episodically covered by sediment.

3.2 Evaluation and interpretation of the facies patterns

Distinct dispersal patterns for various components could be observed along the transect (Figs. 6 and 7). In total four different facies belts have been distinguished.

A clear differentiation in layers is possible within the first four rectangles. The layers have an inclination of 24° - 35°. They form the upper slope, facies belt 4 of WILSON (1975) (Figs. 4 and 6). A detailed description of the facies types present in this facies belt is given in Chapter 4 (Part B: Microfacies of the upper slope). Maximum coral diversity can be found in this zone, but in most cases clearly show that they were redeposited. In addition, a maximum amount of algae, shell fragments and gastropods occurred.

Rectangles 1 to 5 (Fig. 6) are characterised by the occurrence of reef-originated boulders. Besides these boulder areas, relative smooth areas are present covered by sand-sized debris, predominantly pack- to grainstones. The composition of these sediments is similar to that of the biopelsparites that dominate the major part of the slope. Besides the biopelsparites two types of boundstones are present that contain corals or algae. In general, corals typify the boundstones within the rectangles while algae dominate the laminated pelsparite/micrite.

Rectangles 4 - 6 contain high amounts of authigenic quartz. The authigenic quartz probably is related to the

Plate 12 Lower Jurassic biogenic and non-biogenic components of the Jbel Bou Dahar carbonate platform.

Sediments present within the platform interior:

Fig. 1. Authigenic quartz with crossed nicols. Due to the rapid growth of the crystal the former components are not displaced but incorporated. Magnification approx. 10 x.

Fig. 2. This MFT (Pelsparite of rectangles 11 - 14) is characterised by a high percentage of birdseye's with an irregular laminoid structure (LF-B-Structure). The birdseye's are filled with radial fibrous and blocky mosaic cement. Magnification 5x.

Fig. 3. Oncoids with a nucleus of gastropods and spongiomorphidss. The incrusting organisms are normally not distinguishable and only visible as dark micritic rims with some sparitic pores. The organisms most likely are cyanobacteria or sessile foraminifers. Magnification 2.5x.

Fig. 4. Pelsparite with dasycladaceans (arrows). Magnification 2.5 x.

Fig. 5. At the edge the larger birdseye's are filled with dogtooth cement, whereas the rest is filled with greyish to reddish vadose silt. If they are not completely filled by silt the remaining part of the pore is filled with blocky cement. These sediments show all the characteristics for subaeric exposure. The arrow marks way up. Magnification 2.5 x.

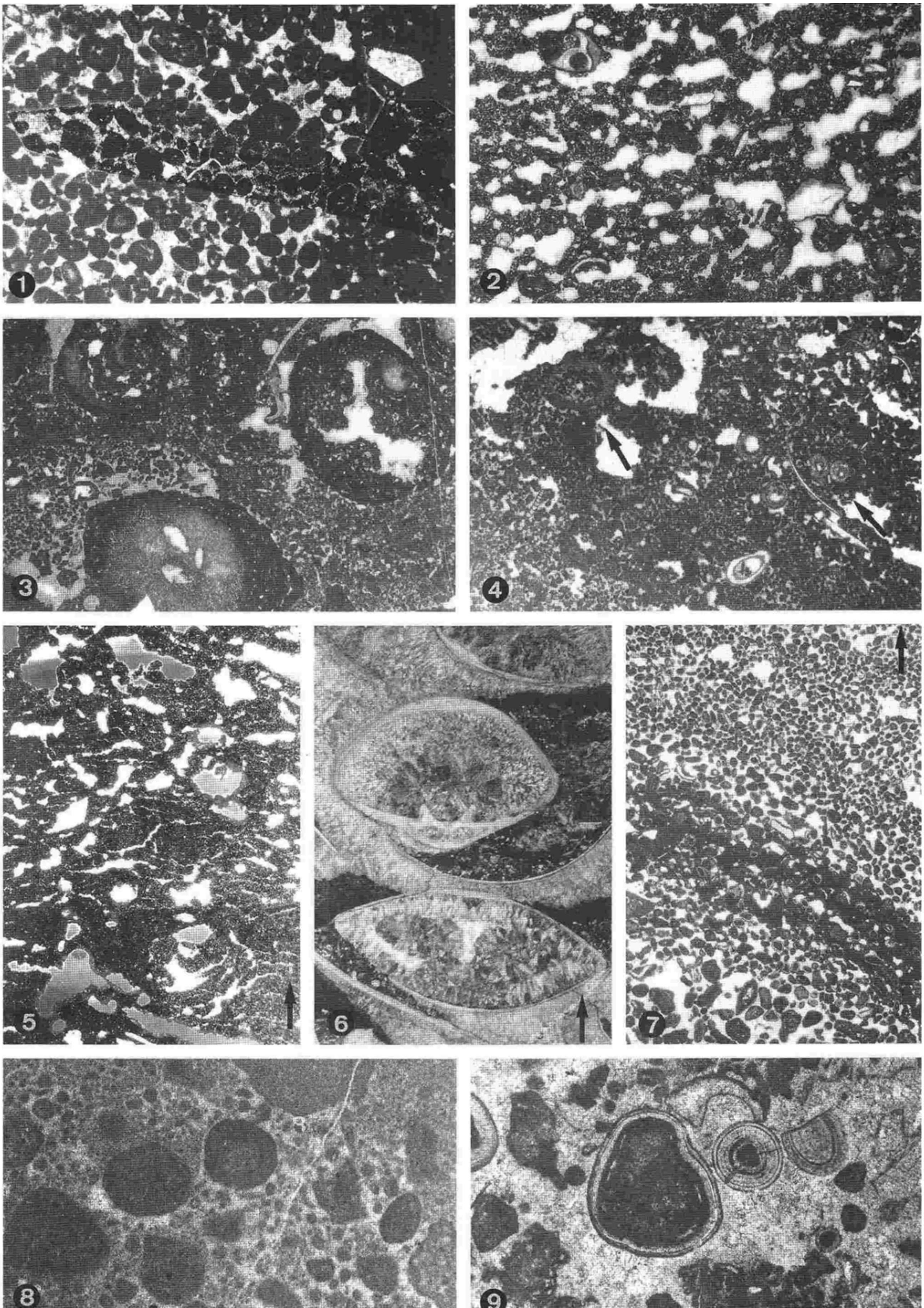
Fig. 6. Cross-section of brachiopods, the arrow marks the " in situ" way up. Magnification 2.5 x.

Fig. 7. Oosparite that is composed of single ooids. The arrow marks way up. Magnification 2.5 x.

Ooids:

Fig. 8. Micritic ooid and peloids present within the laminated pelmicrites (MFT 1). Magnification 50 x.

Fig. 9. Different types of ooids that are partly broken. Magnification 50 x.



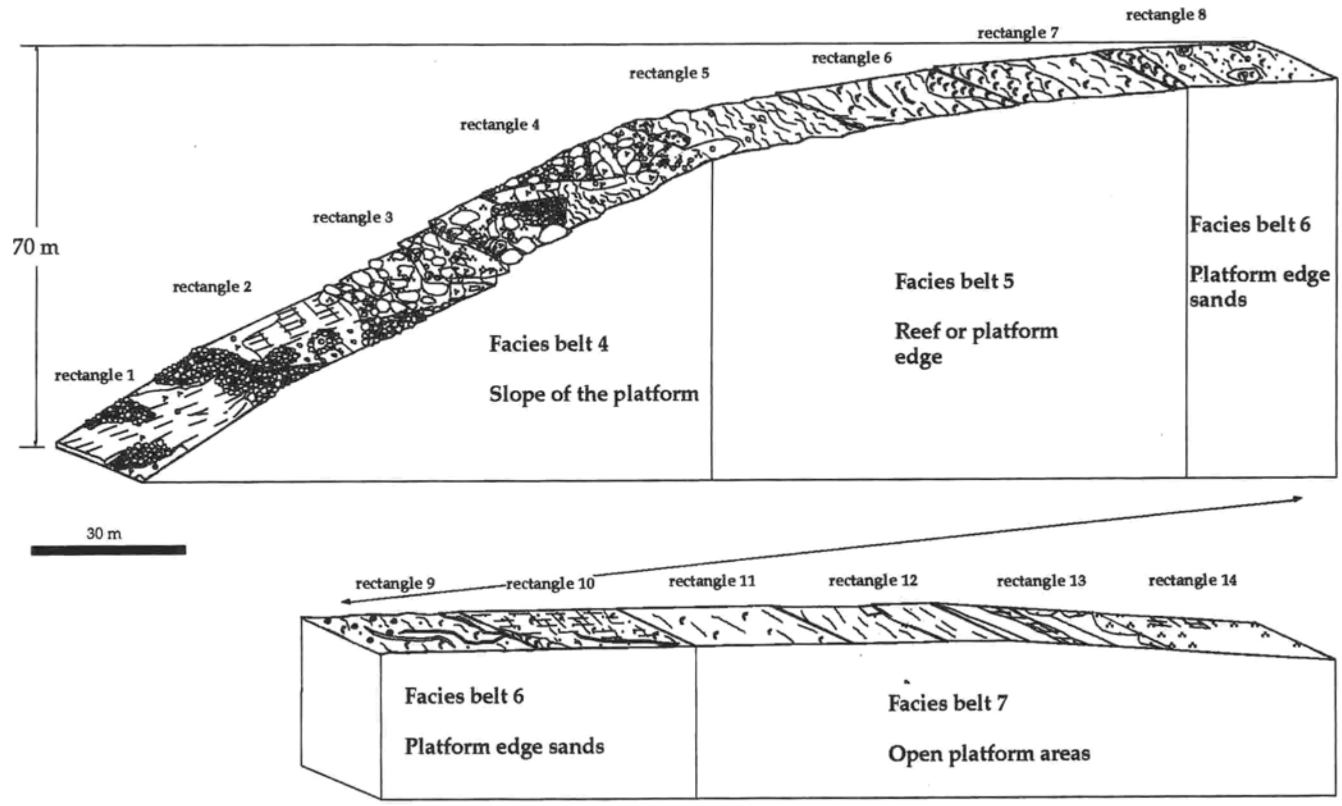


Fig. 6. Facies distribution profile along the platform edge (upper slope to lagoon). The profile is subdivided in four facies belts following the classification scheme of WILSON (1975).

dissolution of sponge needles, however no relicts of sponges were found in the entire area. The observations of KENTER (1990) that sponge mud-mounds were present at a depth of 50 m below the edge of the platform, could not be confirmed by our observations. A slight increase in the number of wacke- to packstones can be observed in the rectangles 5 - 7.

Lithiotis occurs the most in rectangles 6 - 8. These areas are situated at about 7 - 15 m below the top of the platform and thus within the zone of wave activity. These *Lithiotis* mud-mounds or banks separate upper slope deposits from platform edge sands. They probably form the facies belt that could be interpreted as the actual reef. In these rectangles *Lithiotis* specimens reach their maximum size and thus could stand the wave energy. In other rectangles they are smaller, which might be explained by the occurrence of a different species or the adaptation to a more restricted, low-energy environment.

Ooids and oncoids mostly occur in rectangles 8 - 10 (Figs. 6 and 7). This coincides with an increase in grain size in these rectangles. Pack- and grainstones prevail and reflect these more sandy areas. From rectangle 8 onwards the number of foraminifers increases and reaches a maximum in rectangle 13. They are the only biota with maximum values in the upper more platform interior orientated rectangles. All other biotic components are present as well, but with sharply reduced numbers.

Plate 13 Lower Jurassic biogenic and non-biogenic components of the Jbel Bou Dahar carbonate platform:

Microfacies of the slope:

Fig. 1. Laminated Pelmicrite/sparite (MFT 1). Some of the larger intraclasts are well rounded and possess a dark micritic border, probably of algal origin. The arrow marks the way up. Magnification 2.5 x.

Fig. 2. Intrapelsparite/micrite (MFT 2). The intraclasts consists of intraclasts or pelmicrites. Magnification 2.5 x.

Fig. 3. Laminated pelmicrite (MFT 1), with cf. *Microtubus communis* at the base of the picture. Magnification 50 x.

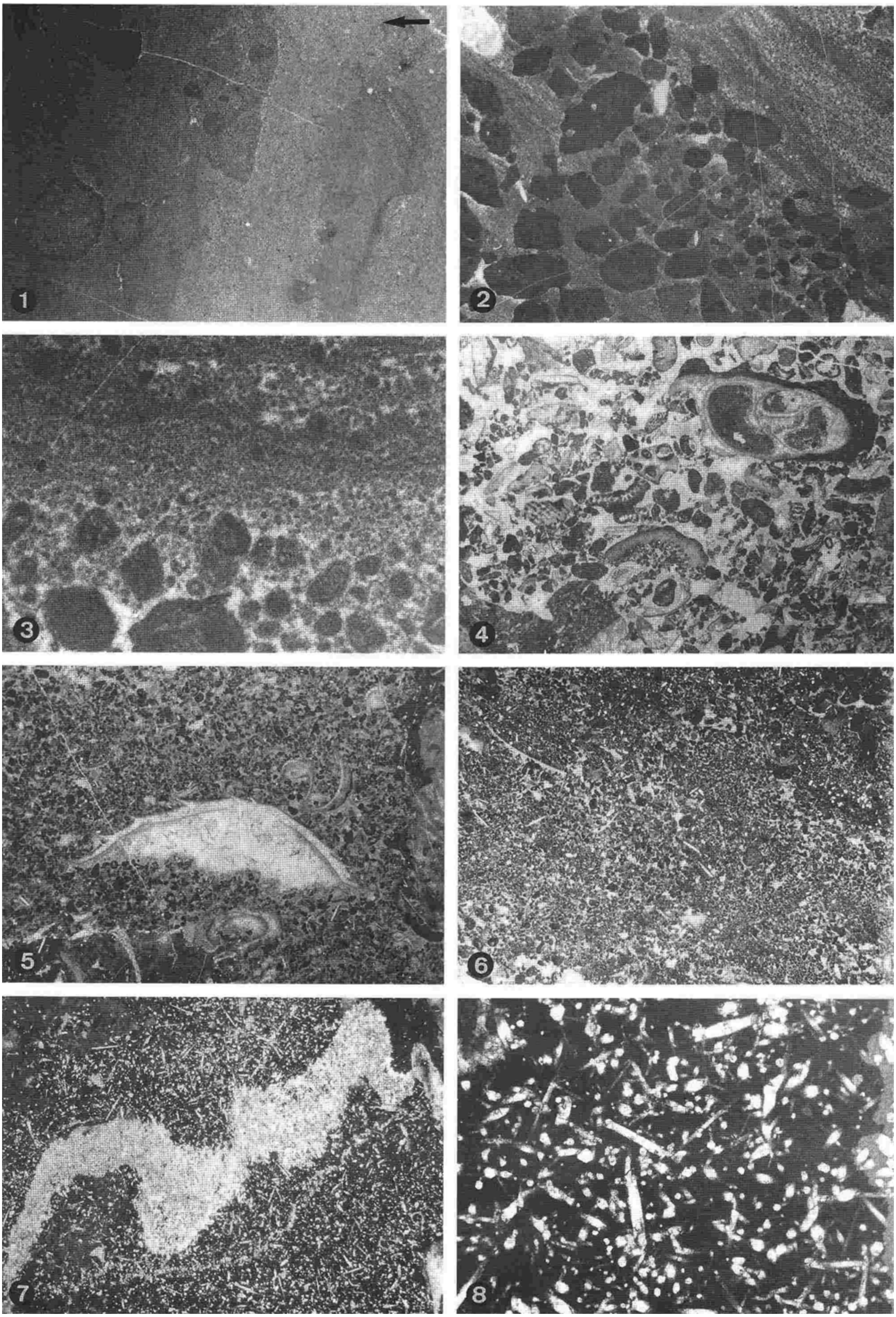
Fig. 4. Biopelsparite (MFT 3). Magnification 2.5 x.

Fig. 5. Shelter structure within the pelsparite (MFT 7). Magnification 2.5 x.

Fig. 6. Poorly washed biopelsparite (MFT 5). Magnification 2.5 x.

Fig. 7. Authigenic quartz. Magnification ca. 10 x.

Fig. 8. Authigenic quartz. Magnification 25 x.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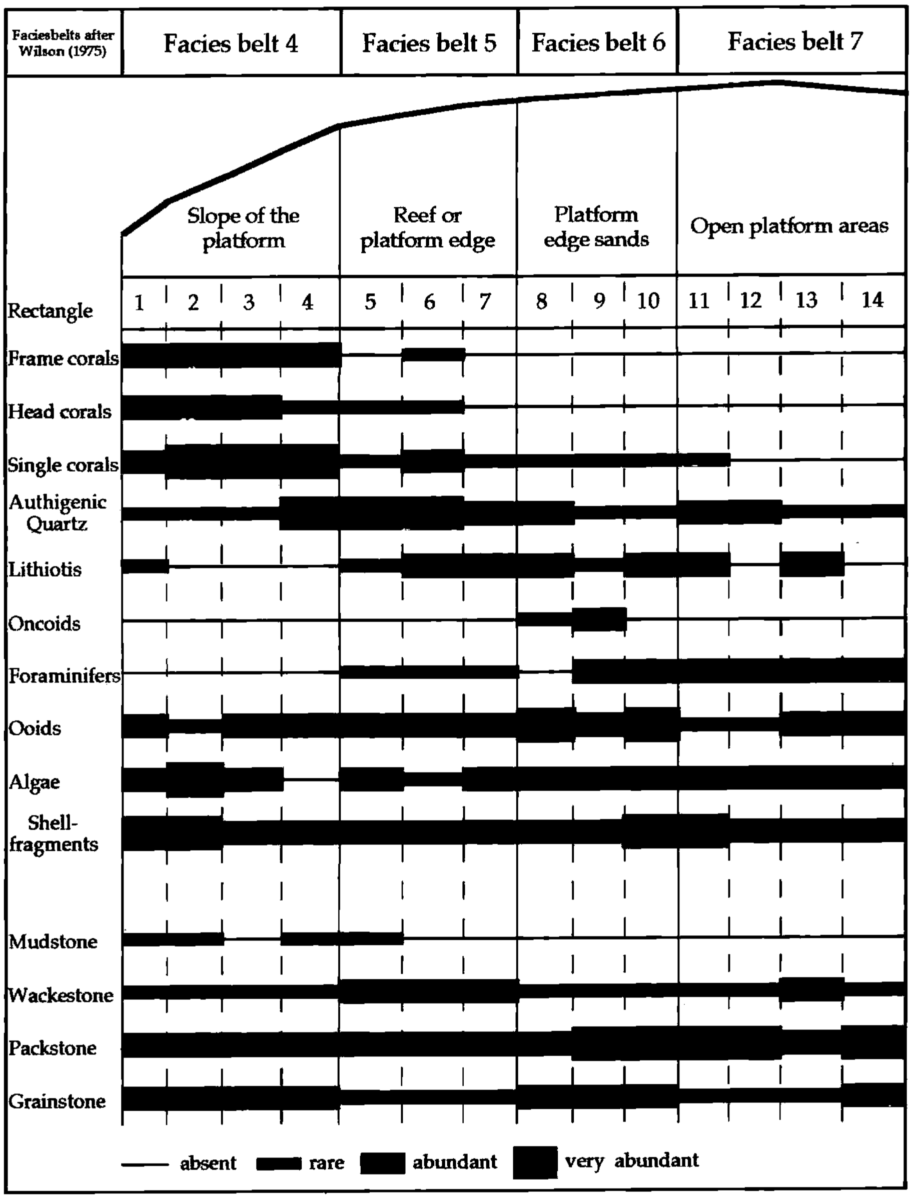

Fig. 7. Grain type distribution within the rectangle profile and the classification of the facies belts along the transect according to WILSON (1975).

Components:

Rocktypes: Packstones are the dominating type of rock in all rectangles. Grainstones and wackestones are slightly less important. Mudstones only play a subordinate role in this part of the platform.

Authigenic quartz: Macroscopically authigenic quartz is characterised by its dark colour, longitudinal habitus and its typical hexagonal structure. It occurs frequently to very frequently in rectangles 4 to 6, and plays a minor role or is completely absent in the others.

Lithiotis (Pl. 18/4): The term *Lithiotis* represents all thick-shelled, longitudinal bend shells. *Lithiotis* can be subdivided into two groups: one with a mean long axis of about 25 cm and another with a maximum long axis of up to 5 cm. A detailed classification of these pelecypods was not made. The *Lithiotis* found probably are *Lithiotis* sp., *Cochlearites* sp., *Opisoma* sp. and *Lithoperna* sp. (LEE, 1983). They were found accumulated in distinct mounds or patches with a high concentration of specimens. Larger and smaller specimens didn't occur together. This might be caused either by variations in environmental parameters or by the fact that different species occupy different facies belts. The main distribution of these type of biota lies within rectangles 6-8. In rectangles 9 to 14 they were observed in minor quantities. In the lower rectangles (1-5), they are almost completely absent. Only two specimens were found.

Gastropods: They can reach sizes of about 25 cm, but also can be of mm-size. Gastropods are present in all rectangles with a slight maximum in the lower rectangles (1-3).

Corals: The corals observed can be divided into three mayor groups: colony building corals, head corals and single corals.

Colony building corals (Pl. 18/3): The frame corals are not found in situ but only resedimented. These colonial corals reach sizes of 110 cm in height and 70 cm in width. Using the thickness of the single corallites two types can be differentiated. The first type has thick (up to 1 cm in diameter) corallites. The second type has thin (3 to 4 millimetre thick) corallites. Frame corals appear only in the lower 6 rectangles, and most frequently in the lower four rectangles. For continuation of text turn page.

Plate 14 Lower Jurassic biogenic and non-biogenic components of the Jbel Bou Dahar carbonate platform:

Corals, spongiomorphids and sponges:

Fig. 1. Corals of the type *Thamnasteria*. Magnification 2.5 x.

Fig. 2. Coral of unknown affinity (*Thecosmilia?*). Magnification 2.5 x.

Fig. 3. Corals of the type *Astrocoenia*. Magnification 2.5 x.

Fig. 4. Spongiomorphid. Magnification 2.5 x.

Fig. 5. A sponge incrusted by spongiomorphids. Magnification 2.5 x.

Fig. 6. Boring sponge within a spongiomorphid. Magnification 25 x

Calcareous algae:

Fig. 7. *Cayeuxia*. Magnification 25 x.

Fig. 8. *Cayeuxia*, on the left the first growth stadium is shown. Magnification 25 x.

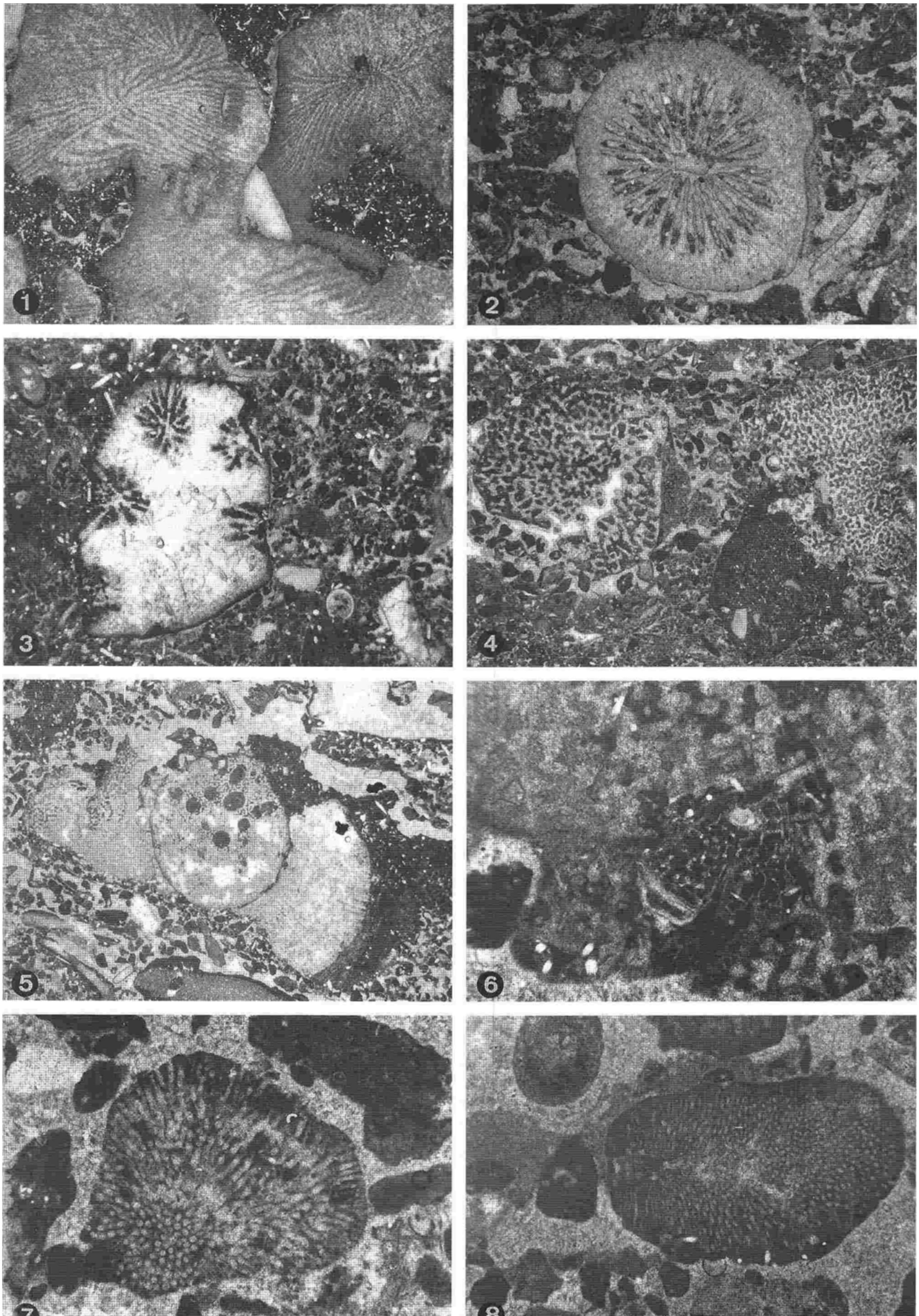
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Fig. 7. Text continued: Head corals: The fragments of single head corals present, reach a maximum size of about 30 cm. They always possess a layered structure. Their general appearance is similar to that of the frame corals but they are less abundant.
Solitaire corals: These type of corals have a maximum diameter of about 5 cm. They occur mostly within the first four rectangles on the slope, but they were also observed in the upper rectangles.
Shell fragments: Shell fragments are defined as all shell-like debris that could not be classified any further. They are found in all rectangles although they reach their maximum in rectangles 1 to 3 and 8 to 11.
Foraminifers: Foraminifers appear more frequently in the upper 6 rectangles (9-14). From rectangle 9 downward, they are found in rectangles 5 to 7, though in minor percentages. For a more detailed description of the individual species found see the thin-section chapter 4.2.2.
Algal structures: All lithological structures that were build by algae like coated grains or laminated structures are incorporated in this group. They occur in minor quantities in all rectangles with a relative maximum in rectangle 2.
Oncoids: The oncoids found do have a typical round to oval formed habitus and can reach sizes of up to 3 cm. They appear in distinct accumulations in rectangles 8 and 9.
Ooids: Ooids are found in all rectangles. Their main occurrence, however, lies within rectangles 8 to 10 as well as 14.
Ore accumulation: Two types of ore accumulations are found. Either as small minerals, small black dots, or as encrustations of about 10 cm in width. The encrustations follow specific joints and they appear as slight elevations in the field. The thickness of the encrustations is about 1 mm. This type of ore accumulation appears slightly more frequent in rectangles 5 and 6.

4 PART B: MICROFACIES OF THE UPPER SLOPE

The previous chapter concentrated on the facies distribution along a transect ranging from the upper slope towards the platform interior (Fig. 6). In this chapter, the upper slope deposits will be described in more detail to illustrate the different types of microfacies present in this sedimentary environment.

4.1 Macroscopic description of the profile (Pl. 18/1,2)

Figure 8 shows the profile measured. The lower part of the profile consists mainly of boulder-layers. Throughout the entire profile the boulder-layers thin up-slope. They lie conformably on a relatively smooth surface with varying microfacies. The only macrofossils found in this profile are *Lithiotis*, colony building corals and minor gastropods. See previous chapter for an extensive description of the upper slope characteristics.

4.2 Microscopic description and component distribution

4.2.1 Non-biogenic components

Peloids: Peloids are common in all microfacies types.

Intraclasts: Most of the intraclasts encountered do have a clear internal structure and show that they are derived from all sediment types. Intraclasts are present in all microfacies types, but mainly occur in the biopelsparites, poorly washed biopelsparites and intrapelsparites.

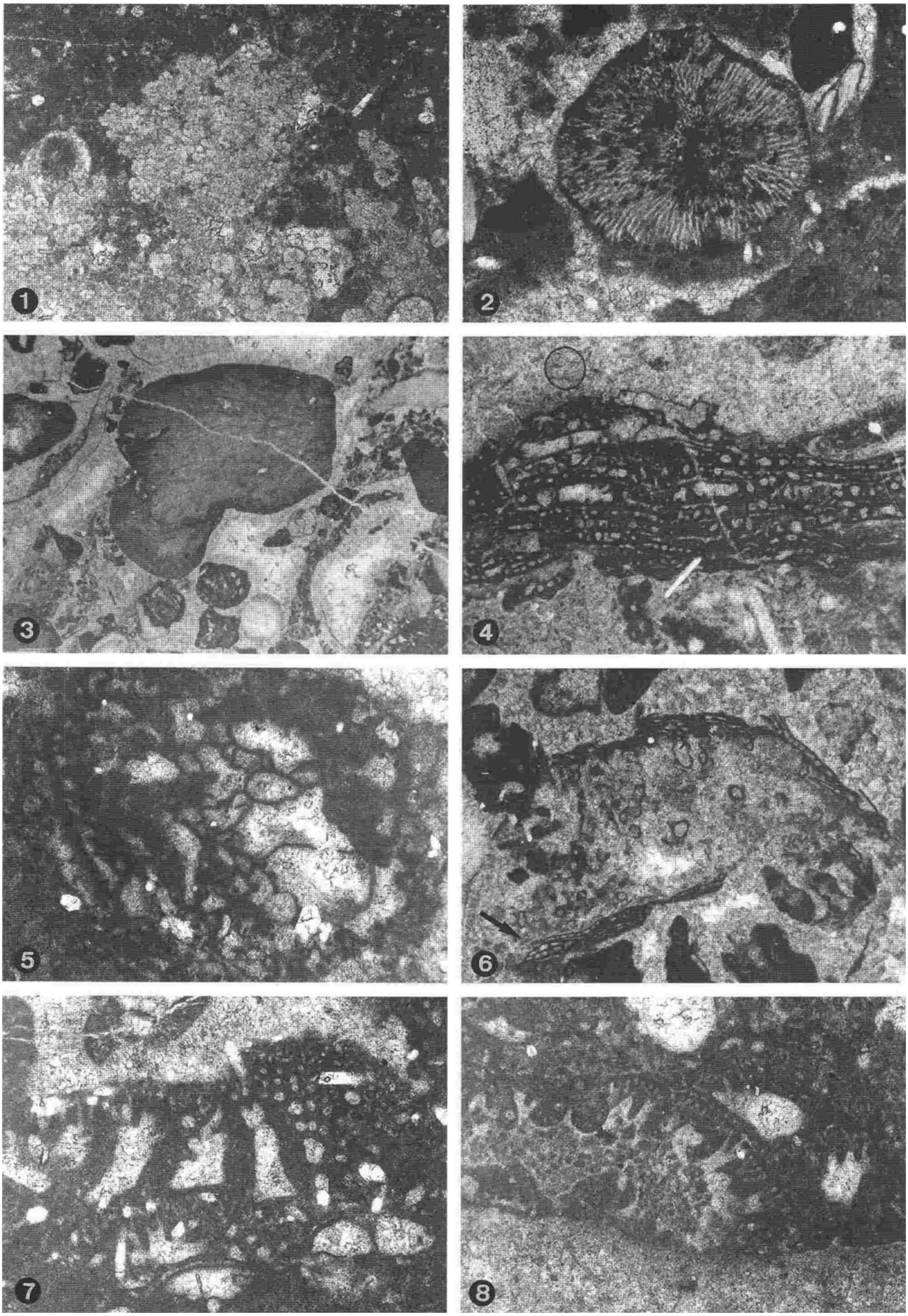
Ooids: Two different types of ooids are present in the thin-sections, each occurring in a different microfacies type. **Micritic ooids**: This type of ooid consists of one or a series of concentric layers around a peloidal nucleus. In most cases the contrast in colour and structure between the individual layers is not very profound. They are only present in the laminated pelmicrites. Neuweiler (1993) describes these types of ooids as "peloidal/in situ ooid microbialites" which may find their origin in "in situ precipitation of calcite in the course of self-burial of microbial mats". **Multi-layered ooids** (Pl. 12/9): The nuclei of these ooids are micritic components, intraclasts or bioclasts. They do not occur in large quantities in the thin-sections studied. In the field, however, they were encountered more frequently. The production area of these ooids lies within the highly energetic environment at the edge of the platform. This might also explain the occurrence of a large amount of broken ooids in the thin sections.

Aggregate grains are present in all types of microfacies except for the pelmicrites. They preferably occur in biopelsparites and poorly washed biopelsparites.

Coated grains are defined as being all components that are covered with a continuous thin micritic layer. This

Plate 15 Lower Jurassic biogenic and non-biogenic components of the Jbel Bou Dahar carbonate platform:

Microproblematica:
Fig. 1. *Baccanella floriformis*. Magnification 50 x.
Calcareous algae:
Fig. 2. *Rivularia moesica* (Dragastan and Bucur)(pers. comm. Schlagintweit). Magnification 50 x.
Fig. 3. Solenoporacea, this specimen forms the substrate of another calcareous algae (*Marinella lugeoni* Pfender, pers. comm. Schlagintweit). Magnification 10 x.
Microproblematica:
Fig. 4. Association of *Thaumatoporella parvovesiculifera* and *Bacinella* sp. Magnification 25 x.
Fig. 5. *Bacinella irregularis*. Magnification 50 x.
Fig. 6. *Bacinella ordinata* incrusting a non-determinable bioclast. Magnification 25 x.
Fig. 7. *Lithocodium*. Magnification 50 x.
Fig. 8. *Lithocodium*, the lower specimen is partly filled with micrite/peloids. Magnification 50 x.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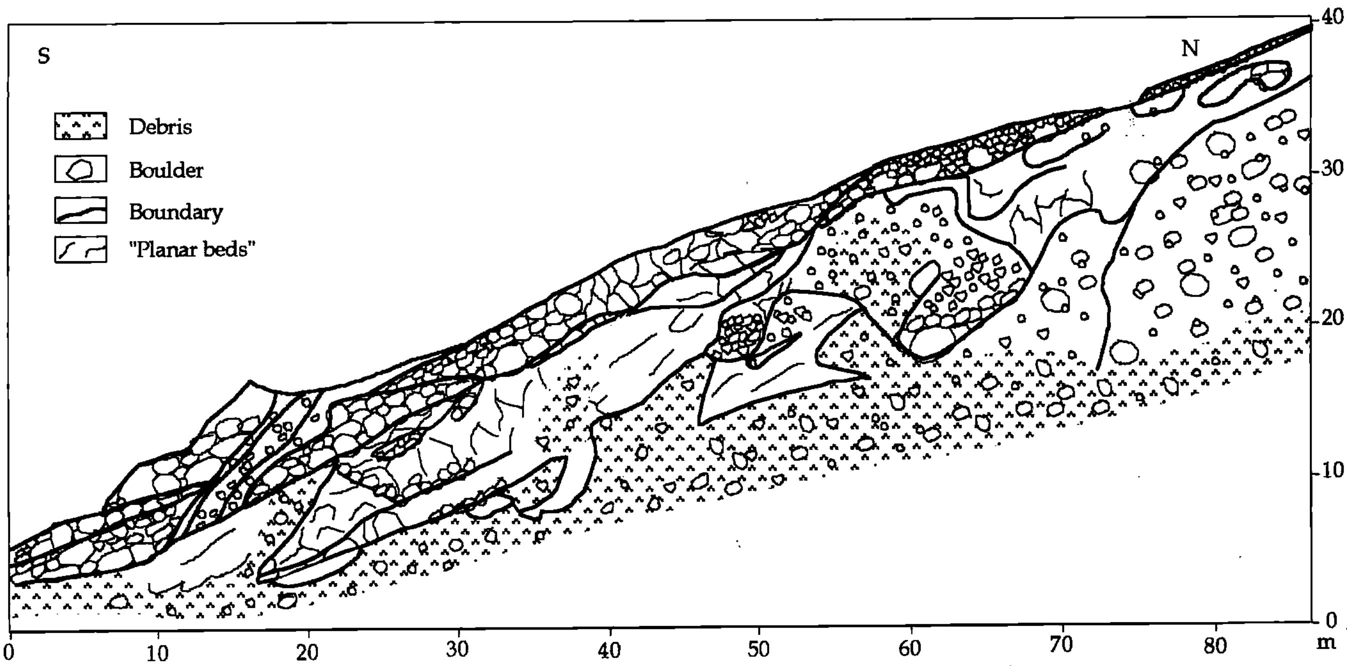


Fig. 8. Segment of upper slope deposits of the Jbel Bou Dahar. This part encloses approximately rectangles 1-4 shown in Fig. 5. It illustrates the upper slope topography and interfingering of the different units. For precise location of profile see Fig. 2.

micritic layer originates from borings of endolithic algae. They occur in biopelsparites and poorly washed biopelsparites.

4.2.2 Bioclasts

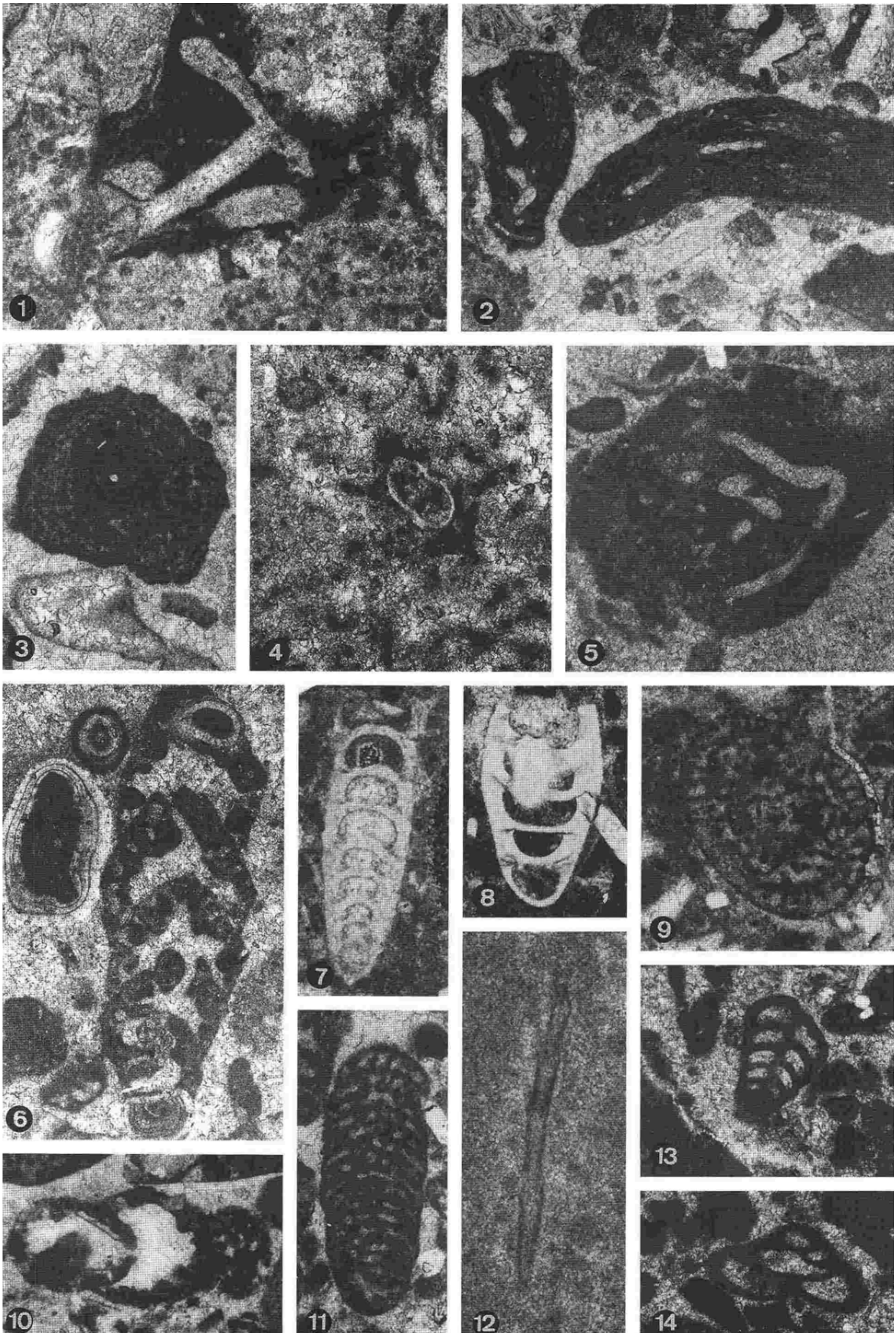
Oncoids: The nucleus of a typical oncoid in the thin-sections studied, consists of a non-identifiable biota. The surrounding layers are made up of sessile foraminifera and/or the microproblematica *Thaumatoporella* sp., *Bacinella* sp., *Tubiphytes* sp. and *Lithocodium* sp. Large parts of the layers are typified by a dark micritic structure, probably of cyanobacterial origin. Oncoids mainly occur in the biopelsparites and poorly washed biopelsparites.

Calcareous algae: The entire spectrum of calcareous algae is present in the thin-sections, e.g. red algae (solenoporacean), green algae (codiacean (Pl. 17/2), dasycladacean) and blue algae (porostromata).

Porostromata Pia, 1927: *Cayeuxia* (Pl. 14/7,8): Most *Cayeuxia* found are solitary specimens showing borings and usually are encrusted. They are present in every type of microfacies except for the pelsparites. Their main occurrence, however, lies within the biopelsparites and poorly washed biopelsparites.

Plate 16 Lower Jurassic biogenic and non-biogenic components of the Jbel Bou Dahar carbonate platform:

Microproblematica:
Fig. 1. Bored *Tubiphytes* sp. as can be found in the boundstone facies. Magnification 50 x.
Fig. 2. Two cross sections of *Tubiphytes* sp., with different chamber orientations are visible. Magnification 50 x.
Fig. 3. *Tubiphytes* sp. with different tight layers. Magnification 50 x.
Foraminifers:
Fig. 4. *Bullopora* sp. within a hydrozoan. Magnification 50 x.
Fig. 5. Miliolid foraminifer. Magnification 50 x.
Fig. 6. *Ammobaculites* sp. Magnification 50 x.
Fig. 7. *Nodosaria* sp. Magnification 50 x.
Fig. 8. *Lenticulina* sp. Magnification 50 x.
Fig. 9. *Kurnubia* sp. Magnification 50 x.
Fig.10. *Ammobaculites* sp. Magnification 25 x.
Fig. 11. *Haurania* sp. Magnification 50 x.
Microproblematica:
Fig. 12. Microproblematicum *Aeolisaccus*. Magnification 100 x.
Foraminifers:
Fig. 13. *Tetrataxis* sp. Magnification 50 x.
Fig. 14. *Trochammina* sp. Magnification 50 x.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Solenoporaceae: The following species were found: *Marinella lugeoni* (Pl. 15/3), and *Rivularia moesica* (Pl. 15/2). The occurrence is similar to *Cayeuxia.*

Dasycladaceae: *Palaeodasycladus* sp. (Pl. 17/5). The shape of the single species found is elongated to club-like. The branches are relatively thick and the thallus can be divided into different parts. According to BASSOULLET et al. (1978) and FLÜGEL (1983) the occurrence of *Palaeodasycladus* sp. is limited to the Liassic.

Other Dasycladaceans: Fragments of other non-classifiable dasycladaceans are found in every type of microfacies except for the pelmicrites. These fragments mainly occur in the biopelsparites and poorly washed biopelsparites.

Microproblematica: *Lithocodium* (Pl. 15/7-8). These encrusting microproblematica have semicircular to elongated semi-oval growth forms. The basal part always contains a large sparitic cavity, which is rarely filled with sediment. Away from this cavity small branching sparitic indentations split into small channels. Usually several layers of *Lithocodium* encrust each other. The combined appearance of *Lithocodium* sp. and *Bacinella* sp. as described in literature (SCHÄFER, 1979; SENOWBARY-DARYAN, 1980; LEINFELDER et al., 1993) is not observed. Most authors refer to *Lithocodium* sp. as green algae (Codiaceae) although they show similarities with blue-green algae as well (LEINFELDER et al., 1993). They are predominantly present in the boundstone microfacies types, encrusting other organisms.

Bacinella : *Bacinella* sp. is described as green algae. *Bacinella irregularis* RADOICIC, 1959 (Pl. 15/5). *Bacinella irregularis* shows a complex pattern of filaments. The space inbetween the individual filaments is always filled with sparite. *Bacinella* sp., and *Thaumatoporella parvovesiculifera* usually appear together. No relationship between the occurrence of *Bacinella* sp. and *Lithocodium* sp. was observed. *Bacinella irregularis* general occurs with *Thaumatoporella parvovesiculifera.*

Bacinella ordinata PANTIC, 1972 (Pl. 15/6): This type of *Bacinella* is characterised by layered sparitic filled tubes that are divided by pilae at varying distances. It either encrusts with multiple tube-layers or appears singular with just one tube. The relationship with *Thaumatoporella* sp. is discussed below. *Bacinella ordinata* occurs rarely in the boundstone microfacies.

Thaumatoporella : *Thaumatoporella parvovesiculifera.* This form is made up of plates with polygonal to round shaped cell-tubes. In cross section *Thaumatoporella* sp. appears flat and very thin. In this orientation the walls of the single cells occur at equal distances.

Community of *Thaumatoporella* sp. and *Bacinella* sp. (Pl. 15/4). In literature *Lithocodium* sp. and *Bacinella* sp. occur jointly, whereas a community of *Thaumatoporella* sp. and *Bacinella* sp. is rarely described (SCHÄFER & SENOWBARI-DARYAN, 1983; FLÜGEL, 1983; LEINFELDER et al., 1993). This type of community is characterised by a two-layer organisation. The base layer consist of different sized cavities that are mostly filled by sparite which is covered by a thin dark micritic border. This base layer represents the *Bacinella* organism, while the dark layer is formed by *Thaumatoporella* sp. This community occurs in all microfacies types although they predominantly appear in the boundstone facies. In the latter facies they usually encrust sponges and corals or form single large crusts. Broken fragments with only one or two double layers are present in all other microfacies types.

Tubiphytes (Pl. 16/1-3): *Tubiphytes* sp. occurs encrusting or solitaire. In cross-section solitaire specimens possess round to oval thalli. The centre of the thallus is marked by a sparitic "eye". Around of this "eye" micritic layers are present, which stacking tends to loosen up towards the edge of the organism.

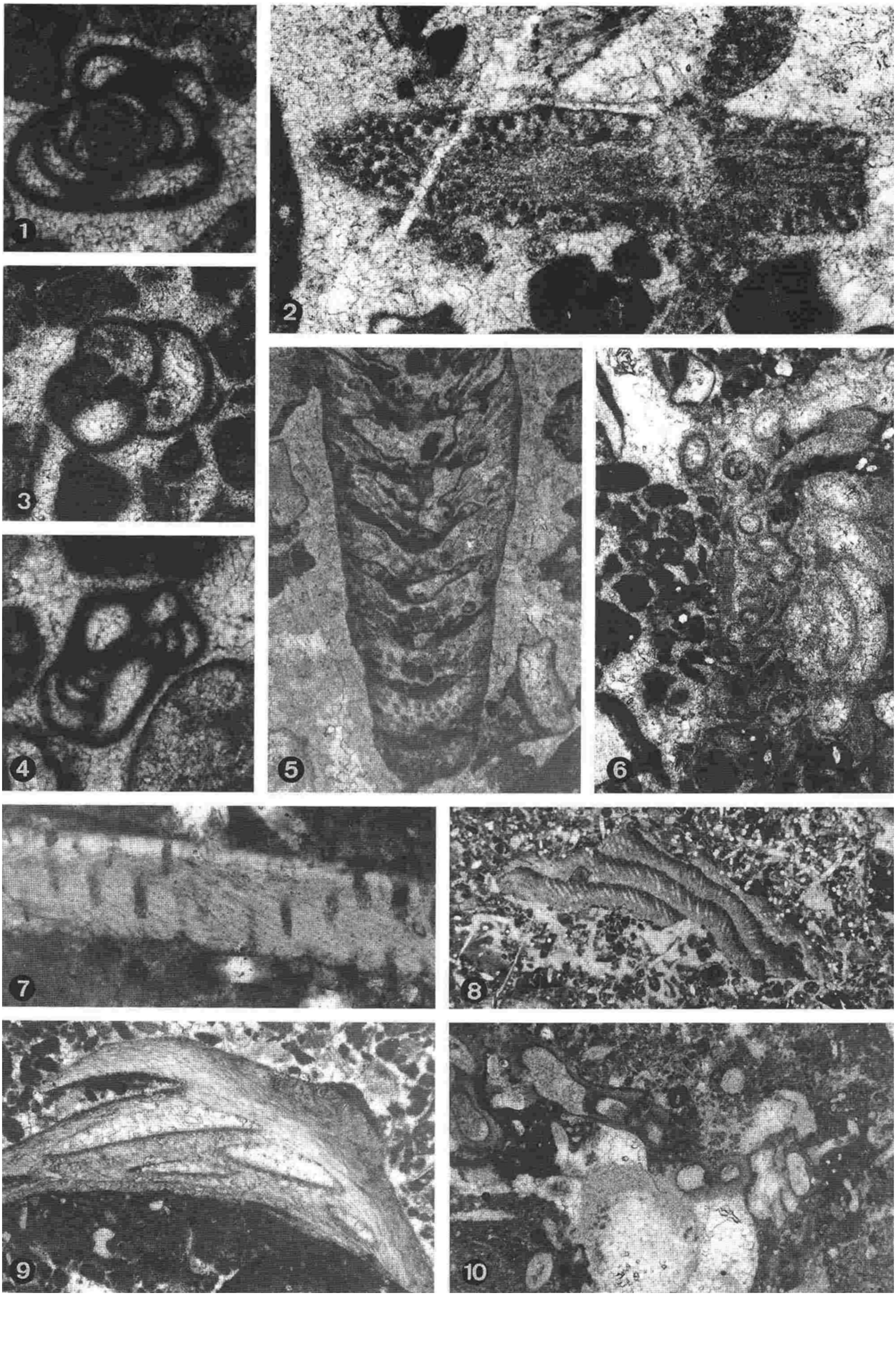
The longitudinal section shows that the "eye" is not a single cavity, but is made up of chambered and non-chambered tubes. The non-chambered tubes are formed longitudinally, can be slightly bent and may vary in width. Other specimens with chambered tubes mostly have a club-like appearance. Quite often the primary chamber is round to oval followed by a subsequent club-like chamber.

The encrusting types are shaped more oval to elongate and are usually attached to the substrate. They occur as crusts in the boundstone microfacies together with other microproblematica. In these crusts their external shape isn't clearly defined as their layers merge with the surrounding micrite.

Plate 17 Lower Jurassic biogenic and non-biogenic components of the Jbel Bou Dahar carbonate platform:

Other biota:

Fig. 1. *Glomospira* sp./*Glomospirella* sp. Magnification 100 x.
Fig. 2. Longitudinal section of an Udoteacea, probably genus *Boueina* TOULA (pers. comm. SCHLAGINTWEIT). Magnification 50 x.
Fig. 3. Cross-section of an polytaxiide foraminifer. Magnification 50 x.
Fig. 4. Textulariide foraminifer. Magnification 50 x.
Fig. 5. Longitudinal section of *Palaeodasycladus* sp. Magnification 25 x.
Fig. 6. Serpulids. Magnification 25 x.
Fig. 7. Punctate brachiopod. Magnification 100 x.
Fig. 8. Not determined bioclast, a balanid? Magnification 2.5 x.
Fig. 9. Oyster with foliated shell structure. Within the shell borings can be observed. Magnification 25 x.
Fig. 10. *Radiomura cautica.* Magnification 25 x.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Tubiphytes sp. occurs in all types of microfacies except for the pelmicrites. Solitary specimens predominate in the biopelsparite and the poorly washed biopelsparite facies. Encrusting *Tubiphytes* sp. are mainly found in the boundstone microfacies.

Radiomura cautica **SENOWBARY-DARYAN & SCHÄFER, 1979a** (Pl. 17/10): This species consists of round to oval chambers with a dark micritic border. The walls are made up of radial formed microcrystalline fibres (SCHÄFER, 1979; SENOWBARI-DARYAN, 1980). These organisms occur exclusively as encrusters and are often accompanied by *Baccanella* sp. and *Muranella* sp. They are only present in the boundstone microfacies.

Baccanella floriformis **PANTIC, 1971** (Pl. 15/1): This microproblematicum consists of small calcite crystals that are orientated in form of rosettes. This species is only found in the boundstone microfacies.

Muranella sphaerica **BORZA, 1975**: Its form is similar to *Baccanella floriformis* and also displays small calcite crystals that are orientated like rosettes. The difference is the presence of a central cavity. Just like *Baccanella floriformis* and *Radiomura cautica*, this species only occurs in the boundstone microfacies.

Aeolisaccus **ELLIOTT, 1958** (Pl. 16/12): This microproblematicum is made up of a thin tube that is open to one side. In literature it is classified as a foraminifer (*Earlandia*). It only occurs in pelmicrites.

? Microtubus communis **FLÜGEL**: The shape is similar to *Aeolisaccus* sp. but the tubes lie partly within each other. SENOWBARI-DARYAN (1980) describes this microproblematicum more in detail. Similar to *Aeolisaccus* sp. these tubes are only present in pelmicrites.

Cyanobacteria: Cyanobacteria are important organisms within the sediment as are other encrusting organisms (e.g. microproblematica, sessile foraminifera, serpulids, and bryozoans). These algal structures appear as thin micritic films around various grains. They are present within all microfacies types.

Corals: *Thamnasteria* (Pl. 14/1): The corals found can be divided into two types:
Type 1 with slightly swinging septa. Type 2 with wave-like septa. Both types occur in one single sample in the coral boundstone facies. ***Astrocoenia*** (Pl. 14/3): In this species only the corallites are visible whereas the walls are totally sparitised. **Thecosmilia** (Pl. 14/2): All colony-building corals with single corallites are incorporated in this category. Some of these corals are strongly dissolved making its precise classification difficult. Astrocoenia and Thecosmilia are present either in the boundstone facies, the biopelsparites or in the poorly washed biopelsparites.

Spongiomorphids (Pl. 14/4): They are characterised by a labyrinth structure of the septa. They occur in the boundstone facies. Fragments were also observed in the biopelsparites and the poorly washed biopelsparites.

Hexactinellid sponges (Pl. 14/5) are easy to determine because of their triaxon shaped needles that seem to float in a micritic matrix. Sometimes the needles form a clearly defined network. Some boring sponges were also found (Pl. 14/6), one for example within a spongiomorphid. Sponges are only present in the boundstone facies.

Foraminifers: The following foraminifers were encountered in the thin sections: *Mesoendothyra* sp. *Haurania* sp. (M. Liassic - Bathonian) (Pl. 16/11), *Trochammina* sp. (Pl. 5/14), *Kurnubia* sp. (Liassic - Kimmeridgian) (Pl. 16/9) and other textulariina (Pl. 17/3-4), *Tetrataxis* sp. (Pl. 16/13), *Nodosaria* sp. (Pl. 16/7), *Lenticulina* sp. (Pl. 16/8), *Ophthalmidium* sp. miliolid foraminifers (Pl. 16/5). Between *Glomospira* sp./*Glomospirella* sp. no further distinction was made, because of their great similarity (Pl. 17/1). *Rheophax* sp. normally appears encrusting biogenic material. *Ammobaculites* sp. is a coarse agglutinating foraminifer with a shell that may partly consisting of peloids. Sometimes they incorporate other components like ooids (Pl. 16/6, 10). *Bullopora* sp. is a boring foraminifer encrusting on spongiomorphids, corals or other organisms (Pl. 16/4).

Distribution of foraminifers: The following species are most frequently found in the profile investigated: *Glomospira* sp./*Glomospirella* sp., *Ammobaculites* sp., *Haurania* sp., *Kurnubia* sp., *Tetrataxis* sp., *Bullopora* sp. and sessile foraminifers. All other species are present in minor numbers (1 – 2 specimens). Two foraminifer communities occur: (1) *Glomospira* sp./*Glomospirella* sp. with *Tetrataxis* sp. and (2) Ammobaculites sp., *Haurania* sp. and *Kurnubia* sp. These two communities are mainly found within the biopelsparites. *Bullopora* sp. either occurs in the boundstone facies or in the pelmicrites/sparites.

Other biota: Serpulids (Pl. 17/6) mainly appear in the boundstone microfacies. Encrusting and solitary Bryozoans are found in minor quantities in every microfacies type except for the pelsparites. Inpunctate and punctate brachiopods (Pl. 12/6; Pl. 17/7), as well as oysters (Pl. 17/9) have the same distribution pattern as the bryozoans. Echinoderms

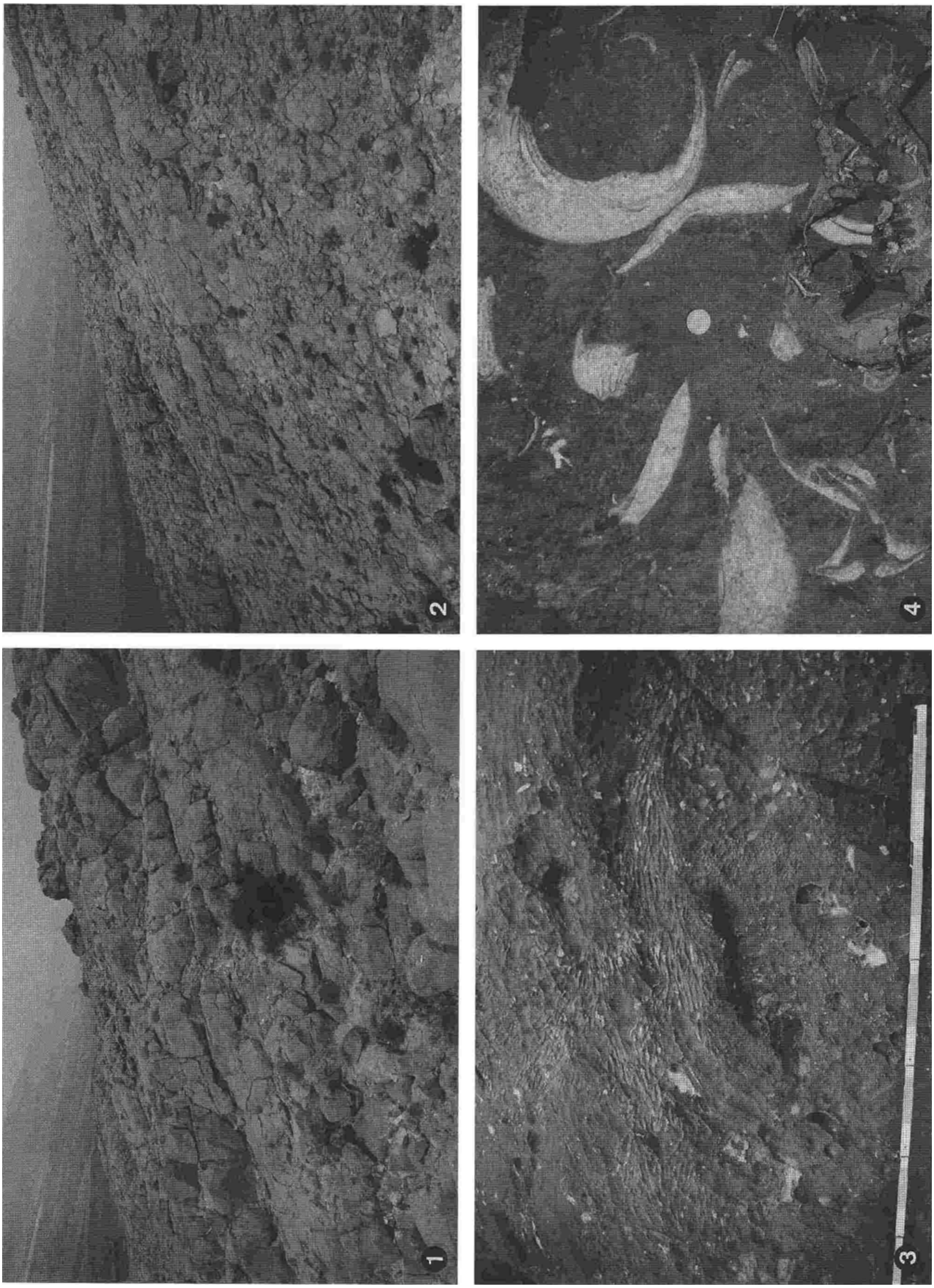
Plate 18 Upper slope outcrop pictures of the Lower Jurassic platform Jbel Bou Dahar:

Fig. 1. Middle section of the profile. On the top of the picture massive to boulder-like layers are present. At the bottom the layers are not cut anymore but the top of the layers are visible.

Fig. 2. Top section of the profile. The boulder layers are thinning out and a distinction in different layers is almost impossible.

Fig. 3. A resedimented specimen of a colony building coral, scale 110 cm, as found in rectangle 2 (facies belt 4, slope of the platform).

Fig. 4. Longitudinal section of *Lithiotis* (facies belt 5, reef or platform edge; rectangle 6). Coin for scale.



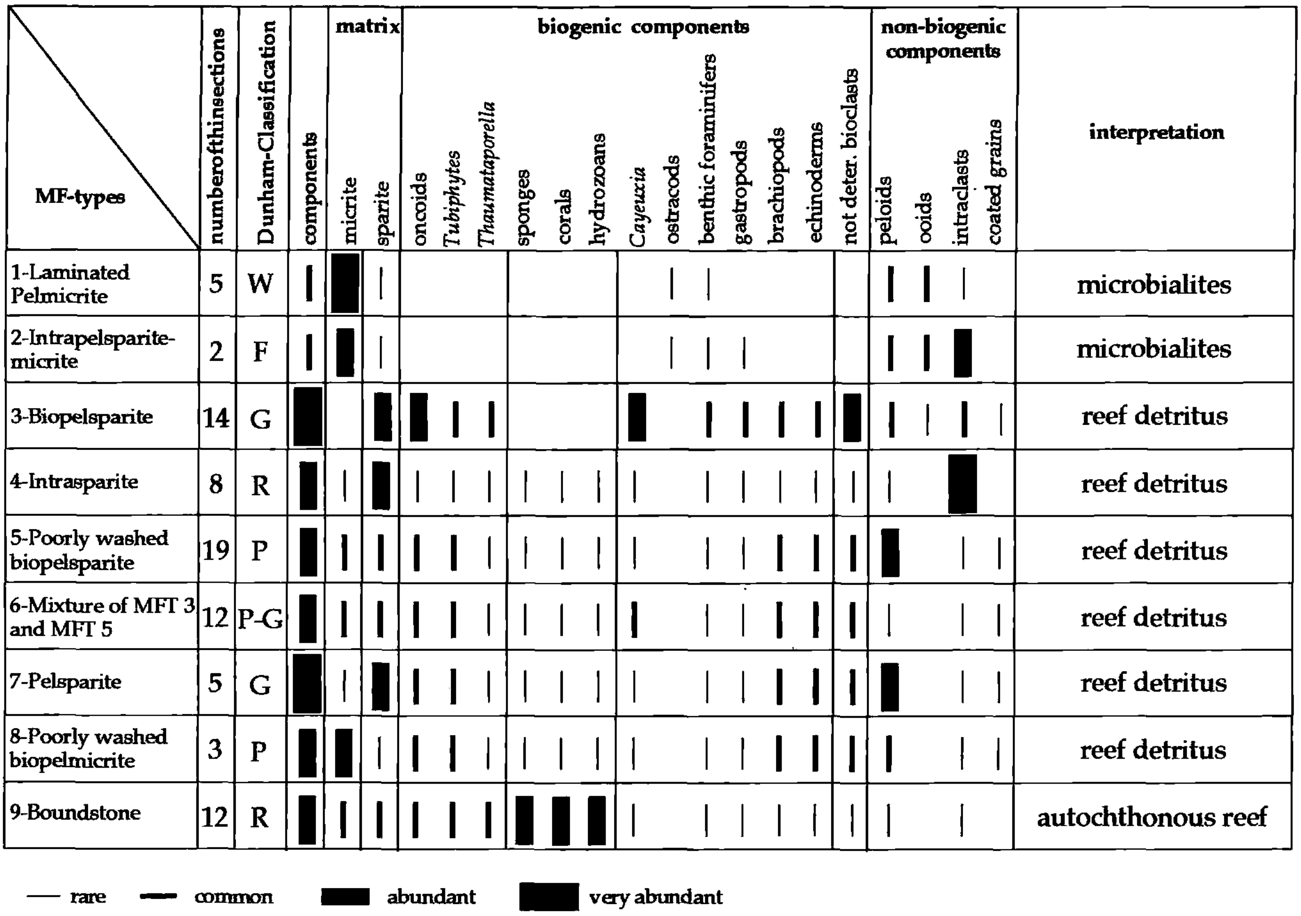


Fig. 9. Component distribution within microfacies types 1 to 9.

occur in every microfacies type. Sea-urchin spines and crinoid segments, often show borings. Filaments (see FÜCHTBAUER, 1988) occur together with ostracods and the microproblematicum *Aeolisaccus* sp. in the pelmicrites. Three types of gastropods were present: two non-sculptured forms with a different stretching degree and another more sculptured form with 13 – 14 cm-long "teeth". The latter mainly occurs in the intrapelmicrite/sparite facies, while the others are frequently encountered in the biopelsparites and poorly washed biopelsparites. Some agglutinated annelids were found in the biopelsparites. In the entire profile only one single ammonite and one possible balanid (Pl. 17/8) were found in the biopelsparites.

4.2.3 Others

Borings: Borings occur in many organisms. The only boring organisms that were found are a hexactinellidae sponge and *Bullopora* sp. The latter preferentially occurs boring into spongiomorphids and/or corals. Coated grains also fit into this category of grain types, while the structure of their outer layer originated from borings of endolithic algae. The following organisms are predominantly affected by this process: *Tubiphytes* sp., oysters and echinoderms.

Glauconite: In the micritic sediments, small green particles occur that can be classified as glauconite.

Authigenic quartz: In some thin-sections authigenic quartz forms one of the most striking components. The crystals can be as large as 1 cm and in cross section show a typical hexagonal outline. Some samples are so heavily recrystallized that no other components can be distinguished. The crystals occur mainly in the micritic lithologies, but can grow into sparites. In areas with abundant sponge needles local accumulations of authigenic quartz were observed. So most likely the SiO_2 is derived from the dissolution of the sponge needles.

4.3 Description and interpretation of the microfacies types (MFT)

Figure 9 gives an overview of the distribution of the main biogenic and non-biogenic components within the microfacies types described below.

MFT 1, laminated pelmicrite (Pl. 13/1,3; Pl. 12/8; 5 thin-sections): This microfacies type (MFT) is made up of 65 - 71% micrite, 0 - 15% sparite and 20 - 29% components. The main components are formed by peloids and ooids (18 - 20%), intraclasts (1- 10%), and bioclasts (0 - 1%). The ooids present are mostly strongly micritized and thus only partly identifiable as ooids. The intraclasts are only characterised by their specific size. Some intraclasts contain ooids or peloids. Some larger well-rounded intraclasts and the ground mass are of micritic origin. These intraclasts probably were only slightly transported or remained in situ. The biota encountered in this facies are ostracods and foraminifers (*Nodosaria* sp., *Bullopora* sp.) and the microproblematicum *Microtubus communis*.

The lamination present in all thin-sections is characterised by thin, dark, micritic layers. At the base a sharp contact is present whereas the top shows a gradual transition towards the ground mass. The lamination is mostly parallel to subparallel orientated but in some parts lenticular. Some of the laminations are formed like U -shaped "valleys". In-between the dark micritic layers uniform sediments are found. They consist of micrite with some rare peloids or ooids. In the micritic areas authigenic quartz is abundant as well as rounded intraclasts, built of the same material as the groundmass. This type of sediment characterises a transition to MFT 3 in which the intraclasts are more angular.

The laminations characterising this MFT probably originate from algal laminations that alternate with sediment layers. Some small channels exist that were also filled by algae. At first the walls of these channels were overgrown by algae and subsequently the entire channel was filled with an alternation of algal mats and sediments. This MFT shows all the characteristics of a bindstone. LEINFELDER et al. (1993) and NEUWEILER (1993) classify this type of sediment as microbialites. These microbialites, partly made up of peloids, are thought to originate in cavities within a variety of environment. but may also grow outside cavities or even build a positive relief. According to GERDES & KRUMBEIN (1987) the peloids and ooids are products of in-situ-precipitation of organic or inorganic processes.

No clear classification can be made in a Standard Microfacies Type (SMFT) after WILSON (1975). The only SMFT's that could match are SMFT 16 and 19, but SMFT 16 describes facies belt 7 (open platform) and SMFT 19 facies belt 8 (closed platform). Both facies belt interpretations do not agree with the sedimentation area, the platform slope, in which the sediments are found.

MFT 2, intrapelsparite/micrite (Pl. 13/2; 2 thin-sections): This MFT is characterised by intraclasts (up to 1.0 cm) embedded in a peloidal micritic ground mass. The differentiation between peloids and the embedding micrite is difficult because many of the small components have no clear boundary and partly melt together with the micritic groundmass. The intraclasts present consist of clasts with other intraclasts or pelmicrites. The peloidal groundmass is mostly laminated. The individual sediment sheets within this MFT are thicker and the transition is due to changes in the grain size. Oblique lamination with an angle of about 45° was also found and probably represents the original angle of repose. The biota consists of ostracods, *Aeolisaccus* sp. respectively *Microtubus communis* sp. and gastropods.

The origin of MFT 2 could be the same as of MFT 1. The amount of intraclasts, however, is striking. These intraclasts could be transported towards this area causing a break in the peloid deposition. Analogues to MFT 1, no clear classification in SMFT after WILSON (1975) can be made. The only SMFT that classify are SMFT 16, 19 and 24, each characterising the open platform and not the upper slope.

MFT 3, biopelsparite (Pl. 13/4; 14 thin-sections): This MFT comprises 32 - 50 % sparite and 50 - 68 % components. The components can be sub-divided in 27 - 45 % biota, 2 - 19 % intraclasts, 1 - 7% coated grains/aggregate grains and 5- 20 % peloids.

The main biogenic components are encrusting organisms, non-determinable bioclasts and calcareous algae. Minor components are echinoderms, gastropods, brachiopods and the microproblematica *Thaumatoporella* sp. and *Tubiphytes* sp. Foraminifera are represented by the following species: *Tetrataxis* sp., *Ammobaculites* sp., , *Nodosaria* sp., *Kurnubia* sp.,*Haurania* sp., and polytaxiide foraminifers, encrusting foraminifers. In thin-sections one genus often dominates (e.g. agglutinating foraminifer or *Kurnubia* sp./*Haurania* sp.). In other thin-sections other components may prevail like gastropods or a relative high amount of ooids is present (max. 7 % in one thin-section). All biofragments are poorly to heavily encrusted. *Cayeuxia* only occurs as solitary specimens. Their halfround to oval thalli are the biggest components within this MFT together with the encrusted non-determinable bioclasts and the intraclasts. Peloids are the smallest components present. In general sediment sorting is poor and no clear stratification is visible. The components are rounded to angular. This MFT is also characterised by its relative large components (> 1mm) and its sparitic cements.

This microfacies type is interpreted as reef detritus deposited in the vicinity of the actual reef and successively encrusted by organisms. In a later stage these sediments were transported to the upper slope forming this microfacies type. It can be classified as SMFT 5 after WILSON (1975), facies belt 4, the slope of the platform, and agrees with the sedimentation area in which the sediments were found at Jbel Bou Dahar.

MFT 4, intrasparite (8 thin-sections): This MFT is characterised by large intraclasts that enclose sparitic areas. Two cement generations are present. Not only sparite occurred in-between the intraclasts, but also different sediment types of MFT 3 and 5. The intraclasts comprise almost all microfacies types observed.

This MFT is composed of reworked material of all other sedimentary facies. After WILSON (1975) the sediments can be classified as SMFT 4 and 6. These SMFT are present in facies belt 4, the slope of the platform. This agrees with the sedimentation area in which the sediments of this MFT are found.

MFT 5, poorly washed biopelsparite (Pl. 13/6; 19 thin-sections): This MFT contains more or less equal amounts of sparite and micrite, 20 - 40 % and 10 - 50 % respectively. The main components are peloids with 13 - 41 %, followed by bioclasts with 8 - 30 %, intraclasts with 0 - 6 % and coated grains/aggregated grains which percentage varies between 0 - 7 %. The bioclasts comprise encrusting organisms, echinoderms and brachiopods. Also present, but with minor percentages, are non-determinable bioclasts, microproblematica *Tubiphytes* sp. and *Thaumatoporella* sp., calcareous algae, gastropods, bryozoans and fragments of sponges, hydrozoans and corals. Foraminifers are represented by *Tetrataxis* sp., *Glomospira* sp., polytaxiide foraminifers, *Ammobaculites*

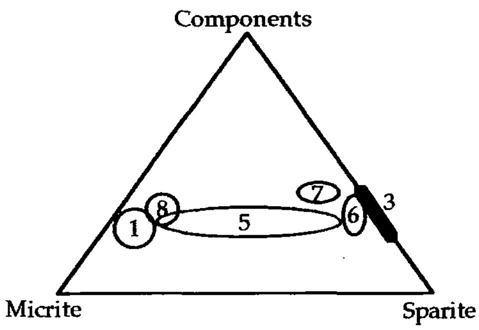


Fig. 10. Mixing triangle showing the distribution of various components within microfacies types 1-9.

sp. and *Haurania* sp. The sediments are moderately to well sorted. Average grain size is by far smaller (< 0,5 mm) than the grain size of MFT 3 (> 1 mm). The only larger components (> 0,5 mm) are echinoderms, non-determinable bioclasts, spongiomorphid fragments and *Cayeuxia*. Partly this MFT is characterised by the occurrence of large amounts of authigenic quartz and minor glauconite.

The grains within this MFT mainly consist of reef detritus. In general, the high amount of peloids is characteristic for a relative quiet sedimentary environment like the platform interior. The peloids found, however, have a totally different structure than the peloids of the pelmicrite facies and do have greater similarities with the peloids of the platform interior that have sharp edges and more angular shapes. So possibly these peloids originate from small bioclasts that are totally micritized. According to the SMFT classification scheme after Wilson (1975) they fall into SMFT 5 deposited in facies belt 4, the slope of the platform. This is in full agreement with the sedimentation area in which this MFT was found at Jbel Bou Dahar.

MFT 6 (12 thin-sections): MFT 6 is a transition from biopelsparite to poorly washed biopelsparite. It has the characteristics of MFT 3 as well as MFT 5. The components and sparitic matrix voids are not as large as in MFT 3 but also slightly differ from the structures of MFT 5. The interpretation and classification of this MFT is identical to MFT 3 and 5, being SMFT 5 (platform slope; Wilson, 1975).

MFT 7, pelsparite (Pl. 13/5; 5 thin-sections): This MFT contains 41 - 50 % sparite, at least 8 % micrite and 48 - 55 % components. The components consist of 9 - 21 % bioclasts, 0 - 2 % intraclasts, 3 - 6 % coated grains/aggregate grains and 25 - 43 % peloids.
This MFT is quite similar to MFT 5 in its structure and composition, but the percentage of micrite in the sediments differs. The facies in which the sediments were deposited is similar to MFT 5, platform slope.

MFT 8, poorly washed biopelmicrite (3 thin-sections): This MFT contains 58 - 64 % micrite, 7 - 18 % sparite and 24 - 30 % components. The components consist of 5 - 12 % bioclasts, 1 - 3 % coated grains/aggregate grains and 17 - 18 % peloids. This MFT is similar to MFT 5, but in contrast to MFT 7 the amount of micrite is relatively high, whereas the amount of sparite is fairly low. SMFT and depositional area of this MFT is similar to that of MFT 5, slope of the platform.

Comparison of the MFT 3 and 5 to 8: All these MFT's can be interpreted as variations of one microfacies type in which the percentages of the main components vary, three in total (micrite, sparite, components), that form the sediment (Fig. 10). The variations in sediment composition could originate from sorting processes in response to varying energy levels in the sedimentary environment.

MFT 9, boundstones (12 thin-sections): Three types of boundstones were found: (1) Hydrozoan boundstone (7 thin sections); (2) Sponge-boundstone (3 thin-sections); (3) Coral-boundstone (2 thin-sections). In all boundstones larger primary voids are present that are filled with sparite. In a later stage these voids were filled with radial fibrous cement and blocky mosaic cement. Some of the frame-building organisms are totally recrystallized and now consist of yellowish, diffuse sparite. The boundstones form the habitat of all encrusting microproblematica. Some of the microproblematica like *Radiomura cautica* and *Baccanella floriformis* are only found in this specific MFT.

(1) Hydrozoans, sponges and corals dominate the hydrozoan boundstone. They are all encrusted by *Lithocodium* sp., *Thaumatoporella* sp., *Tubiphytes* sp., *Baccanella floriformis*, *Radiomura cautica*, encrusting foraminifera, serpulids and bryozoans.

The encrusting respectively boring foraminifer *Bullopora* sp. also characterises this boundstone type. Other components are peloids and bioclasts like ostracods and gastropods.

(2) Well-developed encrusting biota are absent in the sponge-boundstone. The encrusting organisms present are mainly *Thaumatoporella* sp. and *Tubiphytes* sp. The sponges show their characteristic internal meshwork although this internal structure is usually dissolved and only some spiculae are visible in a micritic ground mass. The sponges probably are the original source of the high amount of authigenic quartz present in these sediments. The latter may replace or destroy entire microfacies structures (Pl. 13/7-8). A similar feature from another facies belt is shown in Pl. 12/1. One boring sponge was found within a hydrozoa (Pl. 14/6).

(3) Coral-boundstone is characterised by the occurrence of the colony building coral *Thamnasteria*. These corals form the substrate for hydrozoans and other encrusting organisms. The groundmass in-between the corals is made up of peloids and encrusting organisms. Like in the sponge-boundstone authigenic quartz is frequently observed in the matrix.

The boundstones can be described as a combination of baffle- and bindstones. According to Wilson (1975) MFT 9 belongs to SMFT 7, which forms part of facies belt 5, the reef or platform edge. This agrees with the sedimentation area in which the samples were found.

4.4 Evaluation and interpretation of the microfacies distribution

Seven out of nine microfacies types that could be distinguished within these upper slope deposits, are in good agreement with the standard microfacies types described by

WILSON (1975) for these types of deposits. The peloidal-dominated sediments (MFT 1 and 2), however, form an exception to this rule. They constitute a very specific type of sediment within the upper slope environment of the Jbel Bou Dahar, but are also well known from other Jurassic slope environments (e.g. LEINFELDER et al., 1993; NEUWEILER, 1993). It seems that these microbial originated structures have played an important role in binding and stabilising sediment within the upper part of the slope. The large variety of components present in the alternation of boundstones and pack- to grainstones mainly find their origin within the shallow-water environment of the platform.

This Early Jurassic carbonate platform community contains *Haurania* (M. Liassic – Bathonian), *Kurnubia* (Liassic - Kimmeridgian) and *Paleodasycladus* sp. as well as *Cayeuxia*, *Lithocodium*, *Bacinella irregularis*, *Radiomura cautica*. To some extend the biota thus exists of species that already were known from the Triassic and some new species of Jurassic origin. Further study is needed to quantify and qualify this observation.

5 CONCLUSIONS

This study shows that the platform edge of Jbel Bou Dahar displays a clear separation in distinct facies belts. The standard microfacies type zonation of WILSON (1975) could be used without any major restrictions. Facies belts four to seven of the WILSON-scheme were identified, representing the upper slope to open-platform areas.

The upper slope of the platform consists of two large-scale facies types: (1) relatively coarse sediments, pack- to grainstones, combined with (2) boulder trains that are joined in distinct boulder beds. The spaces in-between the boulders are filled with sediments with peloidal structures formed by early microbial cementation. Microproblematica form the main constituents within the upper slope. In total nine microfacies types were distinguished ranging from coral-boundstones to laminated pelmicrites.

No real reef structures were observed in the entire transect. Small *Lithiotis* mud-mounds form the main "reef-building" structures at the edge of the platform. These mud-mound shoals seem to stabilise the margin and protect the interior of the platform.

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