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THE LIASSIC "LITHIOTIS" FACIES NORTH OF VÉLEZ RUBIO (SUBBETIC ZONE)

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RESUMEN

El estudio de las facies y secuencias reconocidas en las calizas de "Lithiotis" del Lías subbético al norte de Vélez Rubio, permite proponer un modelo sedimentario según el cual estas calizas se interpretan como depósitos de un banco carbonatado marino somero, que se encontraba separado de la plataforma adyacente al continente por una franja más profunda con depósitos hemipelágicos. Se han reconocido dos tipos básicos de secuencias elementales, ambos somerizantes, y se llama la atención sobre la analogía existente entre las facies y secuencias de "Lithiotis" y las facies de rudistas del Cretácico inferior. Desde el punto de vista paleogeográfico estas facies tienen gran interés ya que definen un área o dominio, que comprende la parte más meridional del Subbético Medio y el Subbético Interno, en este sector de la Cordillera.

Palabras clave: "Lithiotis", Lías inferior y medio, Paleoecología, Subbético, secuencias somerizantes, rudistas.

ABSTRACT

The study of facies and sequences of the "Lithiotis" limestones of the Subbetic Liassic outcropping North of Vélez Rubio allows us to propose that they were deposited in a shallow marine carbonate bank which was isolated from the South-Iberian continental margin by a deeper seaway with hemipelagic facies. Two basic types of shallowing upward elemental sequences have been distinguished. A strong ressemblance between the "Lithiotis" lime stones and the Lower Cretaceous rudist limestones is also suggested. The widespread regional distribution of these facies allows to distinguish this Eastern Betic area, during Lower to Middle Liassic times, as an independent paleogeographic realm, including the southern part of the Median Subbetic and the Internal Subbetic.

Key words: "Lithiotis", Lower and Middle Liassic, Paleoecology, Subbetic, shallowing-upward sequences, rudists.

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1. INTRODUCTION

The occasional presence of facies formed by accumulations of bivalves, ussually known as "Lithiotis" facies, is a relatively constant feature of the shallow-water carbonate deposits which make up the Lower Liassic in the External Zones of the Betic Cordillera (Azéma *et al.*, 1979; García-Hernández *et al.*, 1979a,b). These accumulations are especially characteristic of the beds situated inmediately below the discontinuity that was brought about by the disintegration of the platform during the Middle Liassic and the substitution of shallow facies by ammonite-rich hemipelagic sediments.

In the Subbetic series of the central sector, the "Lithiotis" limestone beds are usually between 10 cm and 1 metre thick and are generally some ten metres long (Martínez-Garrido, 1988). They appear closely related to other shallow carbonate platform facies and together constitute characteristic sequences. In the eastern part of the Subbetic Zone, to the North of Vélez Rubio

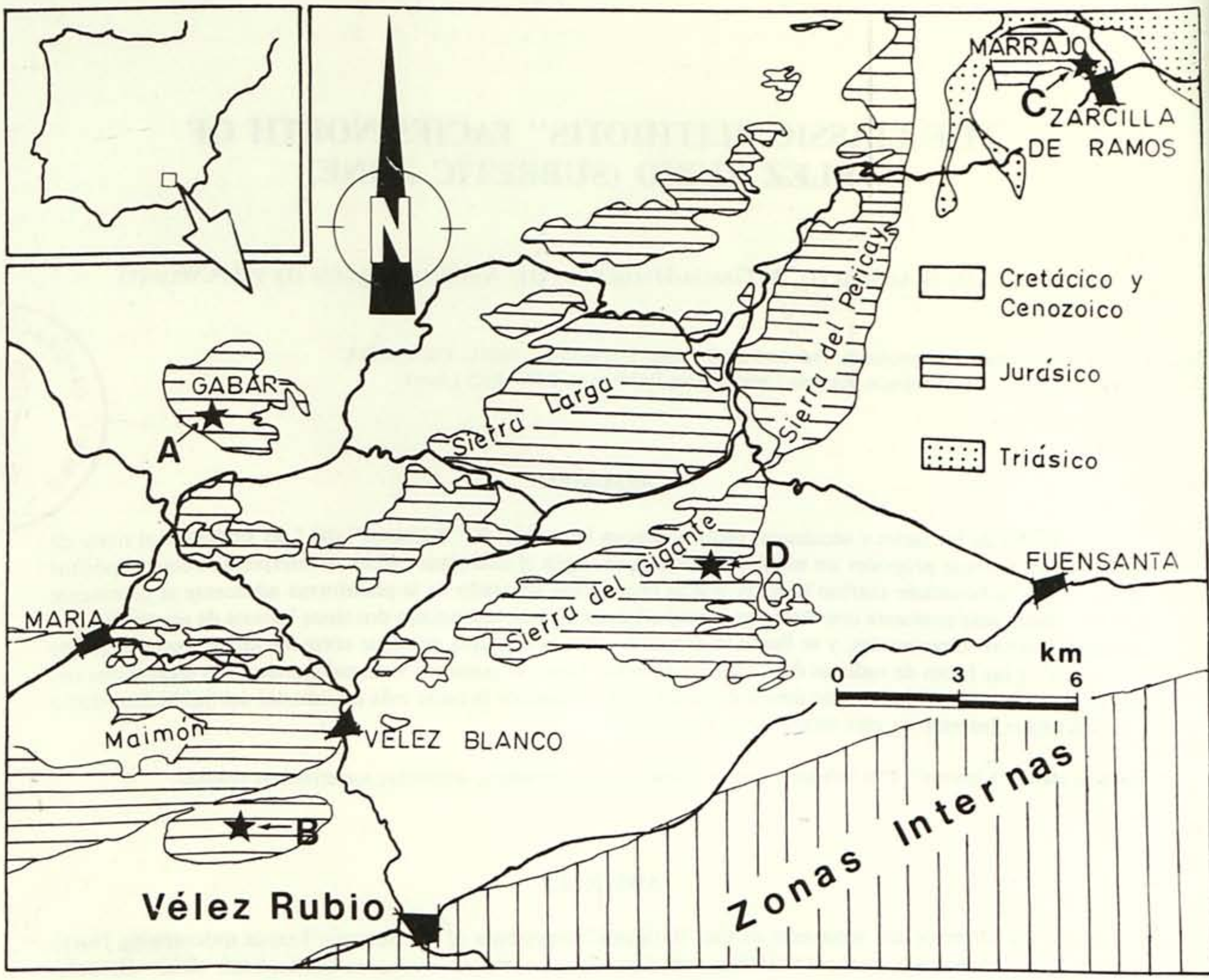


Fig. 1.-Geologic sketch map of the Vélez Rubio and Zarcilla de Ramos region, and position of studied outcrops.
Fig. 1.-Esquema geológico de la región comprendida entre Vélez Rubio y Zarcilla de Ramos y situación de los afloramientos estudiados.

(Fig. 1) the ''Lithiotis'' facies are quite highly developed, far more than their equivalents found in the central sector: to such and extent, indeed, that a tens to hundreds of metres thick lithologic unit some tens of kilometres long, made up mainly of this kind of facies, can be mapped in this area (Fig. 2). In this unit different facies associations are present; these form characteristic sequences according to the texture, type of organisms involved and their position with reference to the stratification surface.

The aims of the present study are the following: to make known the facies associations and sequences which are present; to propose a preliminary interpretative sedimentary model and, finally, to draw attention to the significant convergence of this type of facies and sequences, and of the model thus produced, with facies related to another type of bivalves which are strinkingly similar to the ''Lithiotis'' found in the Subbetic Liassic and which occupied similar ecological niches in comparable and better-know sedimentary environments at other moments in geological history, as in the case of the Cretaceous rudists.

2. PREVIOUS RESEARCH

The considerable extent of the ''Lithiotis'' facies in the Subbetic region between Vélez Rubio and Zarcilla de Ramos has already been recognized by other researchers, and the presence of ''large lamellibranchs'' has been noted by several specialists. However, to our knowledge, a detailed study of these organisms or of the sediments in which they are embedded has not been yet carried out.

As early as 1945, Fallot noted the presence of pinkish limestones with very large lamellibranch sections in the Maimon Liassic (Fallot 1945, p.366, fig.193); he also recorded ''large pelecipods'' to the NW of Zarcilla de Ramos (Marrajo) in materials which he attributed to the Middle Liassic (p.322, fig. 130); in this latter area, Baena (1972) also made the same observation.

Geel (1973, p.80 and fig.19) founds beds of limestones "crowded with predominantly subparallel, strongly recrystallized shell remains" within the upper half of the lower calcilulite member of her "Maimón Formation". This member was later included in the Gavilán Formation by De Clerq *et al.* (1975): near the top of this formation, in other areas outside the Sierra del Maimón sector, these authors noted "levels full of indeterminable molluscs".

Turnsek *et al.* (1975) pointed out the presence of biostromes of "Megalodontid" and "Lithiotid" lamellibranchs in the Marrajo. And in his monographic study of the "Lithiotis" facies in the Liassic Tethysian platform, Geyer (1977) mentioned this locality among those Spanish regions where this type of organisms was to be found.

Seyfried (1978) described *Lithiotis* and *Opisoma biostromes in the Middle Liassic of several Sierras in the Eastern Subbetic: Ricote (p.73), Lavia (p.77), Gigante (p.83) and Marrajo (p.84). In his facies map of the Lower Liassic (fig.26, p.134) he establishes the limits of a domain of Lithiotis* and *Opisoma* biostromes which aproximately coincides with the southernmost part of the Middle Subbetic and the northernmost outcrops of the Internal Subbetic (García-Hernández *et al.*, 1980). When studying the "tidal limestones" of the Middle Liassic of the Eastern Betic Cordillera, this same author (Seyfried, 1979) makes reference to *Lithiotis* and/or *Opisoma* biostromes laterally connected with facies of algal laminites and black intraclast levels.

In the central sector, and outside the area studied by us, "Lithiotis" facies have been described by several authors in stratigraphic or regional geological studies (García-Hernández *et al.*, 1979a; Azéma *et al.*, 1979). A detailed paleontological-stratigraphic study of

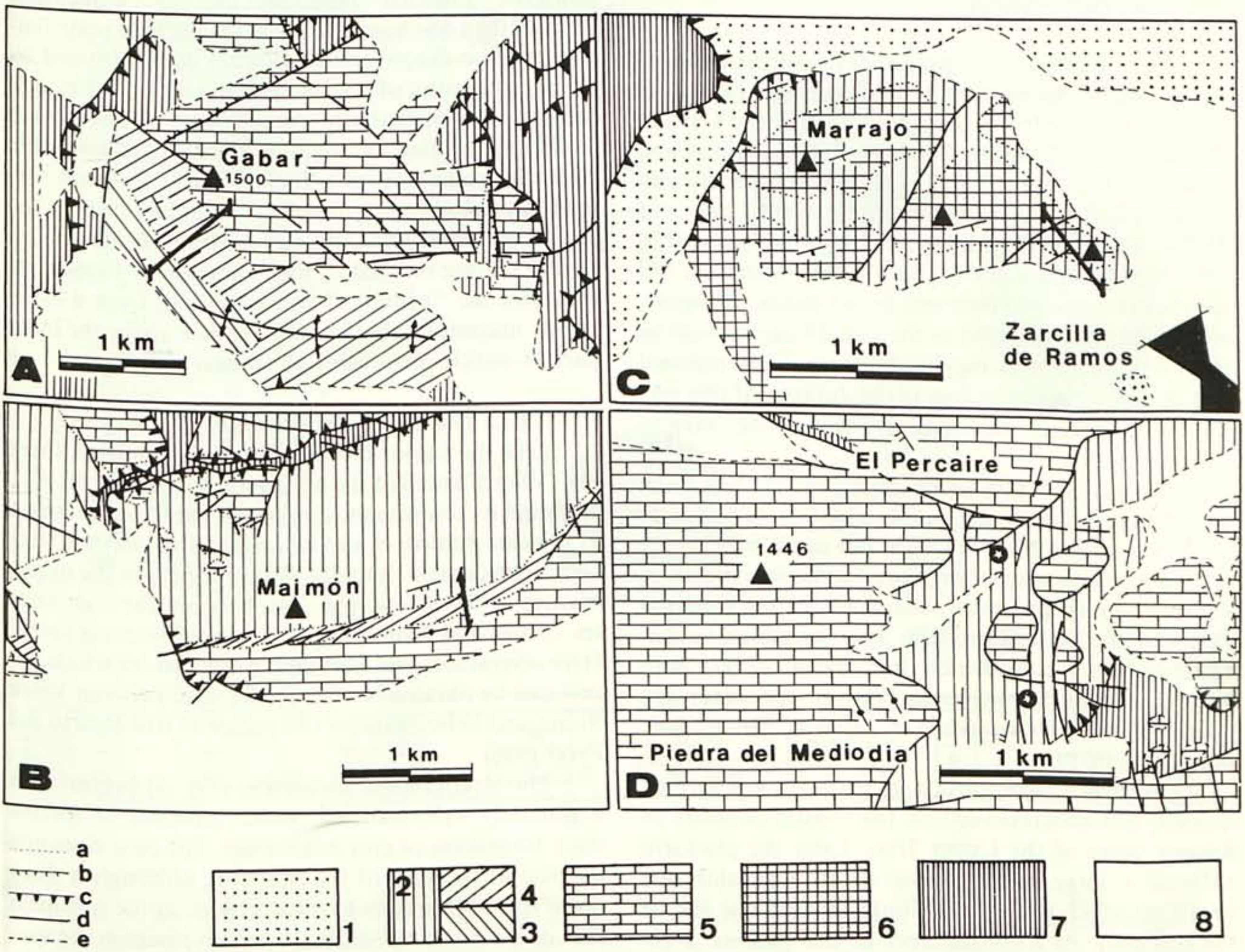


Fig. 2.-Detailed geologic maps of studied outcrops, modified from Baena (1972) and Baena *et al.* (1977). A: Cerro del Gabar. B: Sierra del Maimón. C: Cerro del Marrajo. D: Sierra del Gigante. Legend: a.- Conformable contacts, b.- Normal fault, c.- Thrust fault, d.- indiferenciated fault. e.- Unconformity. 1.- Trias with germano-andalusian facies. 2.- Gavilán Fm. (Lower and Middle Liassic). 3.- Lower member of Gavilan Fm. 4.- Upper member of Gavilán Fm. ("Lithiotis" limestones). 5.- Oolitic limestones (Dogger). 6.- Cherty limestones (Dogger). 7.- Marly limestones and marls (Cretaceous-Tertiary). 8.- Aluvial and scree deposits (Quaternary).

Fig. 2.-Cartografía geológica detallada de las localidades estudiadas, según Baena (1972) y Baena *et al.*, (1977), modificados. A.- Cerro del Gabar. B.- Sierra del Maimón. C.- Cerro del Marrajo. D.- Sierra del Gigante. Leyenda: a.- Contacto concordante, b.- Falla normal, c.- Falla inversa y cabalgamiento. d.- Contacto mecánico en general, e.- contacto discordante 1.- Trias germano andaluz. 2.- Formación Gavilán (Lías inferior y medio). 3.- Miembro inferior de la Formación Gavilán. 4.- Miembro superior de la Formación Gavilán (Caliza de "Lithiotis"). 5.- Calizas oolíticas (Dogger). 6.- Calizas con sílex (Dogger). 7.- Margas y margocalizas (Cretácico-Terciario). 8.- Aluviones y derrubios (Cuaternario).

this group of bivalves has recently been carried out by Martínez-Garrido (1988): the general conclusions this author reaches have been the subject of two recent papers (Martínez-Garrido and Rivas, 1988a,b), where the morphological characteristics of these bivalves and their adaptation to the sedimentary environment (1988a), and their paleo-environmental significance (1988b) have been studied.

In other alpine mediterranean areas these facies have also been described and their paleoecological and sedimentary significance discussed by Dubar (1948), Bosellini (1972), Broglio-Loriga and Neri (1974), and Seilacher (1984), among others.

3. STRATIGRAPHY

3.1. Outcrops studied.

The "Lithiotis" limestones of the sector we study in this paper, that between Vélez-Rubio and Zarcilla de Ramos, are situated in the upper part of the Gavilán Formation established by Van Veen (1969) and De Clerq *et al.* (1975). They are found in carbonate materials with shallow platform facies which constitute the Lower and Middle Liassic of the Median and Internal Subbetic in this region (Hermes, 1978). For the time being, we will use the nomenclature proposed by our dutch colleagues, although the stratigraphy of the Lias-Dogger should be revised in the light of the discovery of several regional stratigraphic discontinuities in the Jurassic of this sector of the Subbetic: this revision will be undertaken in a future paper.

The Gavilán Formation proposed by Van Veen (1969) includes, clasically, subbetic carbonate materials of the Lower and Middle Liassic pro parte, which were deposited on an enormously large carbonate platform which occupied practically the whole of the External Zones of the Betic Cordillera. This formation is characterized by a considerable lithological variety with very significant facies changes between one sector and another (García-Hernández *et al.* 1979a,b, 1986-87; Azéma *et al.*, 1979).

The great Liassic carbonate platform was formed quickly, but progressively, on the coastal deposits of Keuper facies of the Upper Trias. Later the platform suffered in large part a process of disintegration due to rifting which reached its climax towards the end of the Carixian. As a consequence of this process, a general discontinuity that affected the majority of the Subbetic series (García-Hernández *et al.*, 1976, 1979a,b, 1980, 1986-87; Vera, 1981, 1984, 1988) was produced.

In the present paper four outcrops (Fig. 1) have been studied in detail; their specific location on the map is shown in figure 2. The three most significant stratigraphic sections of those which we have studied are shown in figures 3, 4 and 5. We will now describe more fully their location, access and main stratigraphic characteristics.

3.1.1. *The Cerro del Gabar*

This hill is located on sheet 952 (Vélez Blanco) of the M.T.N. on scale of 1:50.000 some kilometres to the North of the village (Fig. 2A). The section has been drawn between the following map grid references: 759799 (bottom) and 765830 (top). Access is by means of a path which leads from the road between the villages of María and Las Almoyas to the foot of the hill. This relief is an independent geological unit, of the Internal Subbetic type, developed on materials from the Upper Cretaceous attributed to the Median Subbetic by Baena *et al.* (1977).

The stratigraphic section (Fig. 3) begins with a group of grey dolostones, the base of which does not outcrop, over 250 m thick. On these dolostones lies a unit of white limestones over which the "Lithiotis" limestones have been superimposed. In places neptunian dykes filled with red limestones can be observed. At this point the "Lithiotis" limestones can reach a thickness of more than one hundred metres and include some flat-convex lense-shaped morphological bodies fromed by the accumulation of micritic and bioclastic sediments, sometimes with fenestral porosity and bivalves, wich could be classified as "mud-mounds". This ensemble ends with some beds of a thickness of tens metres formed by crinoid calcarenites with abundant benthic foraminifers, especially Lituolids. A stratigraphic discontinuity surface marked by marls and marly limestones separates the "Lithiotis" limestone unit from a thick slighty unconformable formation made up for the most part of oolitic limestones of Dogger age.

3.1.2. *The Sierra del Maimón*

Like the Gabar hill, this Sierra is found on sheet 952 (Vélez Blanco) of the M.T.N. on a scale of 1:50.000, although its southernmost outcrops are found on sheet 973 (Vélez Rubio). It also belongs to the Internal Subbetic. The clearest outcrops always appear in the upper reaches of the Sierra (Fig. 2B), between the coordinates 765694 and 764691, and in the neighbouring areas. Here several sections have been produced, to which access can be obtained either by the road between Vélez Rubio and Vélez Blanco or by sector W (the Puerto del Peral pass).

The stratigraphic succession (Fig. 4) begins with a generally well-stratified, some hundreds of metres thick formation of grey dolostones. The base does not outcrop in the area of the Maimón, although it does do so some kilometres to the nortwest, at the northern foot of the Sierra de María. In certain places in the surroundings of the Maimón Grande, the top of this lithologic unit is not dolomitized and, then, its upper part is made up of well-stratified, light-coloured limestones with facies which are similar to those of the underlying dolostones. On top of the latter, or on the limestones, the "Lithiotis" limestones lie, with a flat discontinuity surface marked by a decimetric level of shelly accumulations. The "Lithiotis" limestones reach a thickness of 120 m to 2 km to the east of the Maimón vertex. In this sector these "Lithiotis" limestones comprise a

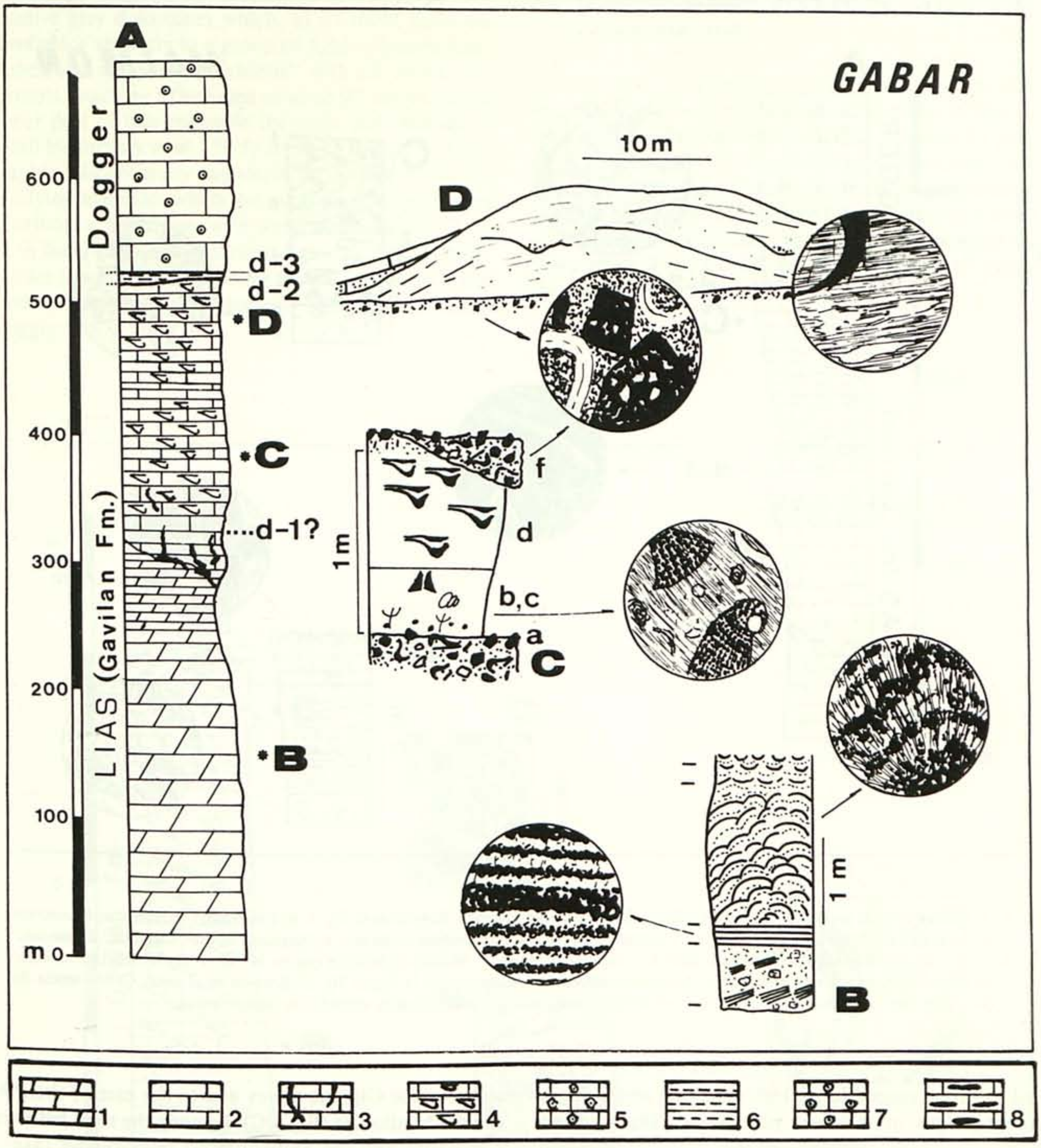


Fig. 3.-A: Stratigraphi section of the Lower and Middle Jurassic in the locality 1 (Gabar). Key: 1.- Grey dolomites (Lower Liassic). 2.- White limestones (Lower Liassic). 3.- White limestone with neptunian dykes of red limestones. 4.- "Lithiotis" limestones (Lower?-Middle Liassic). 5.- Crinoid limestones (Middle Liassic). 6.- Marls (Upper Liassic). 7.- Oolitic limestones (Dogger). 8.- Cherty limestones (Dogger). d-1: Intrasinemurian discontinuity (?). d-2: Intracarixian discontinuity. d-3: Discontinuity at the Liassic-Dogger boundary. B: Elemental sequence of the dolomitic member of the Gavilán Fm. Explanation in the text. Inside circles are sketches of the microfacies. C: Elementary sequence of the "Lithiotis" limestones. a, b, c, d, e, f: facies, see text for details. D: Mound of calcareous mud and bioclastic sediment bearing "Lithiotis'. Note its planar base lying on black intraclastic facies. Note also erosional features filled with bioclastic sediment.

Fig. 3.-A: Sección estratigráfica del Jurásico inferior y medio del Cerro del Gabar. Leyenda: 1.- Dolomías grises (Lías inferior). 2.- Calizas blancas (Lías inferior). 3.- Calizas blancas con diques neptúnicos de calizas rojas (Lias inferior? y medio). 4.- Calizas de "Lithiotis" (Lías inferior? - medio). 5.- Calizas con crinoides con silex (Lías medio). 6.- Margocalizas (Lías superior). 7.- Calizas oolíticas (Dogger). 8.- Calizas con silex (Dogger). d-1: discontinuidad intrasinemuriense(?); d-2: discontinuidad intracarixiense. d-3: discontinuidad del límite Lias-Dogger. B.- Secuencia elemental del miembro inferior de la Formación Gavilán. Explicación en el texto. En círculos aspectos microscópicos de las facies. C.- Secuencia elemental de las calizas de "Lithiotis". a, b. c, d, e, f: facies descritas en el texto. D.- Montículo de lodo calcáreo y sedimento bioclástico con "Lithiotis" dispersos. Nótese su contacto inferior planar y su implantación sobre facies de brechas de cantos negros.

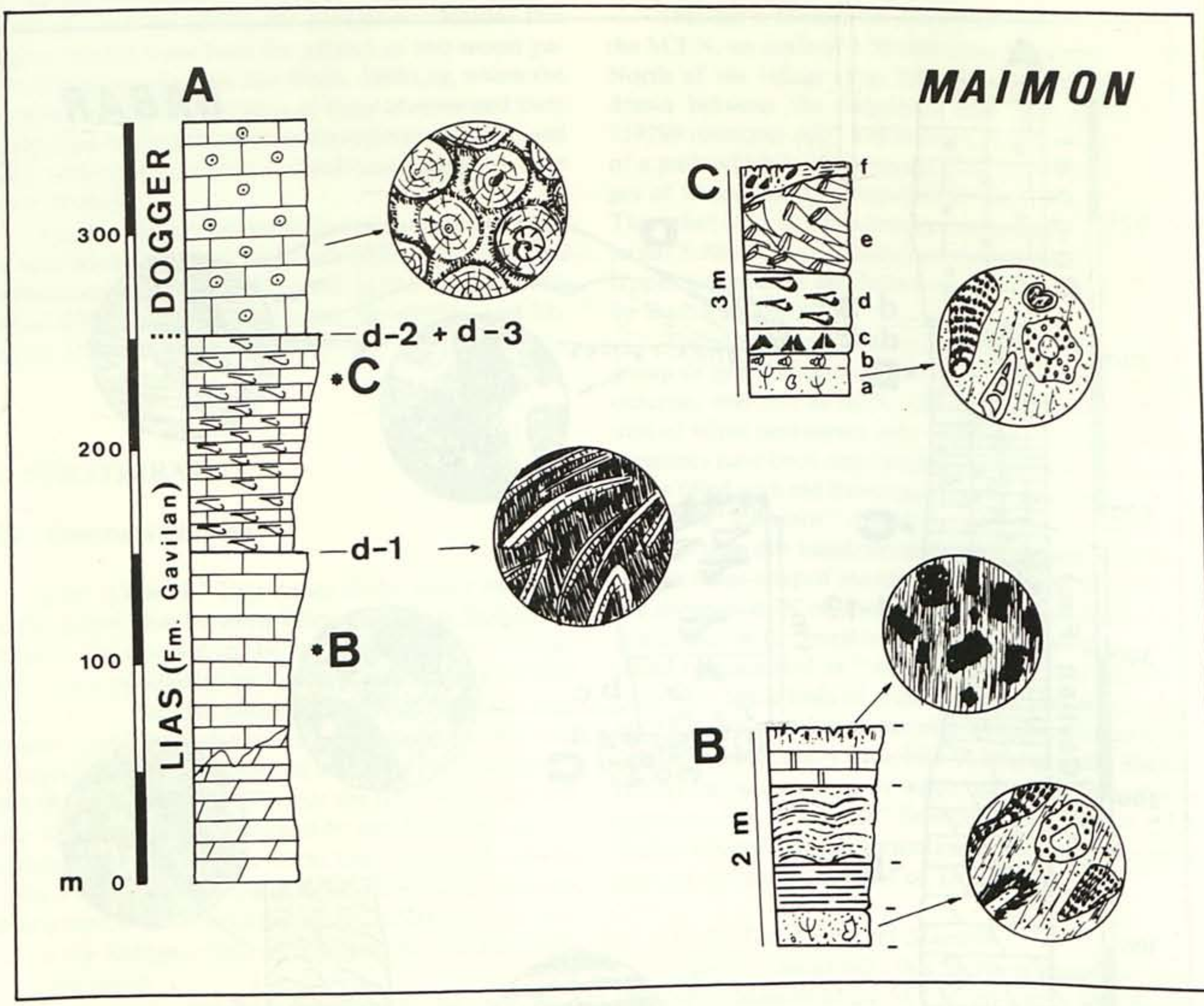


Fig. 4.-A: Stratigraphical section of the Lower-Middle Jurassic of the Maimón. Legend as in fig. 3. B: Elementary sequence of limestones of the top of the lower dolomitic member. Compare with fig. 3B. Explanation in the text. C: Sequence of the "Lithiotis" limestones.

Fig. 4.-A: Sección estratigráfica del Jurásico inferior y medio del Maimón. Misma simbología que en la Fig. 3. B: Secuencia elemental en las calizas que coronan el miembro dolomítico inferior. Compárese con la figura 3B; explicación en el texto. C: Secuencia de las calizas de "Lithiotis". En círculos se representan esquemáticamente algunas microfacies significativas.

well stratified ensemble, pinkish in colour, and at times showing signs of incipient nodulation. Due to their greater susceptibility to erosion they form a depression in the relief, at the northern foot of the oolitic limestones belt of the Dogger, which constitutes the chief feature of the relief. In the sections studied in the surroundings of the Maimón (Fig. 4) the last few metres of the "Lithiotis" limestones are made up of crinoid- rich bioclastic calcarenites and calcilutites with large lituolids, on top of which a new discontinuity surface can be seen. Above this surface we find the thick formation of white oolitic limestones of Dogger age, which may contain chert nodules in its upper beds.

3.1.3. *Sierra del Gigante*

This Sierra is also located on sheet 952 of the M.T.N. on a scale of 1:50.000 and belongs to the Internal Subbetic. The clearest outcrops appear in the SE slope of the Gigante vertex and to the east of the Piedra del Medio Día (Fig. 2C). Leaving the road between Fuensanta and the Valdeinfierno reservoir we take a rough road to the places where observation can best be carried out: the map reference coordinates are 890766 to 883751. The outcrops are very similar to those of the Maimón and for this reason we have not shown the stratigraphic colum of this area.

3.1.4. *Cerro del Marrajo*

This hill is located on sheet 931 (Zarcilla de Ramos) of the M.T.N. on a scale of 1:50.000. Easy access to the outcrops is possible from the village of Zarcilla de Ramos (Fig. 2D). The section has been drawn between the following map coordinates: 986898 and 982900. This outcrop has been attributed to a unit of the Middle Subbetic type if we consider the facies of its post-Liassic materials.

The stratigraphic succession (Fig. 5) begins with massive grey dolostones which, as we move upwards, gives place abruptly to a group of light-coloured limestones with abundant "Lithiotis" with calcarenitic insertions, reaching a thickness of some 90 metres. In the upper part of this ensemble the coral reefs studied in detail by Turnsek *et al.* (1975) are to be found. A stratigraphic discontinuity separates this block from the overlying materials which are made up of some metres of crinoidal limestones with some chert nodules. These, in turn, are again separated by a new discontinuity surface from a formation some tens of metres thick formed by limestones with filaments and chert nodules of Dogger age.

3.2. Lithostratigraphic units of the Liassic materials.

Our study of these four outcrops allows us to distinguish, tentatively, in the area represented in Fig. 1, two members among those materials included by previous researchers in the Gavilán Formation: a lower dolomitic member and an upper limestone member,mainly made up of "Lithiotis" facies. This distinction is only of local significance and can not be generalized to other areas of the Cordillera where "Lithiotis" facies are also found.

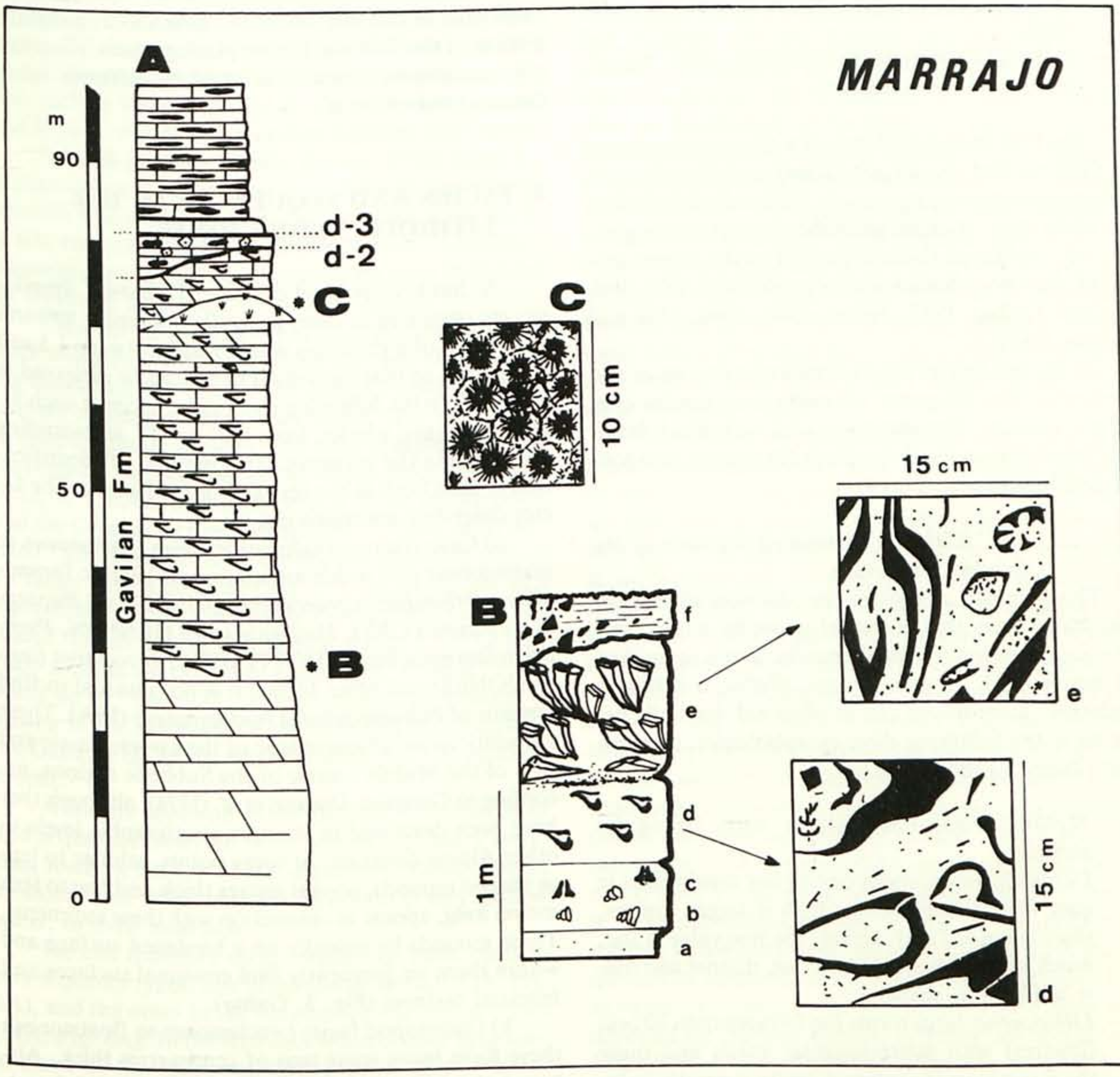


Fig. 5.-A: Stratigraphical section of the Lower an Middle Jurassic to the Marrajo. Legend as in fig. 3. B: Sequence of the "Lithiotis" limestones. C: Field aspect of coral facies.

Fig. 5.-A: Sección estratigráfica del Jurásico inferior y medio del Marrajo. Misma simbología que en la fig. 3. B: Secuencia de las calizas de "Lithiotis". C: aspecto de campo de las facies de corales.

3.2.1. *The lower dolomitic member of the Gavilán Formation.*

This member was originally defined by Geel (1973) as the Vélez Blanco Formation, but it was later redefined by De Clerq *et al.* (1975) as the lower part of the Gavilán Formation. The contact with the lower part of this member is generally tectonic so that we can only estimate a minimum thickness which, at any rate, is greater than 250 m. Despite dolomitization, spectacular stromatolite sequences made up of bodies between 1-2 m high and 10 to 15 m long have been observed. In the basic sequence the following terms can be identified (arranged from bottom to top) (Fig. 3B and 4B):

— Intraclastic and pelloidal calcilutites and calcarenites, with several decimetres thick.
— Cryptalgal laminites (flat laminated stromatolites), gradually changing vepwards to large stromatolitic domes; this interval is about a metre thick.
— Pelloidal calcarenites to calcilutites, with ''tepee'' and des sication features.

The first level is evidence of a transgressive interval (here we find the deepest facies), and the others represent a progressive regression, from subtidal levels to supratidal ones. So these are shallowing-upward sequences, very similar to those described in the classic models of shallow carbonate platforms (Wilson, 1975; Wilson and Jordan, 1983; James, 1984, 1988; Mas and Alonso, 1989).

In the last metres the bed thickness decreases and the stromatolites disappear, although some smaller ones are still present. The sequences end with black intraclast breccias showing desiccation features or even soil-like levels (Maimón, Fig. 4).

3.2.2. *The ''Lithiotis'' limestone member of the Gavilán Formation.*

This member, at least in the Maimon alignment, is separated from that discussed above by a thin layer of an accumulation of lamellibranchs, and is more than 100 metres thick in many places. Within it different ''Lithiotis'' associations can be observed, basically belonging to the following three morphologies, that can be attributed to three genera:

— *Mytilus:* small-sized shells with triangular sections.
— *Gervilleioperna:* shells one to few centimetres in size, with a fixed valve which is larger, convex, slightly curved and thicker; the free valve is flat, much smaller than the fixed one, thinner and more uniform in shape.
— *Lithioperna:* large forms (up to more than 10 centimetres) with subrectangular shells and quite thick sections; the internal cavity is greatly reduced in size. Both isolated and colonial morphologies have been observed.

For a more detailed description of the morphologies of these lamellibrahs the reader is referred to the following studies: Broglio Loriga and Neri (1974), Martínez-Garrido (1988) and Martínez-Garrido and Rivas (1988a).

This member usually appears well-stratified, and several different types of sequences, often ending in remotion levels, desiccation breccias or black intraclastic breccias can be observed. It may on occasion appear partially dolomitized, and it is not unusual to find insertions of oolitic and crinoid-rich grainstones, in some places even showing herringbone-cross-bedding (Maimón, Fig.4) and in others forming thinning-upward sequences which fill in wide small channels (Gigante).

At the top of the ''Lithiotis'' limestones we see an important stratigraphic discontinuity, which can probably be correlated with that described during the Carixian in many points of the External Zones of the Betic Cordillera (García-Hernández *et al.*, 1989). At the same time as this discontinuity came about, a disintegration of the Subbetic Liassic platform took place and paleogeographic domains affected by different subsidence appeared on it.

4. FACIES AND SEQUENCES IN THE ''LITHIOTIS'' LIMESTONES

As has been pointed out, the ''Lithiotis'' limestones are organized in clear, generally thickening upwards sequences, of a thickness which varies between 1.5 and 2.5 metres, so that individual facies can be observed in each bed. In the following descriptive account each facies is assigned a letter, from ''a'' to ''f'', in ascending order within the sequence. This method of identification is used both in the text and in the figures. The facies described are following:

a) Calcarenitic to calcilutitic facies (packstones to grainstones) with a rich association of benthic foraminifers: *Orbitopsella praecursor* (GUMBEL), *Lituosepta recoarensis* CATI, *Haurania amiji* HENSON, *Pseudocyclammina liasica* HOTTINGER, *Involutina liasica* (JONES) and other forms. It is not unusual to find remains of *Paleodasycladus mediterraneus* (PIA). These associations are characteristic of the Lower Liassic and part of the Middle Liassic of the Subbetic regions, according to González-Donoso *et al.* (1974), although they have been described in younger stratigraphic levels in other Alpine domains. At some points, tabular to lense shaped mounds, several metres thick and few to tens metres long, appear in connection with these sediments. These mounds lie ussually on a hardened surface and within them we frequently find erosional surfaces and fenestral textures (Fig. 3, Gabar).

b) Gasteropod facies (wackestones to floatstones): these form levels some tens of centimetres thick. Although the gasteropod are usually small in size (1-3 cm), they may occasionally be larger (up to 7 cm long), and different morphologies have been recognised.

c) *Mytilus* facies: this facies is very often found together with the previous one, and represents the first appearance of "Lithiotis" facies in the sequence. It usually forms fine micritic to calcarenitic (wackestone) beds, some centimetres thick.

d) *Gervilleioperna* facies: these appear in considerably larger intervals than the previous facies, since they are usually some decimetres thick. They are frequently formed by monospecific associations of this type of bivalve, included in bioclastic and pellet-rich micritic sediment (wackestone to floatstone).

e) *Lithioperna* facies: the beds showing this facies can reach a thickness of the order of two metres. The individuals generally appear in horizontal position (Maimón, Gigante), producing important accumulations included in micritic and bioclastic sediments. In places, they show evidence of a slight remotion, practically "in situ", giving rise to rudstone-floatstone facies (e.1 facies). Associated with these, there are stretches where the organisms appear in a sloping or event vertical position, trapping sediments, thus forming bafflestones (e.2 facies). At some points (Marrajo) we have found fan-shaped colonies of these organism in position such as those they had in life (Martínez-Garrido and Rivas, 1988a), which coexist together with corals.

f) Black intraclast facies: the top of the sequence is characterized by the present of breccias and microbreccias with a large number of black clast up to 10 cm in size and some intraclasts and bioclasts. "Lithiotis" fragments are found here. On occasions these levels have an erosional base, and show clear signs of remotion.

These six basic facies-types are organized in metre-thick sequences within the upper member of the Gavilán formation. In most of the sections studied a great number of examples have been found, thus allowing us to establish their typology. The most complete sequences contain, from bottom to top, all the facies listed above (a, b, c, d, e.1 and sometimes e.2). In the Maimón and the Gigante sections, within the "e" level, only isolated "Lithiotis" forms there appear, although typical e.1 facies with a great number of Lithioperna are well represented in outcrops nearer the Maimón vertex, situated further east of that shown in Fig. 4. In the Marrajo section, on the other hand, (Fig. 5), level "e" is made up of "colonial" forms. At times an element is mising in the sequence: in the stratigraphic section of the Gabar (Fig. 3), for example, level "e.2" is regularly absent.

A feature common to the majority of the sections and sequences observed is the presence of black intraclast levels in the top of the sequences. These have an erosional base which indicates remotion in very shallow water, or even emersion.

We can therefore differentiate two basic elementary sequence types, one in the Gabar section (GA, Fig. 6A), and the other in the Maimón or Marrajo sections (MA, Fig. 6A). In the first case the sequence may start at some of the facies mentioned above ("a", "b" or "c"), continue with level "d" *(Gervilleioperna),* which is the thickest, and ends with the "f" interval. In the second case (MA, Fig. 6A) the sequence begins with levels without "Lithiotis" ("a" or "b" facies in the list above), and continues with a relatively thin bed of Mytilus ("c" facies) and with a "d" facies level thinner than in the other sequence type; it then has an "e" level, at the base of which *Lithioperna* individuals lie horizontally, and in the upper part in a vertical position; the sequence finally ends, as in the first case, with a level of black intraclast breccia, usually with an erosional base.

5. DISCUSSION AND INTERPRETATION

5.1. The significance of the sequences.

The two sequence types described above for the "Lithiotis" limestones end in levels which clearly show the existence of short emersions (hardened levels, black intraclast breccias, soil-like horizons, etc.) which demonstrates that it is a shallowing-upward sequence. This fact, together with the existence of a first level which is clearly subtidal, as for instance that formed of bioclastic sediments rich in lituolids and algae, suggests that the distribution of the different types of "Lithiotis" observed must reflect a succession of organisms ranging upward from deeper to shallower environments. The "Lithiotis" successions that we have established are different from those which might be expected if one follows the paleoecological interpretations of previous authors (Broglio Loriga and Neri, 1974; Martínez-Garrido and Rivas, 1988b). If our hypothesis is correct, then, *Lithioperna* must have been a bivalve from shallower waters, while Mytilus must have adapted itself to areas of deeper water.

Throughout the column the shallowing upward sequences constantly recur in a cyclic manner. In order to offer a convincing explanation for this phenomenon we must bear in mind the following factors: sedimentary rate, eustatism and subsidence. As far as the first factor is concerned, it seems reasonable to suppose that the deposition of each of the facies described above took place at a different rate of sedimentation: the upward increase in thickness usually shown by the facies where "Lithiotis" accumulations are the most significant feature ("d" and "e" facies) suggests a progressive increase in sediment supply in the marine intervals of each elementary sequence. It seems quite possible then, that the shallowing evolution of each elementary sequence was due to this very sedimentary process. This interpretation agrees with the autocyclic model proposed by James (1988), according to which the variations in the rate of sedimentation are responsible for the relative variations in sea-level which have been observed in the sequences of numerous shallow carbonate platforms. These variations could in the last instance have been conditioned by climatic factors, possibly connected with Milankovitch's astronomical cycles. We have not been able to demostrate this in the series studied due, among other reasons, to the few time-markers available, but the scale of the sequences in connection with the general thickness of the "Lithiotis" limestone ensemble could reasonably be explained by the ideas we have just discussed.

If we accept this account, the increase in the rate of sedimentation of the sequence towards their top would explain, in the first place, why our sequences are thickening upward and, further, the presence of *Lithioperna* towards their top. These organism must have adapted itself more effectively than other types of "Lithiotis" to a high sedimentation rate. If we assume a progressivelly greater sediment supply, the areas where *Gervilleioperna* lived in would quickly be filled up, and these latter would be replaced by *Lithioperna.* According to this interpretation the disappearance of *Gervilleioperna* might not have been due so much to a water depth decrease as to their own inability to tolerate a high sediment supply, which finally must have buried them.

5.2. A comparative study of these "Lithiotis" types and the rudists.

In order to be able to test the interpretation we suggest above, we thought it would be interesting to compare the conclusions reached there with the data available on the conditions of life and the distribution in the sedimentary environment of the rudist, Cretaceous bivalves which lived in paleoecological and paleogeographical contexts which were similar to those of the "Lithiotis". And, indeed, there are many ecological and morphological similarities between these two groups of organisms. This can help us to provide important information relevant to the "life-style" of the "Lithiotis", about which we have at present far less knowledge. The rudists limestones are one of the most representative deposits of Urgonian platforms: their biotopes were developed very widely in the protected and shallow areas of these Cretaceous carbonate banks, situated between the external parts of the platform (frequently bars and coral reefs) and the marginal areas, often emerged (Arnaud-Vanneau, 1980; García-Hernández, 1978, 1979; Masse, 1976).

5.2.1. *Morphology and "life-style".*

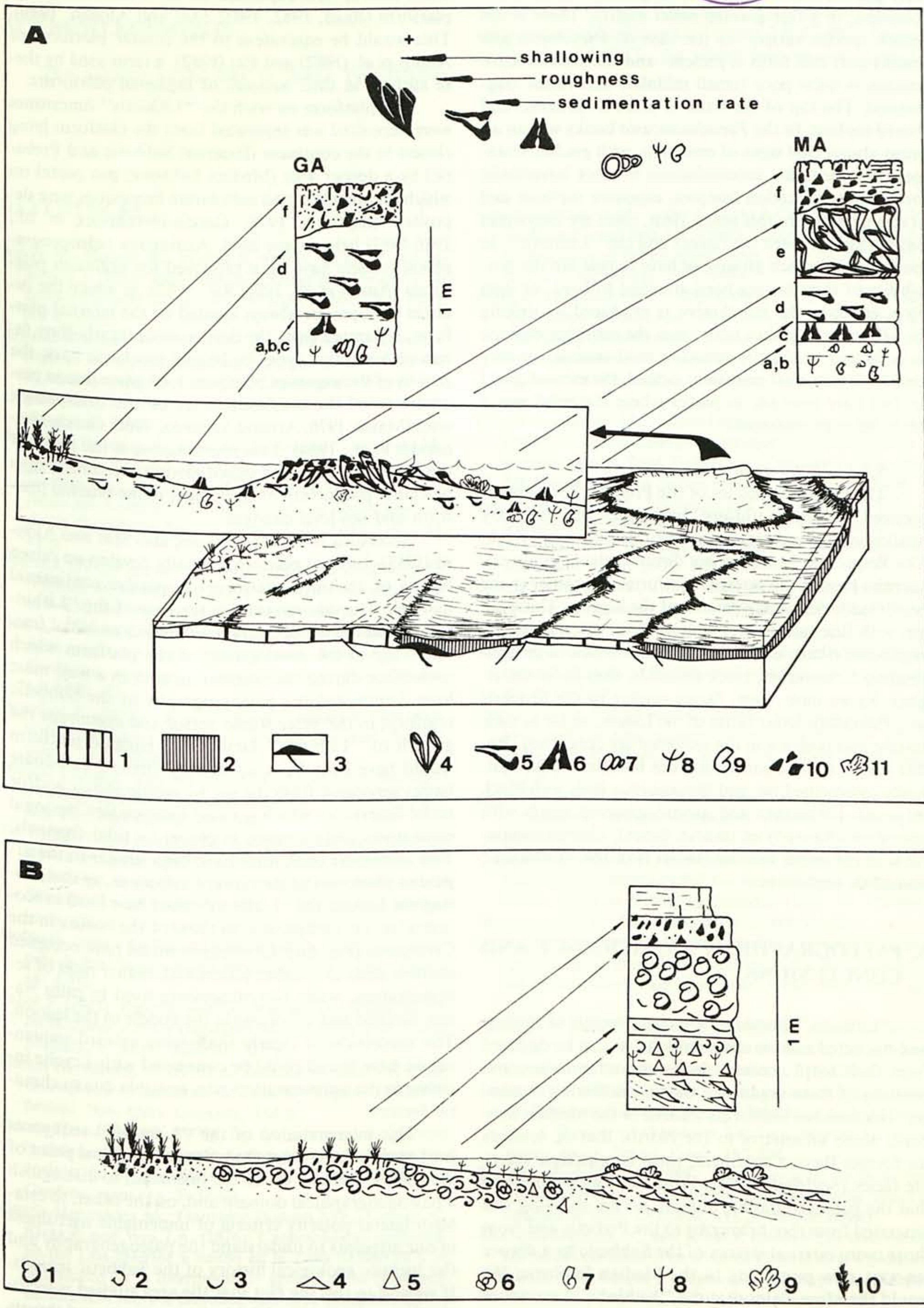
We would emphasize in the first place the morphological similarities. *Lithioperna* is similar in some ways to certain Monopleurids, characterized by having quite one large prolonged conical or tubular valve which is firmly embedded in the sediment, and another smaller, opercular one. On the other hand, *Gervilleioperna* is a form which can be compared to certain Requieniids, wich have a fixed, relatively large coiled valve and another opercular one. Monopleurids, due to their larger fixed surface adapted themselves more easily to zones of greater sedimentation rate and even to those of greater energy (Fig. 6), (Masse, 1976). With such an important sediment supply these bivalves were tipped; nevertheless they must have struggled to recover their position in life through a negative geotropism, a phenomenon which we have also observed in *Lithioperna:* with the increase in sedimentation rate, these organisms tended to avoid being buried by changing from a horizontal to an inclined or finally a quite vertical position. On the other hand, in order to adapt themselves to rough water, Monopleurids tend to join together, forming small tabular constructions which could be equivalent to the fan-shaped *Lithioperna* colonies we have described in the Marrajo, coexisting with other gregarious organisms frequently typical of rough water: corals. Given their morphology (Masse, 1976), the Requiniids are associated with calmer waters: thus, *Gervilleioperna* would rather seem to be a characteristic form of the more restricted and protected zones of the platform, while *Lithioperna* would have occupied rougher areas with a higher rate of sedimentation.

5.2.2. *The geometry of the sedimentary bodies and their internal organisation.*

In the Urgonian limestones of the Lower Aptian in the Prebetic Zone (García-Hernández, 1978), the Requieniid banks (*Requienia* above all and *Toucasia)* are of metric thickness and the forms are essentially tabular or slightly lense-shaped (biostromes); however, this lense-shaped characteristic can be more pronounced in the *Pseudotoucasia* banks of the Upper Aptian. Laterally, these banks usually measure some ten metres and the lateral changes are generally transitional. The base of the bank is usually flat and begins with a accumulation bed of shell fragments which is followed by rudists

Fig. 6.-Genetic models for bivalve facies. A: Paleogeography of the "Lithiotis" facies. MA: sequence of type 1 (Maimón and Marrajo), with colonial or solitary forms. GA: sequence of type 2 (Gabar) with systematic absence of the *Lithioperna* interval ('a', "b', "c', "d" and "e" are the facies described in the text). Key: 1.- Shallow-marine carbonate facies. 2.- Hemipelagic facies. 3.- Submarine volcanic rocks. 4.- *Lithioperna.* 5.- *Gerviolleioperna.* 6.- *Mytilus.* 7.- Gasteropods. 8.- Green algae. 9.- Benthonic foraminifers. 10.- Black clasts. 11.- Corals. B: Rudist biotopes *(Requieniidae)* in the Prebetic Zone (García-Hernández, 1978) and genetic model. Key: 1-2-3.- Rudistes (Requienids) (1.- large forms, 2.- small forms, 3.- bioclasts), 4-5-6-7.- Foraminifers (4.- large Orbitolines, 5.- conical Orbitolines, 6.- Miliolids and 7.- Lituolids). 8.- Green algae. 9.- Corals. 10.- Mangroves.

Fig. 6.-Modelos genéticos de facies de bivalvos. A: Paleogeografía de las facies de "Lithiotis". MA: secuencia de tipo 1 (Maimin o Marrajo) con las formas aisladas ó coloniales. GA: secuencia tipo Gabar en la que sistemáticamente falta *Lithioperna* ("a", "b", "c", "d" y "e" representan las diferentes facies descritas en el texto). Leyenda: 1.- Materiales de facies de plataforma marina somera. 2.- Materiales de facies hemipelágicas. 3.- Rocas volcánicas submarinas. 4.- *Lithioperna.* 5.- *Gerviolleioperna.* 6.- *Mytilus.* 7.- Gasterópodos. 8.- Algas verdes. 9.- Foraminíferos bentónicos. 10.- Cantos negros. 11.- Corales. B: Biotopos de rudistas *(Requieniidae)* en la Zona Prebética (García-Hernández, 1978) y modelo genético. Leyenda 1-2-3.- Rudistas (Requiénidos) (1.- formas grandes, 2.- formas pequeñas, 3.- fragmentos), 4-5-6-7.- Foraminíferos (4.- grandes Orbitolinas, 5.- Orbitolinas cónicas, 6.- Miliólidos y 7.- Lituólidos). 8.- Algas verdes. 9.- Corales. 10.- Manglares.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scattered among micrite. Finally, the rudists appear densely packed together and are frequently found in life position, in a fine-grained pellet matrix. There is not much species variety -in the case of *Pseudotoucasia* banks only this form is present- and the skeletal association is quite poor (small miliolids and rudist fragments). The top of the bank is often a hardened and bored surface. In the *Pseudotoucasia* banks we can almost always find signs of emersion, with gradual changes from the rudist accumulations to black intraclastic beds with desiccation features, exposure surfaces and traces of roots. In this sense, then, there are important similarities between the rudists and the ''Lithiotis''. In both lamellibranch groups we have to rule out the possibility of their having been attached to hard, or even firm grounds; the attachment is produced by sinking in a lime mud, and in both cases the resulting biotope is a flattish or slightly rounded mud mound, in very shallow water, near emersion; indeed, the mound could in fact have emerged in places where the relief was a little more pronounced.

5.2.3. *Facies associations.*

The rudist limestones of the Prebetic Zone are organized, like the ''Lithiotis'' limestones, in elementary shallowing upward sequences up to several metres thick. The Requieniid banks are not directly related to the calcarenite bars of the external platform, but rather to the restricted facies, characteristic of the lagoon. These begin with fine calcarenites which are very rich in microorganisms (sharp-ended conical orbitolinids, large agglutinating foraminifers, thick miliolids, dasycladacean algae). So we have, then, facies similar to the lituolids and *Paleodasycladus* facies of the Liassic, as far as their texture and position in the sequence are concerned. Rudist banks follow, containing the features we have already commented on, and the sequence ends with black intraclast limestones and greyish-greenish marls with abundant charophytes (marsh facies), clearly comparable to the upper interval (facies f) of the ''Lithiotis'' limestone sequences.

6. PALEOGRAPHICAL SIGNIFICANCE AND CONCLUSIONS.

''Lithiotis'' limestones are characteristic of shallow and restricted marine environments, as can be deduced from their fossil content, facies and microfacies, and position of these organisms within shallowing sequences. Isochronous sediments located in the Median Subbetic, some kilometres to the North, that is, towards the former Iberian continent, show hemipelagic spiculite facies (Seyfried,, 1978). From this, we can deduce that the paleogeographic domain we are studying was separated from that belonging to the Prebetic and from those more external sectors of the Subbetic by a deeper sea-way, now pertaining to the Median Subbetic. We would therefore claim that the ''Lithiotis'' limestones of the southernmost Median Subbetic and the Internal Subbetic of the region between Vélez-Rubio and Zarcilla de Ramos were deposited on an isolated carbonate platform (Read, 1982, 1985; Mas and Alonso, 1989). This would be equivalent to the insular platform of Amiot *et al.* (1982) and Rat (1982), a term used by these authors in their account of urgonian platforms.

The platform on wich the ''Lithiotis'' limestones were deposited was separated from the platform lying closest to the continent (External Subbetic and Prebetic) by a deeper area (Median Subbetic, pro parte) on which the spiculitic and radiolarian limestones were deposited (Seyfried, 1978; García-Hernández *et al.*, 1986-1987) below wave level. Analogous paleogeographical models have been proposed for urgonian platforms (Amiot *et al.*, 1982; Rat, 1982), in which the rudistes biotopes are always located on the internal platform, separated from the deeper areas (marly-limy facies of Vocontian type) by largely bioclastic bars; the growth of the urgonian platforms took place due to progradation of the bioclastic facies on the hemipelagic ones (Masse, 1976; Arnaud-Vanneau, 1980; García-Hernández *et al.*, 1984). This phenomenon is the result of the combined action of sinsedimentary tectonics, high bioclastic production of carbonates in the internal platform and sea-level changes.

According to Read (1985) -see also Mas and Alonso (1989)- isolated platforms usually develop on raised blocks of fractured platforms in passive continental margins. The discontinuity in the base of the ''Lithiotis'' limestones member could well reflect an initial fracture stage in the development of the platform which took place during the Sinemurian and, in a way, must have determined the paleogeography of the Subbetic platform in the Vélez-Rubio sector and encourage the growth of ''Lithiotis'' facies. This isolated platform would have been built up of very shallow carbonate banks separated from the sea by oolitic shoals and/or reefal limestones which isolated independent lagoonal ecosystems, only crossed in places by tidal channels. This carbonate bank must have been similar to the urgonian platforms of the Lower Cretaceous, so that, during the Liassic, the ''Lithiotis'' must have lived in ecological niches comparable to those of the rudists in the Cretaceous (Fig. 6B): *Lithioperna* would have occupied shallow areas in rougher waters with higher rates of sedimentation, while *Gervilleioperna* lived in calm waters, isolated and in hollows in the middle of the lagoon. The succession of clearly shallowing upward sequences we have found could be connected with a cyclic increase in the sedimentation rate, possibly due to climatic factors.

This interpretation of the ''Lithiotis'' sequences is of great interest from the paleogeographical point of view, since it allows us, on the one hand, to distinguish a paleogeographical domain and, on the other, to establish lateral polarity criteria of undeniable usefulness in our attempts to understand the paleogeography and the Jurassic geological history of the Subbetic regions. If we add to this the fact that the area studied is tectonically very complex, with block movements and thrusts of variable importance, the interest of this type of facies is even greater.

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