

RUDIST DISTRIBUTION IN THE LOWER APTIAN SHALLOW PLATFORM OF LA MOLA DE XERT, EASTERN IBERIAN RANGE, NE SPAIN

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ABSTRACT

La Mola de Xert is a small well exposed carbonate platform that developed during the early Aptian in the eastern Iberian basin, Spain. Its geometry and development in a rift context are briefly reviewed and the palaeoecological distribution of the megafauna (mainly rudists) is described.

Platform growth took place in two major phases giving rise to an orbitolinic lime-mud rich ramp (= lower platform, early high-stand system tract) and a rimmed platform with calcarenite bank margin facies (including small coral reefs) and lagoonal facies dominated by rudists (= upper platform, late high-stand system tract). The lagoonal sediments can be divided into five shallowing-up cycles (parasequences). The faunal distribution of orbitolinids, rudists and corals within each parasequence reflects a second but weakly developed small scale cyclic pattern.

Rudists and associated fauna, such as *Chondrodonta* and nerineid gastropods, are restricted to the upper platform. Caprinids occur mainly in the coral reef facies while the lagoon was inhabited by species of *Requienia*, *Toucasia*, *Horiopleura*, and rarely *Monopleura*. Only once the environmental situation favoured the growth of *Horiopleura* and *Monopleura* in small bouquets.

Key words: lower Aptian, Mola de Xert, Rudists, paleoecology, lower platform, upper platform, parasequences.

RESUMEN

La Mola de Xert es una pequeña plataforma carbonatada bien expuesta que se desarrolló durante el Aptiano temprano en la cuenca ibérica oriental. Su geometría y desarrollo dentro de un contexto de fosa tectónica extensional (rift) se reseña brevemente y se describe la distribución paleoecológica de la megafauna (principalmente rudistas).

El crecimiento de la plataforma tuvo lugar en dos fases mayores dando lugar a una rampa rica en lodos calcáreos orbitolínidos (plataforma inferior) (early high-stand system tract) y un borde de plataforma formada por bancos de calcarenita de facies marginales (incluyendo arrecifes coralinos pequeños) y facies lagunares dominadas por rudistas (plataforma superior) (late high-stand system tract). Los sedimentos lagunares se dividen en cinco ciclos de disminución gradual de la profundidad (shallowing-up cycles) (parasecuencias). La distribución de orbitolínidos, rudistas y corales dentro de cada parasecuencia refleja el desarrollo débil de un segundo modelo cíclico pequeño.

Los rudistas y su fauna asociada como *Chondrodonta* y gasterópodos nerineidos, se restringen a la plataforma superior. Los caprinidos se presentan principalmente en las facies de arrecifes coralinos, mientras que las facies lagunares están ocupadas por *Requienia*, *Toucasia*, *Horiopleura* y raramente por *Monopleura*. Solamente una vez las condiciones ambientales permitieron el desarrollo de pequeños "bouquets" de *Horiopleura* y *Monopleura*.

Palabras clave: Aptiano inferior, Mola de Xert, Rudistas, paleoecología, plataforma inferior, plataforma superior, parasecuencias.

INTRODUCTION

During the Early Cretaceous, the so-called Urgonian carbonate platforms were extensively developed on the eastern margin of the Iberian Plate and especially in the Maestrat basin. Urgonian carbonate platforms are a typical feature of the Mesogean Sea (Masse, 1992) and their facies have already been described in the classic studies on the stratigraphy of eastern Iberia (Bataller, 1962; Fallot and Bataller, 1927; Hahne, 1930; Canérot, 1974).

From the lithostratigraphic point of view, the "Urgonian facies" corresponds to different units with rudists, which were deposited during the late Berriasian to the late Aptian time interval. The major regional development of such rudist facies is observed in the lower part of the Villarroya Formation, which is early Aptian in age (Canérot *et al.*, 1982).

Despite of the long time that this facies had been known, only few studies exist on the sedimentology and paleoecology of these rudist-rich platforms. More recently, sedimentological studies concerning the platform modelling have been carried out by Esteban (1973), Salas (1984, 1987, 1994), and Soria and others (1994).

This paper presents a preliminary analysis of the rudist distribution in the upper shallow platform facies of La Mola de Xert carbonate platform (lower Aptian) of the Maestrat basin (Iberian basin).

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GEOLOGICAL AND STRATIGRAPHICAL SETTING

The study area is located at the intersection of the easternmost part of the Iberian Range and the southern Catalan Ranges (Figure 1). The area forms part of the intercratonic Iberian basin (Iberian Range, Ebro Basin and Catalan Range *sensu* Salas) in the northeast of the Iberian Peninsula, which developed mainly during Mesozoic times. The basin was predominantly filled with marine shallow water carbonates deposited in an epeiric sea with minor amounts of siliciclastic material sedimented in marginal areas (up to 6,500 m).

The integration of basin fill data, subsidence analysis, sequence stratigraphy, and the intra-Mesozoic tectonic structures observed in the field allows the distinction of four successive evolutionary stages of the basins in the eastern margin of Iberia during the Mesozoic extensional phase: (1) Triassic rift; (2) Early and Middle Jurassic postrift; (3) Late Jurassic and Early Cretaceous rift; and (4) Late Cretaceous postrift (Salas and Casas, 1993; Roca *et al.*, 1994). The La Mola de Xert platform developed during the early Aptian within the Late Jurassic and Early Cretaceous rift phase.

Structurally, the rift was characterized by the development of a system of extensional listric faults detached in a shallow upper crustal level (1.7 - 2.2 km). In this tectonic setting, thick platform carbonates (up to 800 m) were deposited during the lower Aptian depositional sequence. In this rift context the general facies model shows some variations related to local tectonic subsidence and substratum paleotopography which controlled depositional rates, amount of mud supported/grain supported facies and progradation geometries (Salas, 1994).

PLATFORM MODEL

La Mola de Xert is a small (4-6 km) isolated platform and corresponds to the high-stand system tract of the lower Aptian depositional sequence in the Xert area. This platform is characterized by two successive stages of development. The first stage consists of what we term the lower platform (Figure 2), which corresponds to the early high-stand system tract of the lower Aptian sequence and is formed by an orbitolinic lime-mud rich ramp with a moderate development. The second stage displays a significant development and is formed by what we term the upper platform (Figure 2) which corresponds to the late high-stand system tract of the lower Aptian depositional sequence.

The late high-stand system tract is a rimmed platform with a high progradational rate. This platform is characterized by a progradational pattern with downstepping foreslopes. These downward shifts of the shelf break indicate relative falls of the sea level (Figure 3). Northern margins have ramp-like foreslopes, which display low to moderate angles (5 - 20°) with sigmoidal to oblique tangential progradation. Western margins are characterized by a progradation pattern in foreslopes rang-

ing from 10 to 20° with sigmoidal to oblique tangential progradation as well.

The basic depositional model of the late high-stand system tract platform is a sigmoid-shaped unit (Figure 4). This is composed of horizontal rudist lagoon facies passing seaward to a calcarenite bank margin facies with a sigmoidal shape that may contain coral reefs, then to talus-slope clinobeds and to horizontal deeper platform (shallow basin) facies. This elemental unit is bounded by interruptions or erosion surfaces (Figures 5, 6) and their correlative conformities basinward. The stacking pattern of sigmoid units gives rise to the progradational configuration shown in Figure 3.

Shallow platform facies (lagoon) is composed of metric shallowing-upward parasequences (Figure 6) which are bounded by marine flooding surfaces and comprise two units (up to 20 m). The basal unit is generally thin and consists of nodular orbitolinic wackestones which record the initial transgression over the preexisting deposits. This basal unit corresponds to the higher energy deposit of the lagoon facies. The upper part of the parasequence consists of rudist skeletal wackestones-packstones which may also contain chondrodonts, nerineids and corals. These rudist facies pass laterally to the bank margin and to deeper facies seaward.

UPPER PLATFORM

Sediments of the upper platform are best exposed in two quarries located at the SE rim of La Mola de Xert (sections I and III in Figures 3, 5 and Plate 1, figures 1, 3). The two sections belong to different stratigraphic levels of the platform sediments. The geographically intermediate section II (Plate 1, figure 2), however, represents the most complete succession. Although faunistic and sedimentological details were difficult to trace in section II, they allowed to estimate the total thickness of the sediments that crop out (about 70 m) as well as to correlate the two quarry sections and to distinguish five parasequences (already mentioned above).

A complete parasequence is supposed to consist of three units, (i) orbitolinid-rich nodular marls, (ii) variable lagoonal rudist limestones and marls, and (iii) *Toucasia* dominated marls. The basal orbitolinid accumulations may be substituted by predominant bundles of pressure solution structures (*e.g.*, horse tail, clay seams, stylolites) which remain consistent over larger distances of the quarry outcrops. The *Toucasia* shell beds at the top of the parasequences are often compacted and accompanied by a concentration of pressure solution structures.

The first parasequence was additionally divided into three bedsets (1.1 to 1.3 in Figures 5, 6), each about five to seven m thick, using prominent diagenetic discontinuities. As can be seen in the lower quarry, each bedset consists of a number of smaller beds of variable thickness (decimeters to meters).

Variations within each parasequence are described on the basis of their faunal content, distribution of the fauna

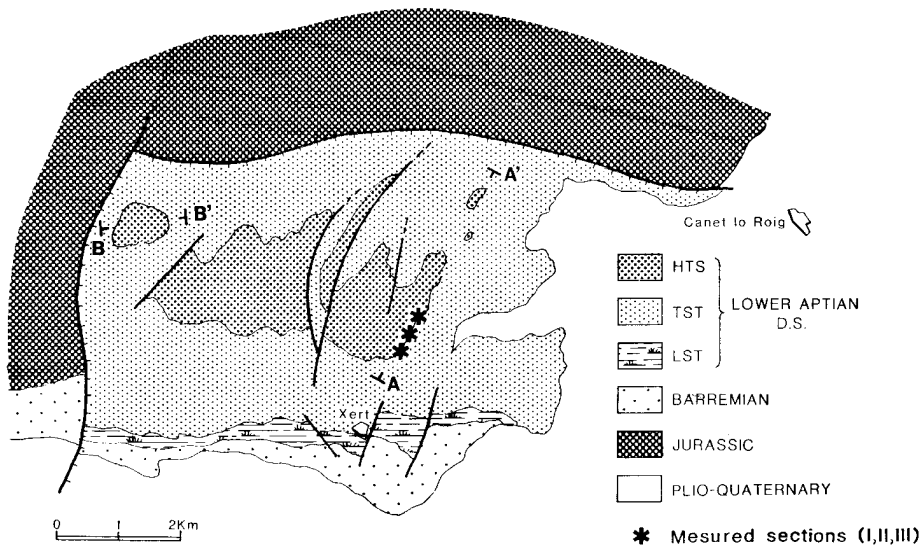
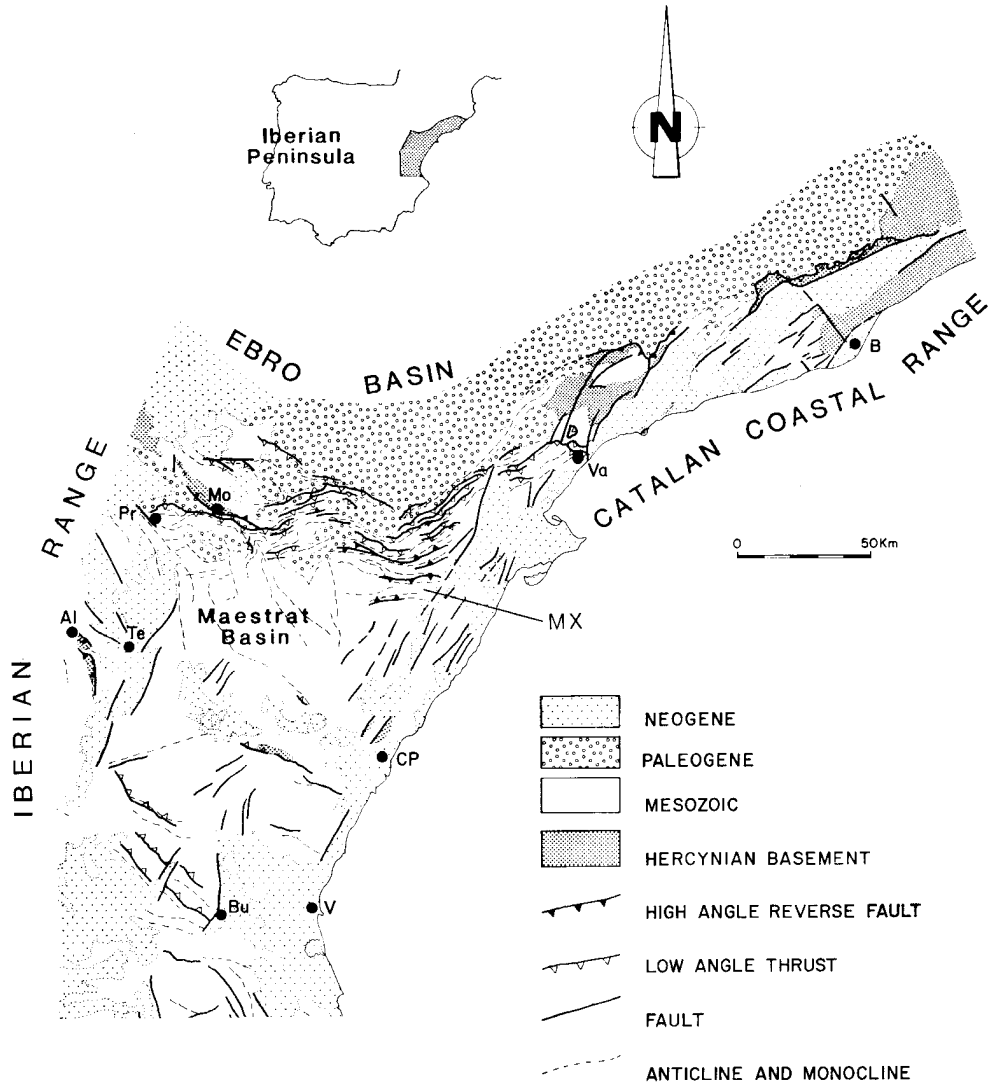


Figure 1. Above, simplified geological map of the region studied; MX, La Mola de Xert; Al, Albarracín; B, Barcelona; Bu, Buñol; CP, Castelló de la Plana; Mo, Montalbán; Pr, Portafrubio; V, València; Va, Vandellós (modified from Guimerà and Alvaro, 1990). Below, Sequence stratigraphy map of La Mola de Xert, lower Aptian sequence.

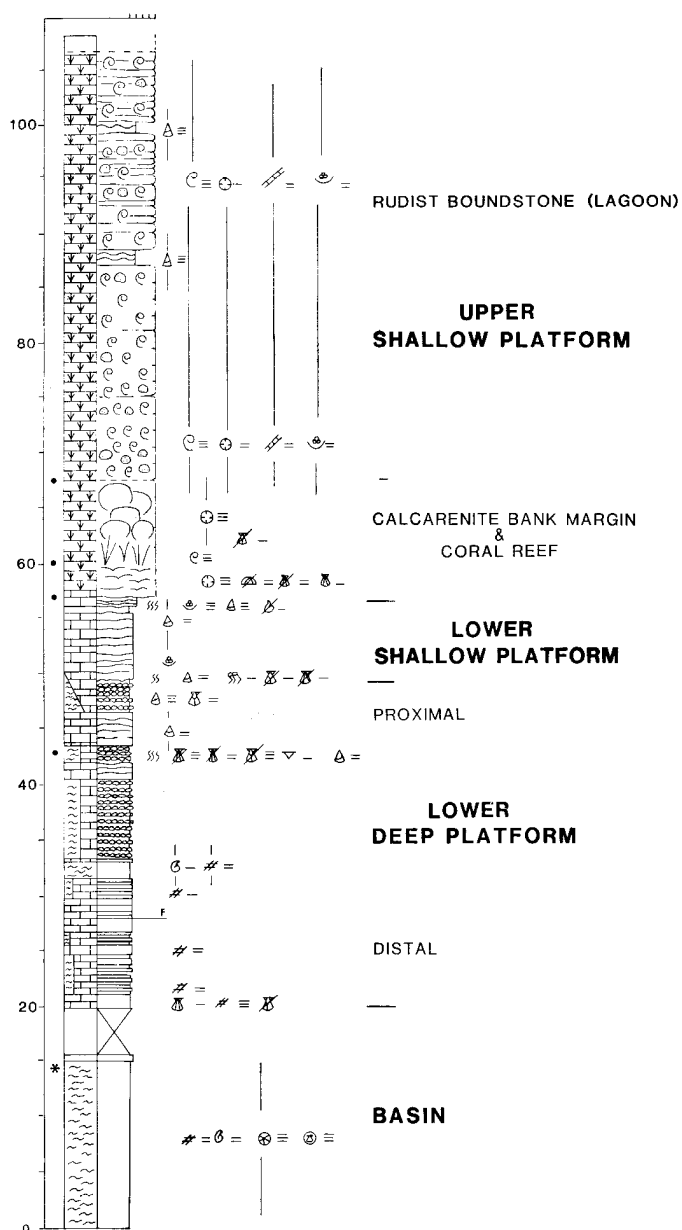


Figure 2. Stratigraphic section of the high-stand system tract. The lower platform is formed by an orbitolinic lime-mud rich ramp and corresponds to the early high-stand system tract. The upper platform is an isolated rimmed platform and corresponds to the late high-stand system tract. Different facies are also indicated.

within each layer, the ratio of fauna to sediment, and on the preservational state of the shells (complete, fragmentary, life position). (The descriptions are based on field observations; a detailed quantitative analysis is in process).

FAUNAL DISTRIBUTION AND VERTICAL DEVELOPMENT OF THE LAGOON FACIES

The top of the nodular marlstones of the lower platform holds a quite abundant fauna of *Panopea*-like heterodont bivalves, pectinids, oysters (pyncnodontids, *Rastellum*), brachiopods, cidaroid and spatangoid echinoids (Plate 1, figure 6, Plate 2, figures 5, 6) and orbitolinids.

The bank margin calcarenites may contain abundant orbitolinids at the base and corals in the upper part.

Coral reef structures show a characteristic zonation from base to top with planar, branching and massive corals indicating increasing energy (Figures 2, 4; examples in Plate 2, figures 2-4). The reef sediment consists of rudstones with numerous rudist (requienids, caprotinids, and caprinids) and chondrodont shell fragments (Plate 2, figure 1).

The megafauna of the lagoon includes the same forms all along the succession. It is dominated by rudist bivalves, mainly *Requienia*, *Toucasia* and *Horiopleura*; other bivalves are represented exclusively by *Chondrodonta*. Nerineid gastropods—*Diptyxis luttickei* (Blanckenhorn, 1890), *Multiplyxis prefluriani* Delpy, 1940, *Aptyxiella libanotica* Delpy, 1940, *Microschyza* (determinations by G. Sirna)—occur in some horizons. Fragments of corals (mostly microsolenid) occur throughout the composite section but in some horizons they are more abundant than in others.

Bedset 1.1 of parasequence 1 is characterized by a high sediment/organism ratio. Organisms are mostly fragmentary (Plate 4, figure 3). Besides the rudist groups already mentioned the bedset contains some caprinid fragments, branching corals and a horizon with nerineid gastropods. Bedset 1.2 starts with layers of nearly exclusively *Requienia* followed by patchy distributions of *Horiopleura*, *Toucasia*, *Requienia*, *Chondrodonta*, and in the upper part with nerineids. In contrast to bedset 1.1 fossils are mostly complete. The succession of bedset 1.3 contains larger fragments of massive corals and few nerineids among the rudist fragments. The organism/sediment ratio continuously changes from low to high until it becomes dominated by aggregates of *Horiopleura* and occasionally *Monopleura* (both in life position). The bedset ends with a *Toucasia* shell layer (Plate 3, figure 5).

The main body of parasequence 2 is formed by a monotonous sequence of *Requienia* limestones. This is underlain by a mixture zone with fragments of various rudist groups and *Chondrodonta* (also orbitolinid marls in section II) and topped by a *Toucasia* marly layer (Figures 5, 6).

Parasequence 3 begins with orbitolinid nodular marls (only in section II). In section III it is composed of layers of complete shells and fragments of rudists and *Chondrodonta*; levels with few fauna, small requienids, and mixed fauna which alternate non-cyclically; a band of *Chondrodonta* in upright position of about 15-20 cm thick and horizontally continuous for several tens of meters (Plate 3, figures 1-3). A sediment-rich layer dominated by *Toucasia* forms the top.

A nearly 2 m thick orbitolinid nodular marlstone forms the base of parasequence 4 (Plate 1, figure 4). The succession continues with a mixed-rudist horizon; a sediment-rich shell layer with coral fragments; a mixed layer dense in small rudist fragments and *Chondrodonta*; a sediment-rich layer with abundant small shell fragments and few large broken *Toucasia* specimens; a dense mixed accumulation with complete and fragmentary specimens, at the base dominated by *Toucasia* and

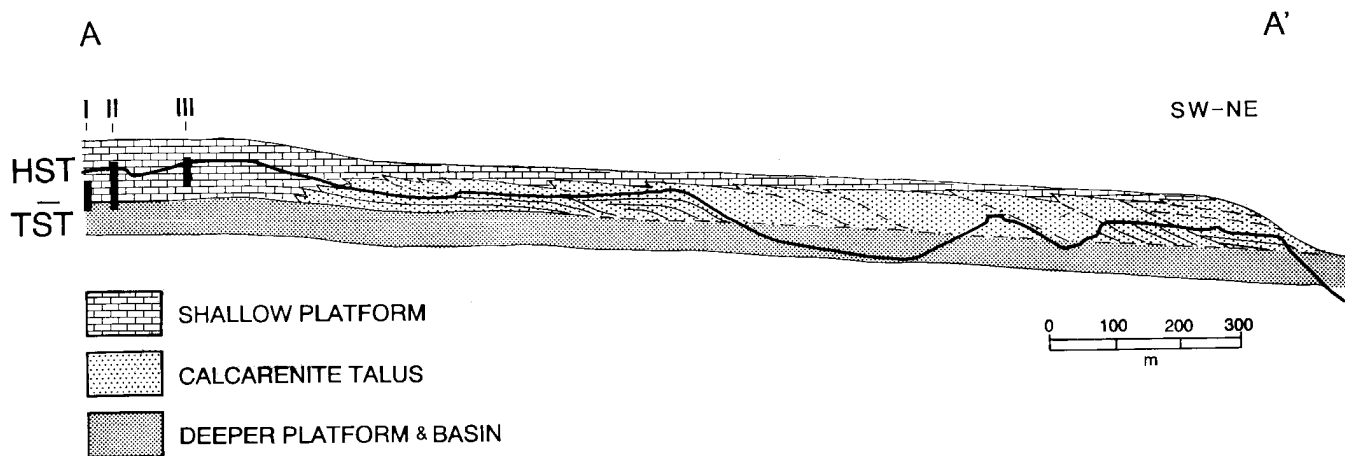


Figure 3. Balanced cross-section of the La Mola de Xert corresponding to northern margin. The high-stand system tract displays sigmoidal progradation.

the rest dominated by *Horiopleura*. This layer contains a horizon with nerineids. The top is a compacted marly limestone with many *Toucasia* and other rudist fragments crossed by bundles of stylolites (Plate 1, figures 3-5; Plate 4, figure 1).

Parasequence 5 contains, from base to top, a layer of many small rudist shell fragments; a sediment-rich layer with large *Toucasia* and coral fragments (the latter often more than 20 cm in size); a mixture-zone of rudist shell fragments with abundant small coral fragments; a *Toucasia* layer with stylolites (and much sediment); a layer with small shell fragments again including small corals which grades into a sediment-rich mixture of very small fragments; a mixed layer dominated by *Toucasia* and *Horiopleura* sandwiched between a sediment-dominated marl with only small shell fragments. The very top of the outcrop contains a level with solitary *Horiopleura* mostly in life position which is overlain by another mixed layer with shell fragments (Plate 3, figure 4).

DISCUSSION AND CONCLUSIONS

Some general considerations about the sedimentary record, faunal distribution and cyclicity arise from our observations.

SEDIMENTARY RECORD

As reflected by the balanced geometrical cross-section (Figure 3), the described sediments form only the lower part of the originally deposited lagoon sediments.

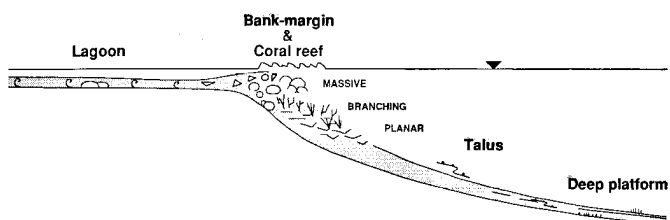


Figure 4. Basic depositional model of the late high-stand system tract.

Of the five parasequences distinguished only the first one appears to be well developed and shows the highest accommodation rate.

FAUNAL DISTRIBUTION

During most of the time, the upper platform was inhabited by solitarily growing rudists with much space and sediment among them. Only once the conditions favoured growth of several generations of rudists forming bouquets, suggesting a time with relatively high sedimentation rate.

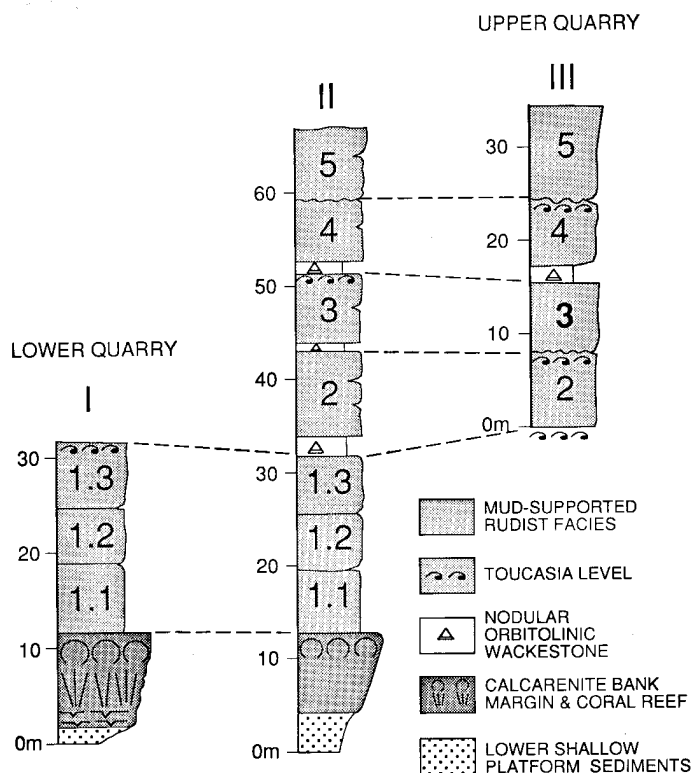


Figure 5. Correlation among the three sections of the upper shallow platform measured at La Mola de Xert. Highly schematic. 1 to 5: parasequences as described in the text; 1.1 to 1.3: bedsets of lagoonal sediments of parasequence 1 overlying the calcarenite bank margin and coral reef.

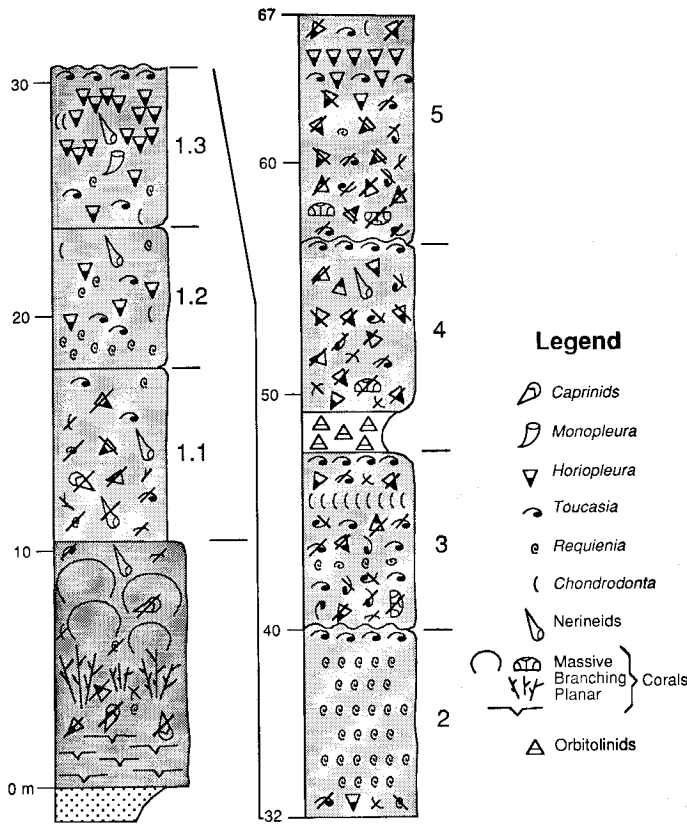


Figure 6. Composite section of the upper shallow platform of La Mola de Xert schematically indicating the faunal distribution within each parasequence. 1 to 5: as in Figure 5.

Corals mainly occur at the bank margin, where they occasionally built small reefs; the vertical succession of coral types indicates increasing energy. In the lagoonal sediments corals are only present as fragments of various sizes near the base of parasequences (except for the second). In bedset 1.1 the branching type predominates, at the other sites massive types (mostly microsolenids).

Nerineid gastropods show an unusual low abundance compared to other Lower Cretaceous rudist environments. They have only been found in two horizons, within bedset 1.1 and near the top of parasequence 4.

Chondrodonts are abundant throughout the section but only in two occasions—near the top of parasequence 1 (bedset 1.3) and near the top of parasequence 3—they form larger aggregates in upright positions.

Requienia is present throughout the section but predominant only at the base of bedset 1.2, in parasequence 2, and in parasequence 3 near the base.

Toucasia is also found throughout the sequence but marly beds with almost exclusively *Toucasia* developed at the top of parasequences.

Although isolated specimens of *Horiopleura* are frequent in the lagoon sediments, well developed bouquets of *Horiopleura* only occur at bed set 1.3 and poorly developed ones at the upper part of parasequence 5.

Monopleura is restricted to bedset 1.3 where it forms bouquets as *Horiopleura*.

Caprinids are restricted to the coral reef and to bedset 1.1 directly above.

CYCLICITY

Cyclicity within the sediments was observed at two different scales: one that allowed to distinguish five parasequences and, within them, the other reflected by the pattern of the faunal distribution. Ideally, a complete smaller scale cycle is composed of (from base to top):

- A nodular marly wackestone with orbitolinids.
- A mixture zone of shell fragments in which also corals occur.
- A mixture zone of complete shells without corals.
- A zone predominated by *Requienia*.
- A zone of constructing *Horiopleura* (and *Monopleura*).
- A mixture zone of shell fragments.
- A zone with predominance of *Toucasia*.

However, interruption and repetition of cycles or parts of them occurred throughout at any stage, showing that the production of the cycles was not a straightforward process.

The distribution patterns of chondrodonts and nerineids do not show any cyclicity.

The cycles are generally cut off by higher energetic (?lag) deposits of orbitolinid marly wackestones which represent the basal part of the next parasequential cycle.

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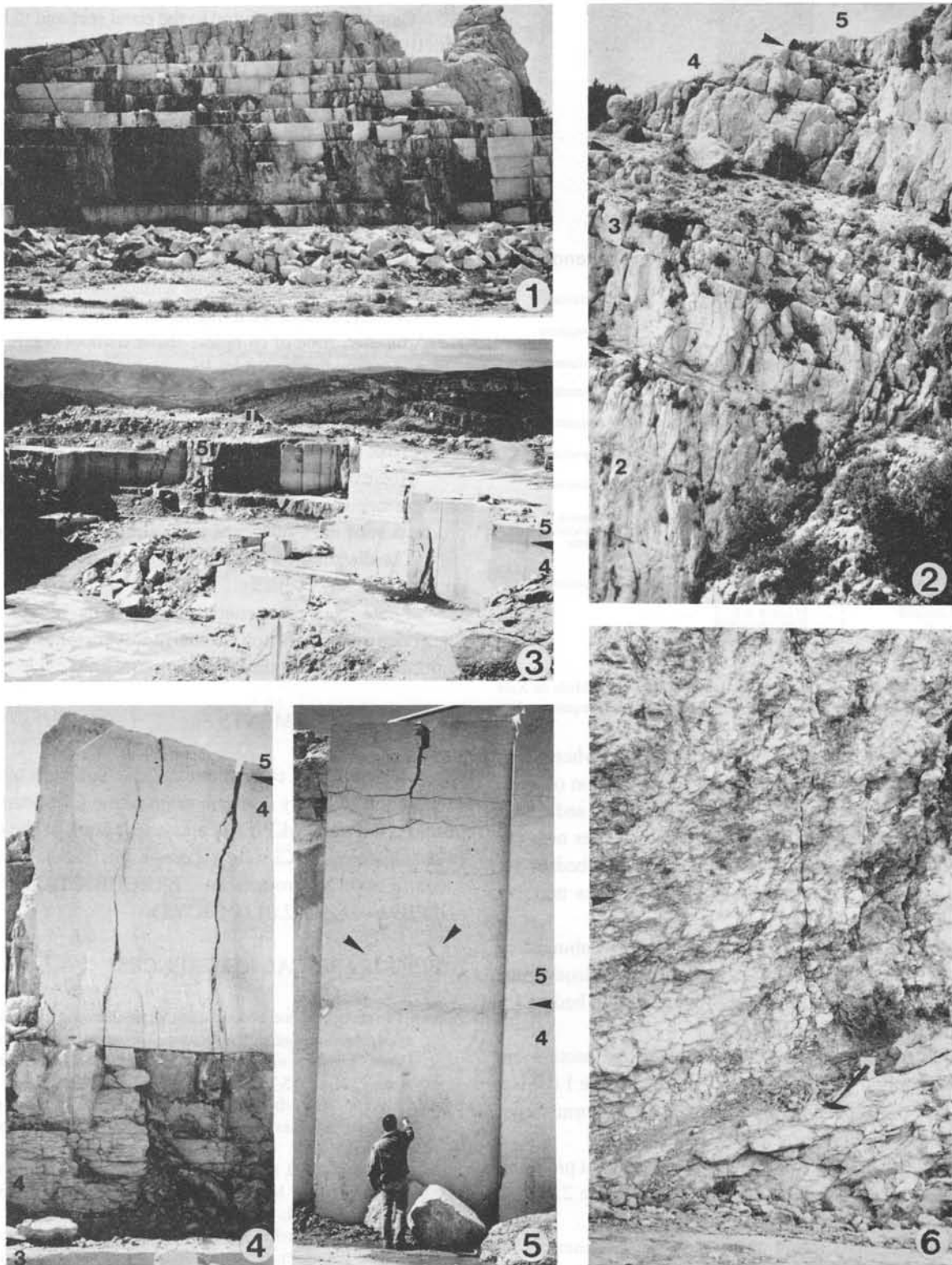


Plate I. Figure 1—The lower quarry at La Mola de Xert, where section I was measured. Bedding, visible at the upper part, cuts quarry step surfaces at an angle of about 20 degrees. Height of quarry steps between 1.10 and 1.40 m. Figure 2—Section II at La Mola de Xert. Parasequences numbered 2 to 5 appear from bottom to top; arrows point at parasequence boundaries. Figure 3—The upper quarry at La Mola de Xert, where section III was measured. Boundaries between parasequences 3 and 4 and between parasequences 4 and 5 are clearly visible and have been indicated by arrows (compare figures 4 and 5). Figure 4—The orbitolinid marlstone bed of the base of parasequence 4 and the boundary between parasequences 4 and 5 (upper quarry, section III); scale measures 1.50 m. Figure 5—Boundary between parasequences 4 and 5 (upper quarry, section III, see detail in Plate 4, figure 1). Arrows point at coral fragments. Figure 6. Base of section I. Bottom: lower shallow platform marls with abundant megafauna; top: coral buildup.

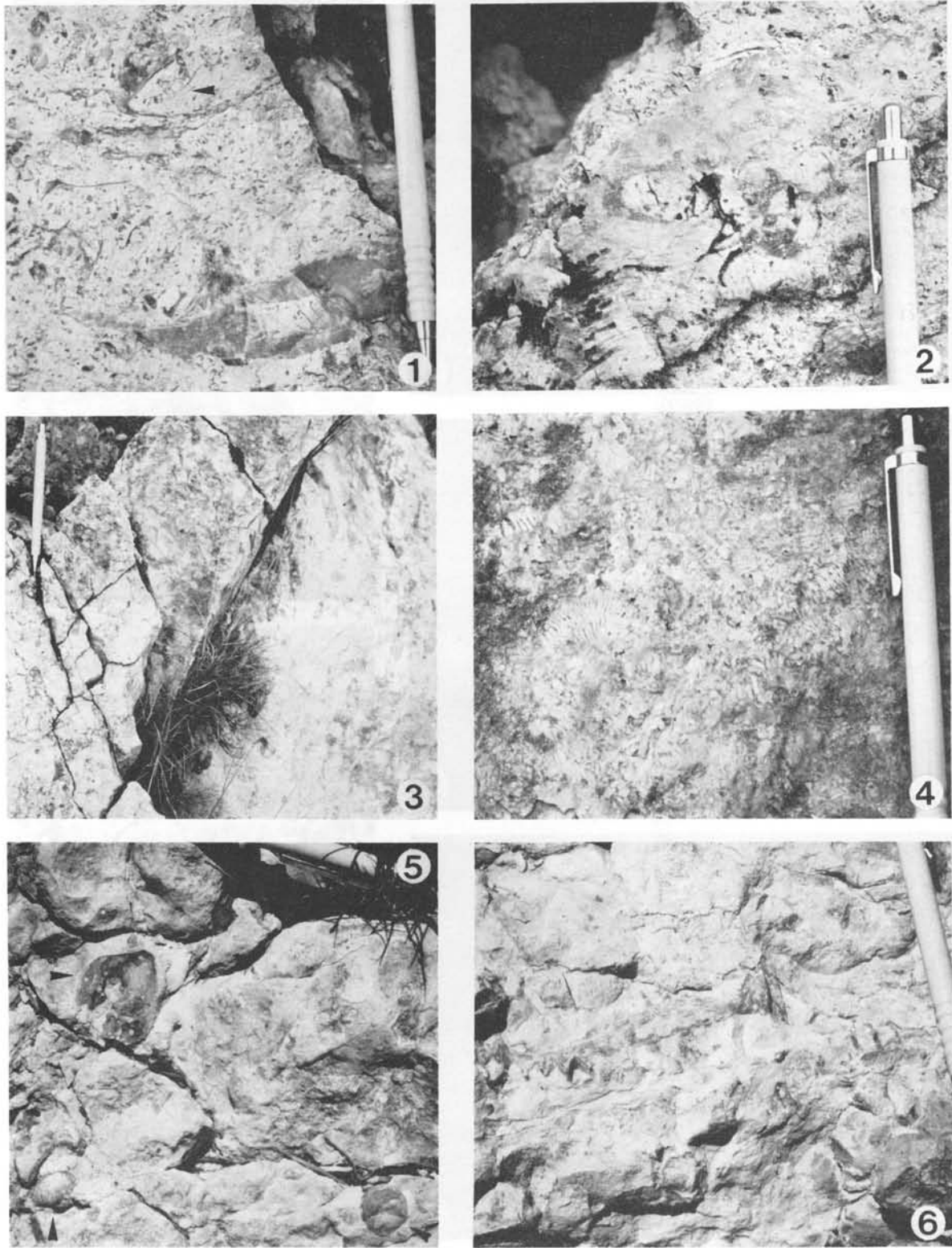


Plate 2. Figures 1-4—Coral reef of the bank margin below parasequence 1 (section I). 1, Interstitial space infillings of the reef, arrow points at a caprinid fragment, a large coral fragment appears at the bottom; 2, microsolenid type massive coral; 3, branching corals; 4, meandroid massive coral. Figures 5, 6—Fauna from the marls of the lower shallow platform (base of section II); 5, a terebratulid brachiopod (upper left), a pycnodontid oyster (lower left) and a spatangoid echinoid (lower right), diameter of echinoid about 1.5 cm; 6, *Rastellum* sp., visible part of specimen measures 10 cm.

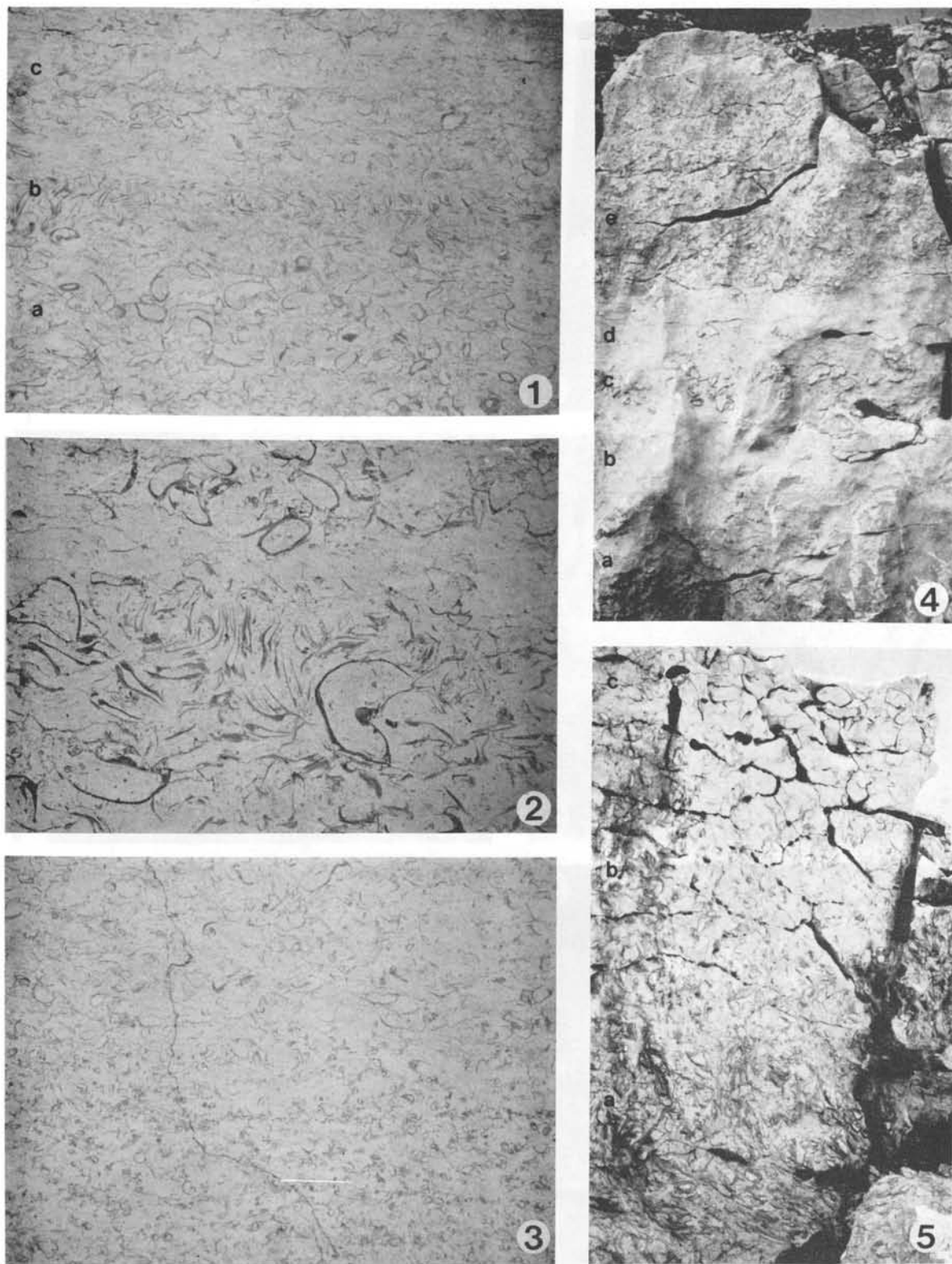


Plate 3. Figures 1-3—Details of vertical sections of parasequence 3 (upper quarry, section III). 1, From base to top, a: mixed layer of big shell fragments, mainly of *Toucasia*; b: band of *Chondrodonta* in upright position; c: sediment rich mixed layer of small shell fragments; total height 80 cm. 2, Closeup of the level with *Chondrodonta*, total height 40 cm; 3, vertical change from a level with small *Requienia* stylolites frequent, to a mixed layer with fragments of diverse fauna, total height 80 cm. Figure 4—Top layers of parasequence 5; a: mixed layer of shell fragments, b: sediment dominated marl with only small fragments, c: large fragments of *Toucasia* and *Horiopleura*, d: same as b, e: layer with *Horiopleura* mostly in life position. Figure 5—Upper part of parasequence 1 (lower quarry, section I); a: upright *Horiopleura*, b: fragments mainly of *Horiopleura*, c: *Toucasia* layer.

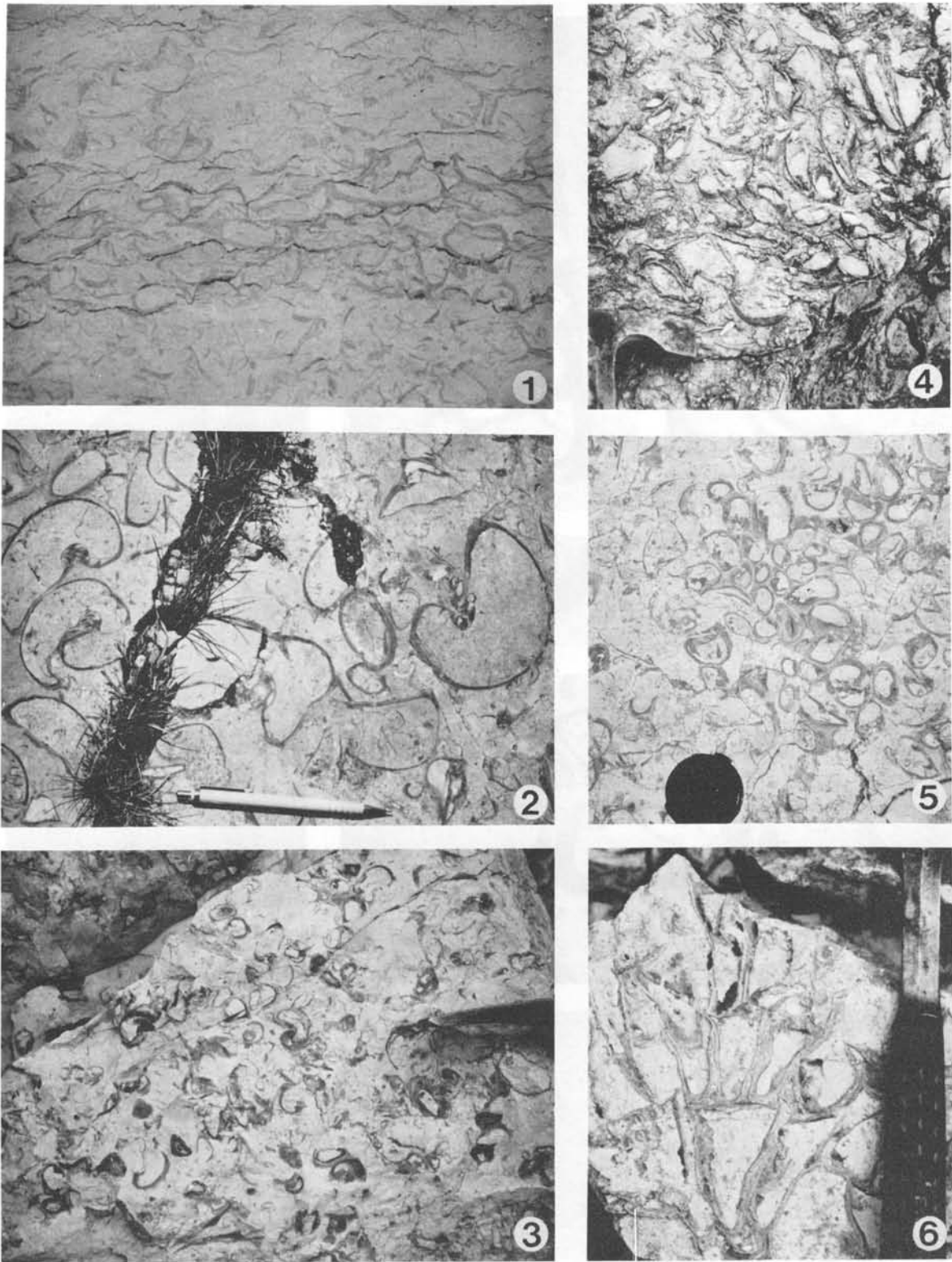


Plate 4. Figure 1—Vertical section of the *Toucasia* level from the top of parasequence 4, upper quarry, section III, total height 40 cm (detail from Plate 1, fig. 5). Figure 2—Horizontal section of the *Toucasia* level from the top of parasequence 1; lower quarry, section I. Figure 3—Mixed layer with requienids, caprotinids and *Chondrodonta* from the lower lagoonal part of parasequence 1 (bed set 1.1, lower quarry, section I). Figures 4-6—Fauna from the upper part of parasequence 1 (bed set 1.3, lower quarry, section I). 4, *Monopleura* sp.; 5, horizontal section of a *Horiopleura* bouquet; 6, vertical section of a bouquet with three generations of *Horiopleura*.

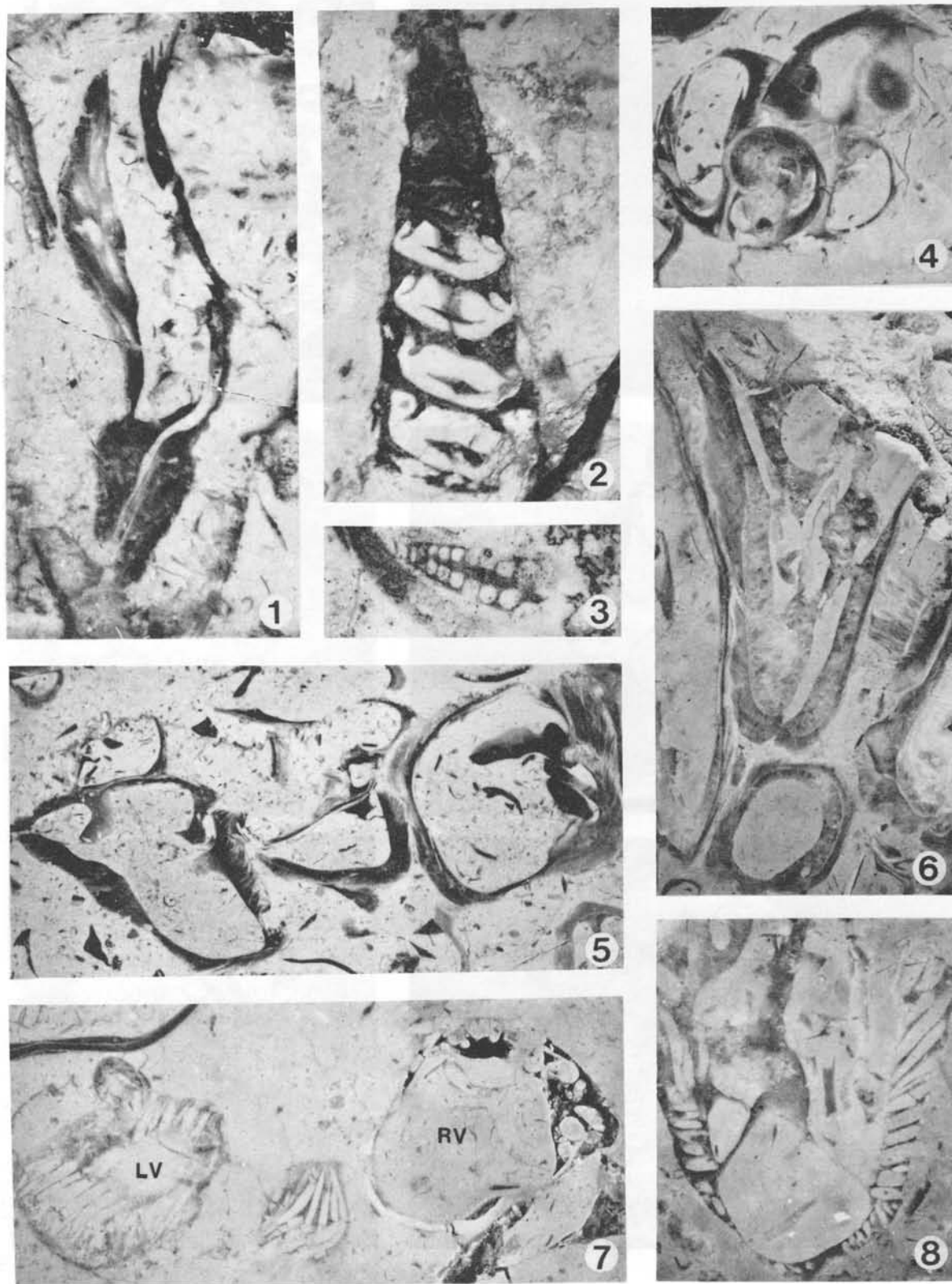


Plate 5. Figures 1-6—Fauna from the parasequence 1, lower quarry, section I. 1, *Chondrodonta* sp.; 2, *Diptyxis luttickei* (Blanckenhorn); 3, *Aptyxiella libanotica* Delpy; 4, *Requienia* sp.; 5, *Horiopleura* sp., from right to left, vertical, oblique and transversal sections; 6, *Horiopleura* sp., vertical section. Figure 7—Caprinid, sections of left and right valves (LV and RV); bed set 1.1, lower quarry, section I. Figure 8—Caprinid, transversal section of left valve; coral reef, lower quarry, section I.

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