

APPENDIX.

MICROPALEONTOLOGICAL AND SEDIMENTOLOGICAL ASPECTS OF HIGH ATLAS CRETACEOUS ONSHORE SEDIMENTS (ATLAS-GULF, MOROCCO)¹

Arif Butt, Universität Tübingen

and

Johannes Stets and Paul Wurster, Geologisches Institut der Universität Bonn²

ABSTRACT

Micropaleontological and sedimentological data of the Lower to mid-Cretaceous sequence in the Western High Atlas of Morocco support the existence of a deltoid/triangular Atlas-Gulf. Transgressions and regressions in the Gulf area documented by the micropaleontological record include significant transgressive events during the Berriasian to Valanginian, early Barremian, late Aptian, and Turonian, and regressions in the late Hauterivian and late Barremian to early Aptian. Frequent sea-level oscillations are recorded in the Cenomanian. Continental, lagoonal, littoral, and inner to mid-shelf conditions are deduced from micropaleontological and sedimentological data. Intertonguing of marine and nonmarine paleoenvironmental conditions exhibits transitional characteristics between the Atlantic province and the inner part of the Gulf. Assuming a steady subsidence of the Gulf area because of its location in the mobile High Atlas belt, eustatic changes in sea level may be the most important factor controlling sedimentation, paleoenvironment, and paleobathymetry in the Atlas-Gulf.

INTRODUCTION

Since 1975, a working group of the Geologisches Institut der Universität Bonn has conducted geological field work on the Cretaceous of the High Atlas area of Morocco to reconstruct the Cretaceous geography of the region (Behrens et al., 1978; Behrens and Siehl, 1982; Wurster and Stets, 1982; Stamm and Thein, 1982). This work is equivalent to the offshore activities of the Deep Sea Drilling Project. The onshore activities of the Bonn working group were initiated by Dr. Hans Closs as a means of estimating the continental influence on oceanic sedimentation.

One of the basic aims of the onshore activities in the coastal basins of Morocco was to establish a precise lithologic and stratigraphic subdivision of the Cretaceous rock series. This was done in cooperation with researchers from the University of Tübingen (Wiedmann et al., 1978, 1982), who erected standard sections for the Cretaceous near the Atlantic coast between Agadir and Cap Rhir, and near Essaouira. The Askouti section described in this paper represents the eastern landward facies of the High Atlas Cretaceous deposits. Located about 20 km inland (Fig. 1) the Lower to mid-Cretaceous sequence of Askouti contrasts with the western margin facies near Agadir. It displays frequent alternation of marine and nonmarine sediments and exhibits characteristics transitional between the open-marine Atlantic province to the west and the basin margin province to

the east. The eastern province is characterized by a more abrupt alternation from lagoonal to continental and open-marine sediments (Wurster and Stets, 1982, figs. 2, 6).

Detailed study of the Western High Atlas began in 1930 with work by Roch. It was continued by Ambroggi (1963) and Duffaud et al. (1966). Some important geologic aspects of the Mesozoic deposits of the Western High Atlas were also discussed by Ager (1974). Although Ambroggi made a detailed study of stratigraphy and paleontology, little attention was paid to environmental, ecological, and bathymetric aspects of the Cretaceous. Wurster and Stets (1982, fig. 9) established a sedimentation model for the Lower to mid-Cretaceous sequence of the Western High Atlas, using lithological data because the sediments are often barren of foraminifers. In the Askouti area the microfossils are locally rich, and this model is now corroborated by the micropaleontological record provided by A. Butt.

GEOLOGICAL SETTING

The Askouti section is situated at the southwestern edge of the Western High Atlas mountain range, in the Imouzzer des Ida Ou Tanane area. Toward the south it is bordered by the Plain of Souss, which is filled with Quaternary sediments. The Mesozoic rock series cropping out in the southwestern High Atlas extends from the Triassic to the Cretaceous. In general, younger sediments successively appear toward the coastline, as the mountain chain plunges toward the Atlantic Ocean. This geological situation is modified (Fig. 1) by anticlinal and synclinal structures that are the structural response to a fault pattern which affected the Paleozoic basement. In contrast to the structural interpretation of Rod (1962), this chapter does not distinguish a distinct fault cutting through the Mesozoic—called the “Agadir fault”—in this region.

¹ Hinz, K., Winterer, E. L., et al., *Init. Repts. DSDP*, 79: Washington (U.S. Govt. Printing Office).

² Addresses: (Butt, present address) Al Rahim 50 II B, Model Town, Lahore, Pakistan; (Wurster, Stets) Geologisches Institut der Universität Bonn, Nussallee 8, D-5300 Bonn 1, Federal Republic of Germany.

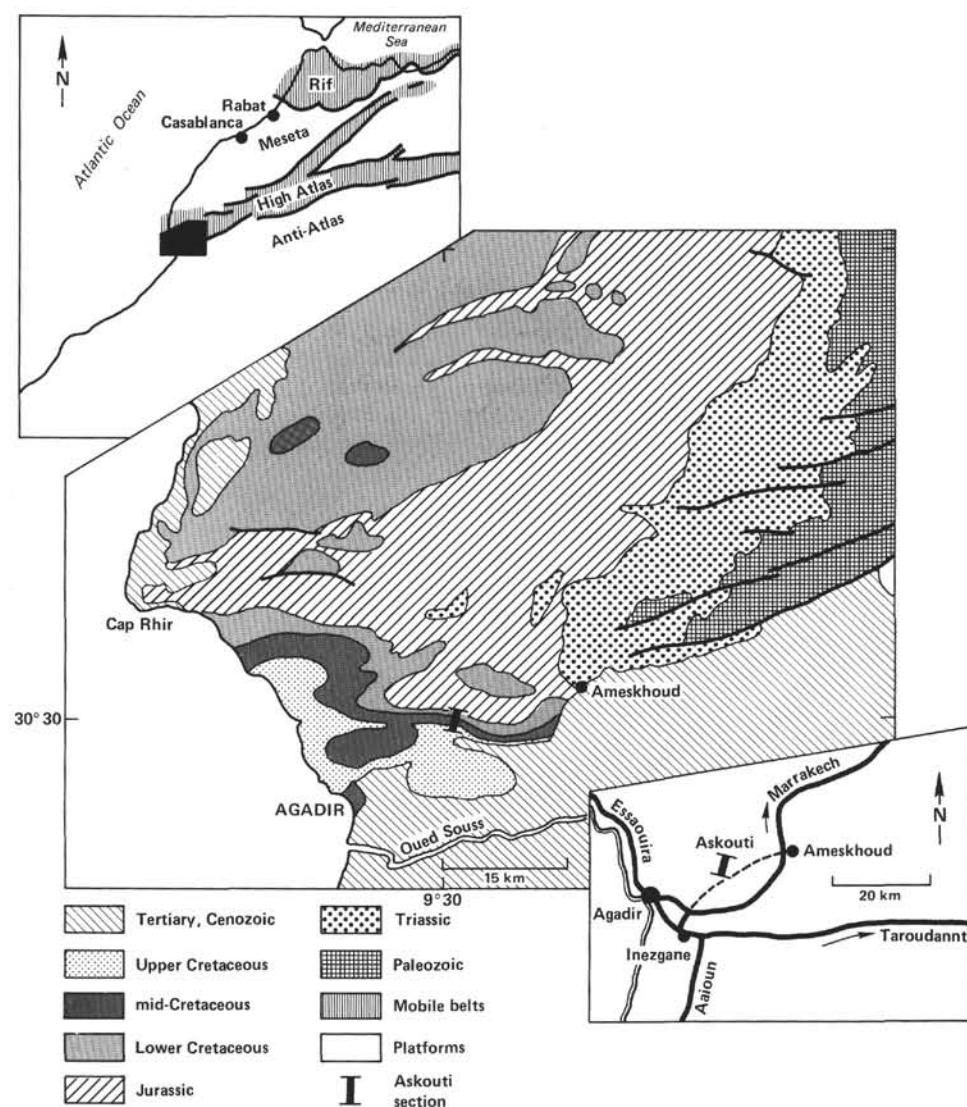


Figure 1. Geology of the southwestern edge of the Moroccan High Atlas and location of the Askouti section.

The Askouti section is located at the southern flank of one of these anticlinal structures, the anticline of Djebel Lgouz. Here, the Cretaceous sequence crops out in the valley south of the small village of Askouti. Bedding dips steeply toward the north at the inverted limb of the anticline. According to the correlation of the Cretaceous rock series with those farther to the west and in the Ameskhoud area to the east, the profile is affected by two minor faults (see Fig. 3, later). Nevertheless, from the stratigraphic point of view, the Askouti section contains the complete Lower to mid-Cretaceous sequence from which the micropaleontological and sedimentological aspects of onshore basin development are deduced.

PALEOGEOGRAPHICAL SETTING

A well-defined deltoid sedimentary basin, called the Atlas-Gulf (Behrens et al., 1978) is apparent from profiles currently available from the Western High Atlas Cretaceous (Wurster and Stets, 1982). This Gulf stretches landward to the east and is bordered by two stable plat-

form areas: the Moroccan Meseta to the north, and the Anti-Atlas to the south. Thin sedimentary units occur at the margins of these structural and paleogeographical highs (Fig. 2). The deltoid/triangular Atlas-Gulf opens toward the Atlantic, and the sedimentary sequence increases in thickness toward the interior and toward the Atlantic along the axis of the basin. Toward the east, the sedimentary sequence decreases gradually in thickness, and red beds are found increasingly in the Atlas-Gulf. Accompanying facies changes are discussed in more detail by Wurster and Stets (1982); the western margin is considered by Wiedmann et al. (1978) and Butt (1982).

The structural position of the Gulf area roughly coincides with the Mesozoic Atlas Rift, which here intersects with the Atlantic continental margin (Stets and Wurster, 1982). According to data compiled for the Gulf area, subsidence during Early and mid-Cretaceous time took place rather continuously, whereas the neighboring stable platform areas remained elevated. In Late Cretaceous time conditions changed. From the Turonian on-

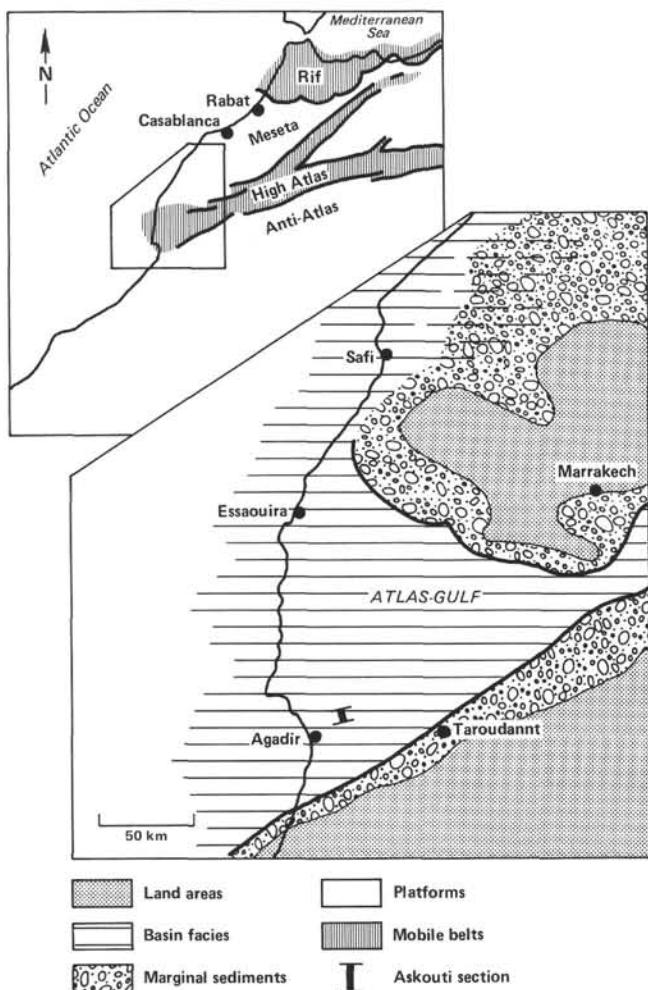


Figure 2. General configuration of the Early to mid-Cretaceous Atlas-Gulf and adjacent areas of the Moroccan Meseta and the Anti-Atlas.

ward, two separate basins developed along the northern and southern flank of the rising High Atlas mobile belt.

ASKOUTI SECTION

The Askouti section is divided into two parts termed Aa and A (Fig. 3); both are located along the valley south of Askouti at approximately $30^{\circ}30'N$, $9^{\circ}27'W$. Part Aa comprises the Lower Cretaceous, part A the mid-Cretaceous. The sedimentary sequence is subdivided into several rock units as generalized in the stratigraphic column of Figure 3. The section was surveyed in detail by Wurster and Stets at a scale of 1:50. A. Butt conducted the micropaleontological research.

Berriasian to lower Aptian Sequence

The lowest rock unit (Aa 270–289 m) conformably overlies an Upper Jurassic sequence of alternating well-bedded carbonates and marls. This first Cretaceous unit consists of grey to greenish marls, dolomitic limestones, and arenites. It is followed by a limestone sequence (Aa 289–320 m) with interbedded thin layers of marls, in which the limestones contain oysters with shell diameters up to 120 mm, brachiopods, echinoids, and occa-

sional corals. Above the limestones, gray marls grade upward into red marls (Aa 320–360 m). A fault forms the upper contact of the red beds. The next series (Aa 360–400 m) starts with intraformational breccias and layered conglomerates with interbedded marls. Grey to greenish marls again follow with interbedded dolomitic limestones. The limestones contain quartz (up to 20%) and shell debris. At Aa 400 m the next rock unit again begins with a basal conglomeratic and calcarenous sequence that exhibits occasional large-scale cross-bedding. Pebbles reach diameters up to 5 mm and intercalated oyster shells range to 40 mm. Layers rich in shell debris occur. Above this coarse-grained littoral sediment, red and grey marls follow that are rich in brachiopods, especially at Aa 430–435 m and Aa 441–443 m. The sequence from Aa 443 to Aa 460 m consists of multicolored, red to grey marls, interbedded limestones, and nodular dolomites. Oysters with shell diameters up to 50 mm occur in the lower portion of the sequence, whereas the upper part is unfossiliferous.

Aptian-Albian Sequence

At Aa 460 m the next sequence starts with another basal conglomerate, consisting mostly of quartz pebbles, that represents the main transgressive event of the Early Cretaceous. This conglomerate is overlain by marls and calcarenous followed by a well-bedded sequence of grey marls and interbedded micritic limestones that contain complete shells and shell debris of small oysters, brachiopods, other mollusks, and ammonites up to 492 m. The ammonite faunas indicate the first occurrence of open marine environments within the gulf. According to Wiedmann (pers. comm., 1977) this rock unit belongs to the late Aptian (Gargasian, Clansaysian).

The following rock series, from Aa 492 to A 610 m, consists mainly of green to olive marls with bituminous layers and frequent interbedded yellowish layers of calcarenous and calcareous sandstones, a few up to 10 cm thick. In the lower part (Aa 500 m) are oxidized small ammonites and mollusks, in the upper part small oysters and other mollusks occur. The lower sequence is not complete: a fault truncates the unit. In the uppermost part (A 550–610 m) are well-bedded and nodular limestones and calcarenous that contain mollusk shells and shell debris.

The next unit above (A 610–805 m) consists of grey to green marls with four intercalated arenitic rock sequences (series 1–4, Fig. 3), each 15 to 20 m thick. These consist of reddish to pink calcareous sandstones, grey and white limestones, and dolomitic limestones. Within the calcareous sandstones cross bedding, ripple cross bedding and lamination are observed. In the basal parts of the dolomitic limestones intraformational breccias are often found. Trace fossils are rare, whereas oysters with maximum shell diameters up to 120 mm and coquina beds are abundant.

Cenomanian-Turonian Sequence

The sequence from A 805–1125 m consists mainly of grey marls. Intercalations of limestones and calcarenous show cross stratification, shell layers, and coquina beds.

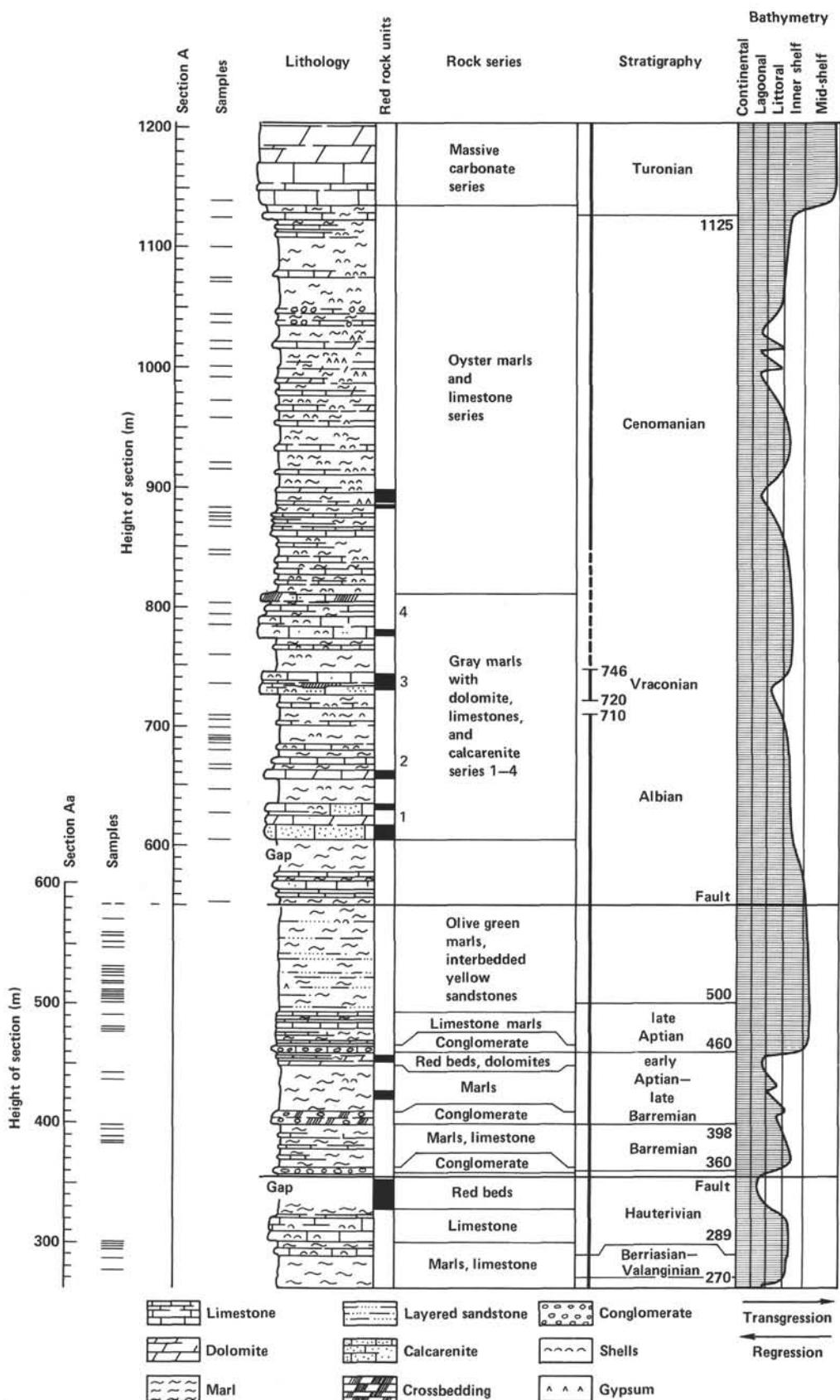


Figure 3. Generalized profile of the Lower and mid-Cretaceous sequence at Askouti, containing standard lithology, rock units, biostratigraphic data, and paleobathymetry. Sample number in text corresponds to the position in sections Aa and A; stratigraphic boundaries correspond to data in Table 1.

Rich assemblages of oysters with shell diameters up to 150 mm suggest nearby oyster reefs. Trace fossils, mollusks, and several fragments of echinoids indicate periods of rich benthic life in some places and at certain times. Dolomite, red marls, and gypsum are also observed. Alternation of these quite different rocks within this sequence suggests that the sediments accumulated under fluctuating shallow-marine to lagoonal conditions.

The uppermost rock unit (A 1125–1200 m) consists of a massive carbonate sequence with limestones and dolomites (Fig. 3). The limestones are often rich in nodules and layers of chert. This unit is followed in the field over large areas and is one of the most important reference horizons of the Cretaceous in the High Atlas. It represents the second main transgressive event in the Cretaceous Atlas-Gulf (Stamm and Thein, 1982).

BIOSTRATIGRAPHY

Several marlstone samples and thin sections of the carbonate facies were studied to document the following foraminiferal stratigraphy. The stratigraphic scheme (Table 1) is applied following van Hinte (1976). Diagnostic species used in this report are listed in Table 2.

Lower Cretaceous: Berriasian–Aptian (Aa 270–500 m)

In the lower part of the section, samples Aa 287.0 and Aa 287.7 are dominated by *Buccicrenata italica* with some rare specimens of *Triplasia* (Plate 1, Fig. 2). Occurrence of *B. italica* may indicate a Berriasian through

Table 1. Biostratigraphic summary of the Askouti section.

Interval ^a (m)	Ages with diagnostic foraminiferal species
270–287	Berriasian–Valanginian <i>Buccicrenata italica</i>
289–360	Hauterivian <i>Dorothia kummi</i>
360–398	Barremian <i>Choffatella decipiens</i> <i>Dorothia kummi</i>
398–460	late Barremian–early Aptian Barren
460–500	late Aptian <i>Globigerinelloides ferreolensis</i> <i>Clavihedbergella bizonae</i> <i>Globigerinelloides blowi</i>
500–710 ±	Albian <i>Favusella washitensis</i> <i>Ticinella bejaouaensis</i> <i>T. primula</i> <i>Hedbergella amabilis</i> <i>H. planispira</i> <i>Globigerinelloides gyroidinaeformis</i>
± 720–746	Vraconian <i>Heterohelix moremani</i>
746–1125	Cenomanian <i>Praealveolina</i> <i>Pseudodomia</i> <i>Cribratina texana</i> <i>Gavelinopsis</i>
± 1130–1200	Turonian “Zone à grandes Globigérines”

^a See Figure 3.

Table 2. Diagnostic species of foraminifers cited in this chapter.

<i>Gavelinella intermedia</i> (Berthelin)
<i>Globigerinelloides blowi</i> (Bolli)
<i>Favusella washitensis</i> (Carsey)
<i>Clavihedbergella bizonae</i> (Chevalier)
<i>Cribratina texana</i> (Conrad)
<i>Valvulinaria gracillima</i> (Dam)
<i>Buccicrenata italica</i> Dieni and Massari
<i>Hedbergella infracretacea</i> (Glaessner)
<i>Heterohelix moremani</i> (Morrow)
<i>Globigerinelloides ferreolensis</i> Moullade
<i>Hedbergella sigali</i> Moullade
<i>Globigerinelloides gyroidinaeformis</i> Moullade
<i>Epistomina spinulifera</i> (Reuss)
<i>Pseudonodosaria humilis</i> Roemer
<i>Choffatella decipiens</i> (Schlamberger)
<i>Lamarckina lamplughii</i> (Sherlock)
<i>Ticinella bejaouaensis</i> Sigal
<i>Hedbergella planispira</i> (Tappan)
<i>Hedbergella amabilis</i> (Tappan)
<i>Dorothia kummi</i> Zedler

Valanginian age for the lowermost rock unit (Aa 270–289 m, Fig. 3). Ascoli (1976) reported *B. italica* from the Cretaceous shelf basin of Nova Scotia, North America; thus an isochronic biostratigraphic level between the High Atlas and Nova Scotian basins is indicated. Samples Aa 296.0 and Aa 299.0 contain rare specimens of *Dorothia kummi*, *Ammodiscus*, and *Lenticulina*, abundant echinoid spines, and small mollusks that suggest a probable early Hauterivian–Valanginian age. The red bed facies of Hauterivian age (Aa 330–360 m, Fig. 3) is barren of microfossils.

The lower Barremian marls and interbedded limestone samples in the interval Aa 380 to 398 m contain variable amounts of ostracodes and of calcareous benthic and agglutinated foraminifers. The assemblage also includes sporadic distribution of small mollusks, echinoid spines, and a few bryozoans. Typical Barremian species include *Dorothia kummi* and *Choffatella decipiens* in addition to *Trochammina depressa* and species of *Lenticulina*, *Haplophragmoides*, and *Ammobaculites*. The upper Barremian–lower Aptian facies (Aa 398–460 m, Fig. 3) is almost barren of microfossils.

The overlying marls and limestones in the Aa 460–500 m interval contain relatively abundant foraminifers. Planktonic species indicate a late Aptian age (samples Aa 443.5; Aa 475.5; Aa 481.0; Aa 490.7; Aa 497.1). Typical Aptian species include *Globigerinelloides ferreolensis*, *G. blowi*, *Clavihedbergella bizonae*, *Hedbergella infracretacea*, *H. planispira*, *H. sigali*, and *Ticinella bejaouensis*. Some benthic taxa are *Vaginulina*, *Lenticulina*, *Dentalina*, *Fondicularia*, *Nodosaria*, *Epistomina spinulifera*, *Gavelinella intermedia*, and *Lamarckina lamplughii*. In addition, the assemblage also shows sporadic occurrence of *Dorothia*, *Textularia*, *Tritaxia*, and *Reophax*. Sample Aa 481.0 typically contains upper Aptian species, and planktonic: benthic ratios average 20:80 (Plate 1, Fig. 1). In general, the upper Aptian samples contain relatively abundant nodosariids, whereas rotaloid forms and agglutinated foraminifers are rare.

Mid-Cretaceous: Albian-Turonian (Aa 500-A 1200 m)

The Aptian-Albian boundary occurs at approximately 500 m, whereas the Albian extends upward to more than 710 m in the Askouti section (Fig. 3).

The Lower Albian marls contain rare planktonic foraminifers, but benthic foraminifers are frequent and diverse. Typical planktonics are *Ticinella bejaouaensis*, *Favusella washitensis*, *T. primula*, *Hedbergella amabilis*, and *H. planispira*. Typical benthics are *Valvularia gracillima* and *Epistomina spinulifera*. Nodosariids are abundant with a high frequency of lenticulines, but agglutinated foraminifers such as *Textularia*, *Dorothia*, *Reophax*, and *Haplophragmoides* are rare; sample Aa 517.5 yields an abundant assemblage of *Trochammina depressa*.

The middle and upper Albian series (samples Aa 552.2, Aa 557.0, Aa 560.0, A 627.5, A 647.5, A 680.0, A 685.9, A 688.0, A 689.0, A 692.5, A 699.0, and A 709.5) in the interval from 552 to 710 m are nearly devoid of pelagics, and the upper Albian samples from A 605 to 710 m are barren of planktonic species. However, some middle Albian species include *Globigerinelloides gyroideaformis*, *Hedbergella amabilis*, and *H. planispira*. These foraminifers are epipelagic (they inhabited the upper few meters of the water column) and indicate nearshore conditions. Benthic foraminifers are rare to frequent, and ostracodes show variable abundances; echinoid spines, small mollusks, and fish teeth occur as minor components in the samples. Interestingly, the upper Albian sample yields relatively abundant fresh-or brackish-water algae (charophytes, Plate 2, Fig. 1), and ostracodes. Typical benthic foraminiferal species are *Valvularia gracillima*, *Pseudonodosaria humilis*, extremely small specimens of *Dentalina*, and relatively common lenticulines.

The uppermost Albian, or so-called Vraconian, includes oyster limestones and interbedded marls (samples A 735.0; A 760.5; A 784.7; A 802.7; A 844.0). The marl samples contain abundant epipelagic heterohelicids such as *Heterohelix moremani* (samples A 760.5; A 802.7). The assemblage also includes other minor components such as ostracodes, small mollusks, and agglutinated foraminifers such as *Haplophragmoides*. The interbedded calcareous limestones and calcarenites yield specimens of *Dicyclina*, miliolids (*Quinqueloculina*, *Cuneolina*), and shell debris, including echinoid spines and algal fragments (A 735.5; A 847.7).

The first occurrence of *Praealveolina* in sample A 846.3 marks the Vraconian/Cenomanian boundary; the Cenomanian is represented in the interval from A 846 to 1125 m in the Askouti section. The Cenomanian sequence displays an upward continuation of the underlying Vraconian facies. Thin sections of samples A 846.3, A 866.5, A 874.3, and A 1046.0 include imperforate foraminifers such as *Praealveolina*, *Pseudodomia*, *Quinqueloculina*, and *Dicyclina*, algal fragments, and shell debris. These microfossils are embedded in sparry oolitic and intraclastic micritic matrix (Plate 3, Figs. 1-3).

The marl samples A 877.2, A 879.0, A 921.3, and A 972.5 represent an early Cenomanian age. They contain

rare to common benthic microfossils, whereas planktonic species are absent. The lower Cenomanian assemblage includes *Quinqueloculina*, *Cibratina texana*, *Cuneolina*, *Daxia*, and *Gavelinopsis*. In addition to this benthic fauna, the assemblage yields abundant ostracodes in some samples; small mollusks, bryozoans, and echinoid spines are present as minor components. Sample A 993.5 in the upper part of the early Cenomanian is barren of microfossils; the washed residue contains only gypsum fragments. Sample A 1001.5 consists mainly of agglutinated foraminifers including *Haplophragmoides*, *Ammobaculites*, and *Reophax* (Plate 2, Fig. 2). The upper Cenomanian samples (A 1014.2, A 1037.1, A 1046.5, A 1071.5, A 1073.5, A 1100.0, and A 1125.0) display variable amounts of ostracodes and calcareous benthic foraminifers (Plate 2, Fig. 3). The benthic forms include *Ammobaculites*, *Cibratina texana*, *Haplophragmoides*, and *Cuneolina*. The rotaliid forms such as *Gavelinopsis* are frequently distributed in the upper Cenomanian samples. Other miscellaneous microfossils such as echinoid spines, bryozoans, and small mollusks were found.

The lithologic change at A 1125 m (Fig. 3) coincides with the biostratigraphic boundary, marking an important stratigraphic horizon at 1125-1200 m in the Askouti section that can be correlated in the entire High Atlas region. Sample 1139.0 exhibits a foraminiferal biomimetic microfacies (Plate 3, Fig. 4) containing small-sized and abundant hedbergellids. The hedbergellids in the fine, muddy matrix correspond stratigraphically to the *Hedbergella lehmanni* Zone—"Zone à grandes Globigéries" of the lower Turonian proposed by van Hinte (1976). This zone is also identified in the western facies of the Atlas-Gulf (Wiedmann et al., 1978; Butt, 1982).

PALEOECOLOGY, PALEOENVIRONMENT, AND PALEOBATHYMETRY

After the deposition of the Upper Jurassic shallow-water carbonate platform facies (Adams, 1979), the Atlas-Gulf evolved into a near-shore shelf environment during the Berriasian through Valanginian. The interbedded oyster shell beds and marly limestones containing abundant lituolids such as *Buccicrenata italica* (Plate 1, Fig. 2) and rare *Triplasia* suggest an intertidal water mass within the littoral zone, with water depths of a few meters. Rare specimens of textulariids such as *Dorothia*, nodosariids such as *Lenticulina*, and *Ammodiscus*, including rare bryozoans near the Valanginian-Hauterivian boundary, imply a progressive deepening of the basin during the Cretaceous transgression (Fig. 3). The Hauterivian red bed facies, however, suggest a regression and lowering of the sea level.

The Lower Barremian facies apparently represent lagunal to inner-shelf environments with oscillating brackish conditions following the Hauterivian shallowing event. This interpretation is based on the presence of relatively abundant ostracodes, nodosariids such as *Lenticulina*, and variable amounts of foraminifers such as *Haplophragmoides*, *Ammobaculites*, and *Trochammina depressa*, as well as other miscellaneous microfossils, such as echinoid spines, small mollusks, and rare bryozoans.

The upper Barremian to lower Aptian deposits (Fig. 3) reveal nonmarine fluvial to deltaic activity. These

sediments document a retreat of the sea level, revealing another basinwide regression of marine conditions.

The upper Aptian marls contain abundant nodosariids such as *Lenticulina*, *Nodosaria*, *Frondicularia*, and *Dentalina*, rotaliid forms such as *Gavelinella* and *Epistomina*, and rare to common small planktonic foraminifers. Sample Aa 481.0 consists of a relatively diverse foraminiferal assemblage with a planktonic: benthic ratio of 20:80 that suggests an inner-shelf environment with open sea conditions. The upper Aptian flooding, however, marks a basinwide transgression revealing both a submergence and elimination of the early Aptian deltaic environment in the inner Atlas-Gulf basin.

The late Aptian deep-water shelf environment continued during the early Albian period. Although the lower Albian facies reveal a marked decrease of the planktonic species, the benthic foraminifers are more diverse; they include upper Aptian long ranging and diverse nodosariids and rotaliid forms such as *Valvularia gracillima*. The lower Albian bituminous marls also contain some agglutinated foraminifers such as *Reophax*, *Saccamina*, *Trochammina*, *Haplophragmoides*, *Dorothia*, and *Textularia*. Such facies may signal calcite depletion related to reducing conditions in a relatively deep shelf-basin environment.

The deep-water shelf environment continued, through the middle Albian, but during the late Albian the abundance of the microfossils was greatly reduced; the planktonic foraminifers are absent, and benthic forms are very rare. In contrast, some upper Albian samples consist mainly of abundant ostracodes and charophytes, whereas others include miscellaneous microfossils such as echinoid spines and small mollusks. The upper Albian microfossils suggest a shallow shelf basin, and the charophyte assemblage indicates brackish to freshwater conditions (Plate 2, Fig. 1).

The uppermost Albian or Vraconian carbonate facies with interbedded marls contains abundant heterohelicids and rare ostracodes, small mollusks, and a few agglutinated foraminifers. These microfossils suggest deepening of the basin following the upper Albian shallowing. The interbedded calcarenites that contain algal fragments and the associated miliolids indicate near-shore deposition.

The Vraconian carbonate depositional environment continued during the Cenomanian period. Imperforate foraminifers such as *Praealveolina*, *Pseudodomia*, *Quinqueloculina*, and *Cuneolina*, in association with algal fragments, echinoid, and shell debris (Plate 3, Figs. 1-3) embedded in micritic and oolitic matrix, indicate oscillating low- and high-energy environments. The praevalveonid microfacies shown in Plate 3 (Figs. 1-3), comprising *Praealveolina*, *Pseudodomia*, and *Cuneolina*, was also documented from the mid-Cretaceous shallow-water deposits in the Tethyan region (Hamaoui, 1979). The algae and larger foraminifers such as *Praealveolina* and *Cuneolina* favored warm, sunlit conditions of the littoral zone. Accordingly, interbedded gypsum and red-bed facies suggest intense, warm, hypersaline to oxidizing conditions. Sample A 1001.5, comprising agglutinated foraminifers such as *Rheophax*, *Haplophragmoides*, and *Ammobaculites*, indicates fluctuating hypersaline or salt

marsh conditions. Similar depositional environments for the Upper Cretaceous marginal sediments of the Horsehoe region of southern Alberta were proposed on the basis of agglutinated associations by Wall (1976).

The intermittent evaporitic and brackish environment of the late Cenomanian implies a retreat of the sea level. Interbedded marls containing rotaliid forms such as *Gavelinopsis* and agglutinated forms such as *Cribratina texana* and *Cuneolina*, with variable ratios of ostracodes to benthic foraminifers and a total lack of pelagic foraminifers, suggest oscillating inner-shelf to lagoonal depositional environments during the Cenomanian (Fig. 3).

During the Turonian, a major facies change occurred. Lithologic data document the cessation of the shallow-marine Cenomanian environments. Abundant hedbergellids (Plate 3, Fig. 4) were apparently deposited in mid-shelf environments with open sea conditions. The inner Atlas-Gulf basin reveals a greater water depth that coincides with a large-scale submergence and a transgression of the entire Atlas region during the early Turonian. This increase in water depth also corresponds to the deepening of the western margin of the Atlas coastal basin, suggesting a synchronous transgressive event.

PALEOCEANOGRAPHIC REVIEW

In summary, microfossils from the Lower to mid-Cretaceous sediments of the Askouti section document the development of lagoonal to mid-shelf environments. Combined with lithological data, microfossil data from the section record frequent changes of depositional environments. According to all the data now available, the proposed sedimentation model is based on the assumptions of continuous subsidence in the Gulf, lack of major climatic changes in this region, and a somewhat elevated position of the bordering highs. The model is substantiated by the character of the marginal facies and of the sediments in the interior of the Gulf. Terrigenous influx from the continent may have continued during the Early to mid-Cretaceous under these conditions.

Figure 4 shows the sedimentation model which was proposed by Wurster and Stets (1982) for the inner part of the Atlas-Gulf using sedimentological data only. Episodic rises of the sea level, shown on the left, correspond with the position of the littoral zone, on the right. Sedimentological and paleoenvironmental data show that subsidence in the Atlas-Gulf was nearly offset by sedimentation during the Cretaceous. According to our model, minor variations or oscillations of the sea level caused major transgressions or regressions that had a strong influence on benthic and planktonic life and controlled the terrigenous influx from the adjacent continent. High-standing sea levels restricted the clastics from the continent to the inner part of the basin, whereas the lowering of sea level allowed the clastic material to reach the Atlantic coastal margin.

In the sedimentation model the Askouti section is situated to the west, far away from the strong influence of continental conditions (Fig. 4). The micropaleontological data support this model. The low frequency of planktonic foraminifers prohibited us from using planktonic: benthic ratios as a reliable paleobathymetric parameter.

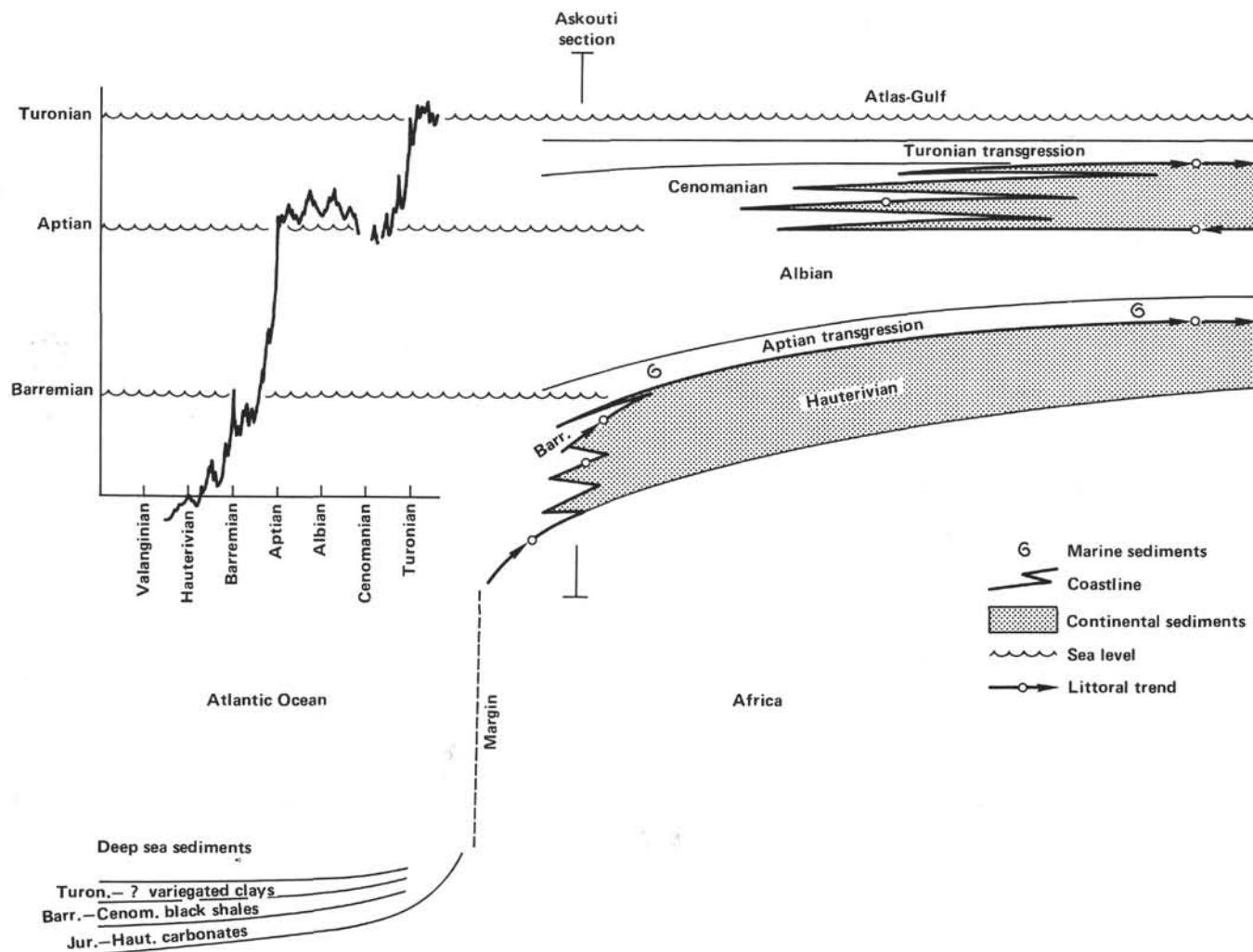


Figure 4. Sedimentation model of the Atlas-Gulf: interpretative sketch elucidating the migration of the littoral zone and the facies distribution, caused by several stages of a rising sea level; based on Wurster and Stets (1982).

Nevertheless, small-sized planktonics reveal epipelagic zone activity from a near-shore water mass. The benthic foraminifers also lived under stressed biotope conditions and were influenced by sediment influx derived from a lowering of sea level. The syndepositional subsidence was nearly continuous, but markedly lower in comparison to the western margin of the Atlas-Gulf (Wiedmann et al., 1978). In response to sea level changes, the basin experienced episodic marine and continental conditions during the Early to mid-Cretaceous period in the Askouti area.

The upper Barremian-lower Aptian deltaic and continental facies and the bituminous olive green marls of early Albian age are equivalents of the deep-sea black shale in the Atlantic Ocean (Fig. 4). The environments of the organic-matter-rich Early Cretaceous facies are discussed by Schlanger and Jenkins (1976) for the other coastal basins around the Atlantic. These authors argued that such facies may indicate oceanwide anoxic events during the Early to mid-Cretaceous because of the restricted circulation and a maximum expansion of the oxygen-minimum zone (Arthur, 1979; Einsele and Wiedmann, 1982; Butt, 1982; Ryan and Cita, 1977).

Following the frequent Cenomanian oscillations in sea level, the inner Atlas-Gulf was submerged under a deeper water mass during the early Turonian. According to Arthur (1979) and Roth and Bowdler (1981), deep-water connections within the Atlantic improved at the end of the mid-Cretaceous, resulting in better ventilation and in the replacement of black shales by a multicolored clay and chalk facies (Fig. 4). Structural opening of the North and South Atlantic may have produced this major paleoceanographic change (Butt, 1982), which in turn controlled the contemporaneous flooding of the coastal basin by the rise in sea level (Sliter, 1977; Wiedmann et al., 1978, 1982; Lancelot and Winterer, 1980; Wurster and Stets, 1982).

Among the variables thought to be responsible for changes of lithofacies, paleoenvironments, paleoecology, and paleobathymetry in the Askouti section and elsewhere in the Gulf area, changes in sea level may have been the most important factor.

CONCLUSIONS

Detailed studies of a Lower to mid-Cretaceous sequence near Askouti at the southwestern flank of the High At-

las mountain range corroborate data from Atlantic Ocean sediments and from sediments in the interior of the Atlas coastal basin of Morocco.

1. The Askouti section is subdivided into several rock units which reflect frequent changes in sedimentary depositional environments, ranging from continental red beds to open marine carbonates. Different transgressive events are documented by conglomerates in the Barremian and late Aptian and by marine carbonates in the Berriasian-Valanginian and in the Turonian; regressions are expressed by deltaic to fluviatile red beds in the Hauterivian and in the late Barremian to early Aptian, and by lagoonal deposits containing gypsum in the Cenomanian.

2. The micropaleontological record supported by planktonic and benthic foraminifers allows an approximate biostratigraphic classification of the rock units. Stratigraphic boundaries are less precise in unfossiliferous parts of the section or those barren of conclusive foraminifers such as those of the Vraconian and Cenomanian sequences.

3. Foraminifers, ostracodes, charophytes, and other miscellaneous microfossils and relicts display shallow-marine to lagoonal and brackish depositional environments, with relatively frequent oscillation of water depths during the Early to mid-Cretaceous. Marine sediments range from the littoral zone to mid-shelf conditions. The transgressions and regressions suggested by the lithological data in the Askouti section are thus sustained by the micropaleontological record. Increasingly frequent changes of living and depositional conditions during the latest Albian and the Cenomanian are documented.

4. A sedimentation model based on the data now available suggests that eustatic sea level changes versus subsidence are considered the main factors that controlled depositional conditions, paleoecology, and paleoenvironment. Within this model, it is suggested that major rises of the sea level occurred in the late Aptian and early Turonian, minor ones in the Berriasian to Valanginian, early Barremian, and Cenomanian.

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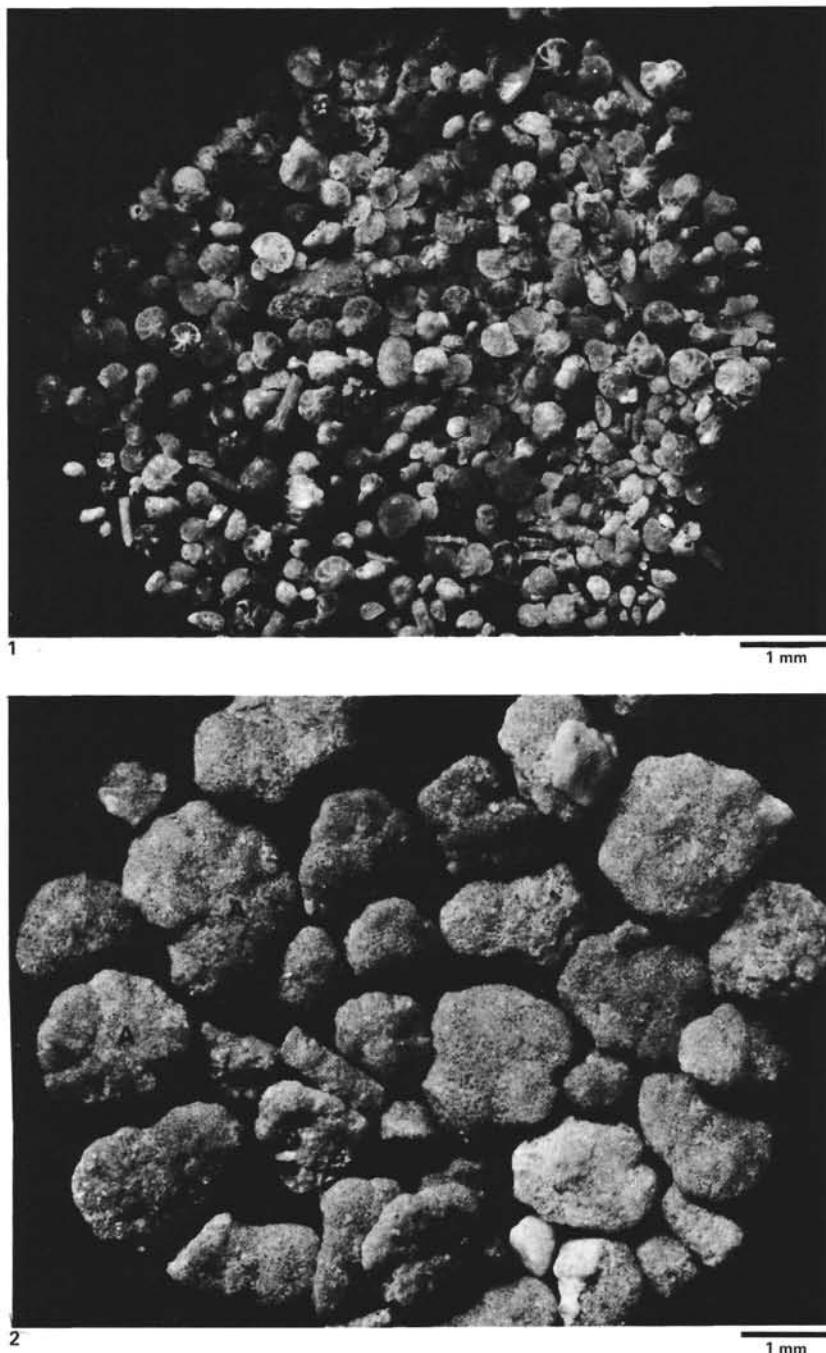


Plate 1. Lower Cretaceous microfossils in the High Atlas coastal basin. 1. Upper Aptian nodosariids; note abundant lenticulines and rare echinoid spines. Paleobathymetric zone, inner shelf; Askouti section, sample Aa 481.0. 2. Berriasian–Valanginian assemblage of *Buccicrenata italica* Dieri and Massari (A). Paleobathymetric zone, littoral; Askouti section, sample Aa 287.0.

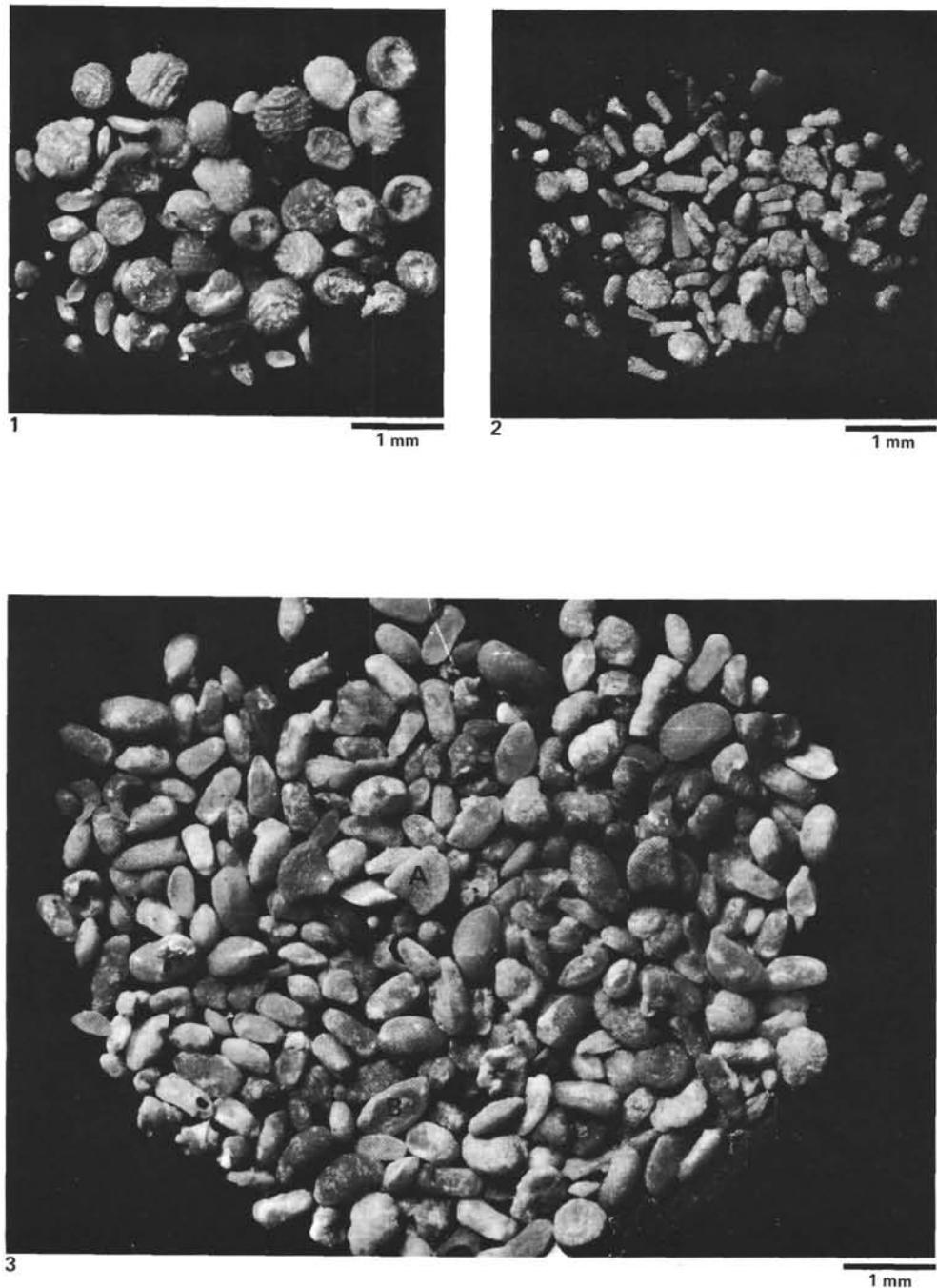


Plate 2. Mid-Cretaceous microfossils in the High Atlas coastal basin. 1. Upper Albian charophyte assemblage. Paleobathymetric zone, lagoonal with brackish or freshwater conditions; Askouti section, Sample Aa 709.5. 2. Upper Cenomanian agglutinated foraminiferal assemblage, showing specimens of *Reophax*, *Ammobaculites*, and *Haplophragmoides*. Paleobathymetric zone, lagoonal with brackish or salt marsh conditions; Askouti section, Sample A 1001.5. 3. Upper Cenomanian microfossil assemblage; note abundant ostracodes and rare foraminifers such as *Cuneolina* (A) and *Quinqueloculina* (B). Paleobathymetric zone, lagoonal-inner shelf; Askouti section, Sample Aa 972.5.

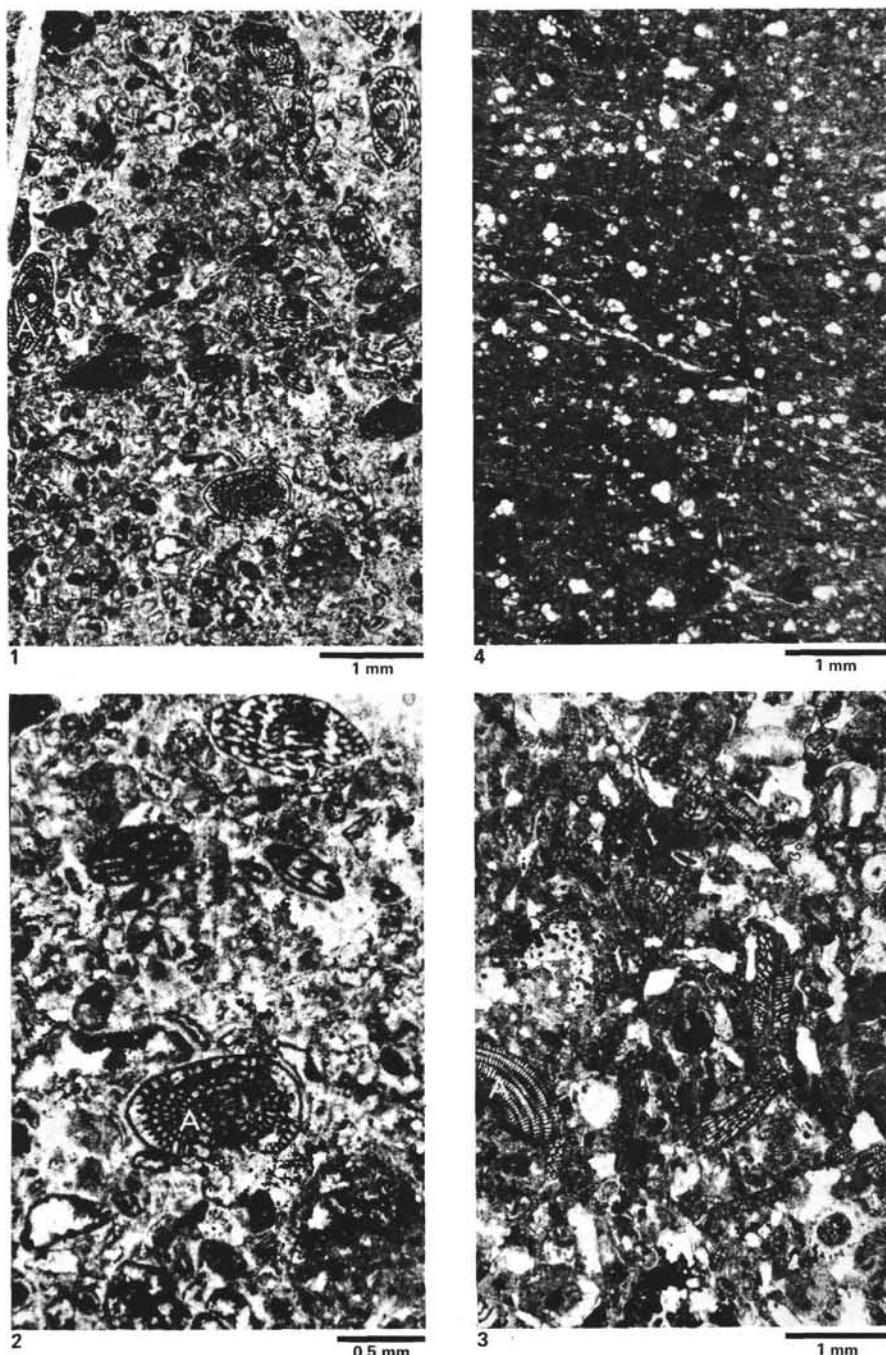


Plate 3. Photomicrographs of mid-Cretaceous microfacies in the High Atlas coastal basin. 1. Cenomanian *praecalveolinid* biomicrite (A). Paleo-bathymetric zone, near shore-inner shelf; Askouti section. 2. Enlargement of 1. Specimen of *Pseudedodoma* (A)? 3. Cenomanian cuneolinid intraclastic biomicrite. Paleobathymetric zone, near shore-inner shelf; (*Cuneoliona* (A)). Askouti section. 4. Early Turonian globigerinid biomicrite. Paleobathymetric zone, mid-shelf (*Hedbergella lehmanni*, "Zone à grandes Globigérines"); Askouti section.