

4.2. Stratigraphy and biozonation of a reference Aptian – Albian p.p. Tethyan carbonate platform succession: The Sierra del Carche series (oriental Prebetic zone – Murcia, Spain)

By Jean Pierre MASSE*), Consuelo ARIAS**) and Lorenzo VILAS**).

Abstract

The Sierra del Carche succession represents the Aptian-Albian p.p. of the Prebetic zone. It is characterized by platform carbonates and terrigenous sediments. Two formations can be distinguished: the stratigraphically lower formation was deposited on a carbonate platform during the Bedoulian-Early Gargasian. The stratigraphically higher formation was deposited on a mixed carbonate-siliciclastic platform during the Late Gargasian-Late Albian p.p. Vertical ranges of benthic foraminifera, calcareous green algae and rudists previously recorded in this region show that many taxa can be used either alone, in association, or according to the order of their stratigraphic appearance as indices for biozonation. Thus, 10 biozones have been distinguished in the Bedoulian p.p. – Upper Albian p.p. interval; each one is interpreted with regard to its chronological value. As many of the taxa involved in this framework have a large paleobiogeographic distribution, the proposed biozonation may prove valuable for the stratigraphic correlation of carbonate platform successions wide apart in the Tethyan realm.

1. Introduction

In the circum-mediterranean areas important paleogeographic changes occurred during Aptian-Albian times which affected especially the carbonate platforms. The indispensable basis for detailed studies of these changes are

*) Laboratoire de Stratigraphie et de Paléoécologie, URA, 1208 du C.N.R.S., Université de Provence, 3 Pl. V. Hugo. F-13331 Marseille Cedex 3. France.

**) Dpto. de Estratigrafía. Univ. Complutense y U.E.I. de Correlaciones estratigráficas y Paleogeografía C.S.I.C. 28040 Madrid, Spain.

regional correlations and a precise biostratigraphy of the series. The objective of the present work is to illustrate a detailed local succession which is considered as a reference for the biozonation of three biological groups: foraminifera, calcareous algae and rudists, each being important in "urgonian facies".

The choice of the La Sierra del Carche section was based on:

- good outcrop conditions and access, which are favourable for the observation, despite certain tectonic complications of the whole succession,
- the three above-mentioned groups occurring in a subcontinuous carbonate sequence,
- abundance, diversity and good preservation of the palaeontological content, especially of rudists.

The Aptian-Albian series of the Iberic and Betic regions have been the subject of numerous biostratigraphic studies. Several biozonations, mainly based on foraminifera have been proposed (FOURCADE, 1970; FOURCADE et al., 1972; GARCIA-HERNANDEZ, 1978; AZEMA et al., 1979; GARCIA-HERNANDEZ, 1981).

Detailed investigations of many of the local series (ARIAS et al., 1987, and work in progress) allow us to focus on the Sierra del Carche. This is considered to be a valuable reference section for the biostratigraphy in the meridional zone of the Iberian Peninsula.

The Sierra del Carche is situated in the north of the province of Murcia, East of the village Jumilla (Fig. 1). It is located near the northern boundary of the Inner Prebetic tectonic zone sensu GARCIA-HERNANDEZ et al. (1980) and shows strong tectonic deformation and prominent faults. According to authors (RODRIGUEZ ESTRELLA, 1979; BAENA, 1981) its base is affected by a thrust with a sense of movement toward the north. Cretaceous rocks are the main constituent of the Sierra del Carche; these rocks indicate the development and disappearance of a carbonate platform and a mixed platform during the Aptian and Albian p.p.

2. General Stratigraphy

The exposed base of the Cretaceous in the Sierra del Carche is formed by basinal sands and marls with fragments of *Spitidiscus* aff. *intermedius* (D'ORB.), dated by AZEMA (1977) as Barremian. In addition, we have found fragments of ammonites classified as *Leptoceras* sp., *Barremites* sp. and *Pulchellia* sp. This association indicates a Middle-Upper Barremian age. A carbonate platform and a mixed terrigenous-carbonate succession ranging into the Upper Albian, overlies this unit. It is followed above by a sequence of terrigenous deposits and dolomites. We have found *Neorbitolinopsis conulus* (DOUVILLÉ) and *Caprina choffati* DOUVILLÉ in limestones intercalated at the base of this sequence. The lowermost levels of the terrigenous sequence are dated as Upper Albian-Vraccian by these faunal elements.

We have distinguished several divisions within the carbonates and the terrigenous-carbonate succession. They are principally based on stratigraphic dis-

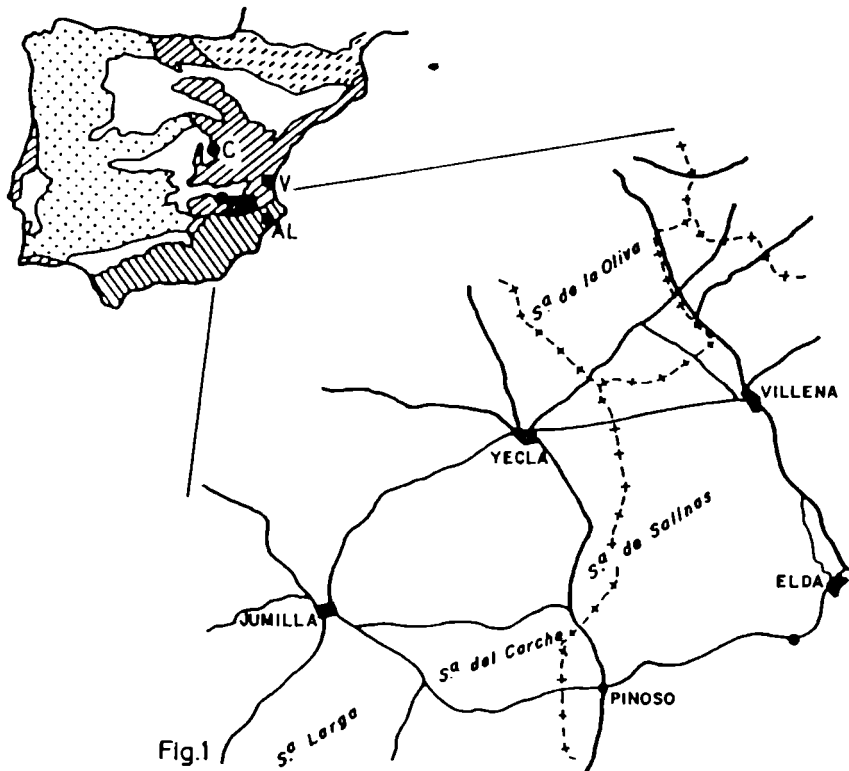


Fig. 1: The geographical and geological position of the Sierra del Carche.

continuities which form boundaries between the sedimentary sequences, and on palaeontological and lithological characteristics (Fig. 2).

According to the stratigraphic position two major formations can be distinguished, each is composed of several units and subunits:

Formation I (434 m)

Limestones with both, biocalcarenic and rudist facies, are dominant. Terrigenous sediments are poorly represented. Two units can be distinguished:

- a lower unit (Ia) (248 m) made of well sorted bioclastic to oolitic limestones, orbitolinid to coral packstones, caprinid packstones-wackestones, requienid (*Toucasia*) beds, wackestones-packstones and marly limestones rich in bivalves (ostreids and pholadomyids).

- an upper unit (Ib) (186 m) consisting of both terrigenous and calcareous facies: sands, clays and marls with some plant remains intercalating with requienid limestones, *Bacinella* wackestones-packstones with some branching corals, *Toucasia* and black-pebble horizons.

Based on third-order facies assemblages and discontinuities, unit Ia has been further subdivided into three subunits (Ia1, Ia2, Ia3), two (Ib1–Ib2) have been distinguished in unit Ib.

The age of formation I is Bedoulian in its lower part, its upper part belongs to the Early Gargasian.

Formation II (316 m)

Calcareous and terrigenous facies are nearly equally developed and form three lithologic units.

– a lower unit (IIa) (99 m) with dominating terrigenous sediments, the calcareous portions consist of a *Radiolitid-Polyconites* rudist assemblage with some corals.

– a middle unit (IIb) (113 m) with successive sequences of rudist limestones and terrigenous facies,

– an upper unit (IIc) (104 m) in which terrigenous facies (sands are well developed) are associated with high energy (mainly calcarenitic) limestones.

Using the same parameters as for the formation I, each of the units of formation II has been subdivided into three subunits. The age of the formation II ranges from Upper Gargasian to Upper Albian pp.

3. Biostratigraphic dating within the general biochronological framework

3.1. General Biochronologic framework

CHAMPETIER and MOULLADE (1968), BUSNARDO et al. (1968), and FOURCADE (1970) called attention to the biochronological value of taxa which can be used for biozonation: *Iraquia simplex* (HENSON), *Orbitolinopsis reticulata* MOULLADE and PEYBERNES (= *O. carochi* in FOURCADE), *Mesorbitolina parva* (DOUGLASS), *Pseudochoffatella cuvillieri* DELOFFRE, *Simplorbitolina manasi* CIRY and RAT, *Mesorbitolina texana* (ROEMER) and *Neorbitolinopsis conulus* (DOUVILLÉ). The authors proposed six biozones from the Bedoulian p.p. to the Albian p.p. in the Iberic and Betic regions. In 1976, PEYBERNES recognized five biozones characterized by the following species (from base to top): *Mesorbitolina parva*, *Pseudochoffatella cuvillieri*, *Simplorbitolina* cf. *manasi* (= *S. chauvei* FOURCADE), *Simplorbitolina manasi*, *Simplorbitolina conulus* SCHROEDER. This author was the first to propose that the Clansayesian is represented by the first appearance of *Mesorbitolina texana*. AZEMA et al. (1979), introduced a zone with *Simplorbitolina chauvei* according to FOURCADE (1970) between to zones with *Pseudochoffatella cuvillieri* and *Simplorbitolina manasi* although the object of their work was not the subdivision of the Clansayesian.

In 1979, PEYBERNES revised his former zonal scheme by transferring *Simplorbitolina chauvei* into the Lower Clansayesian and *Simplorbitolina manasi* into the Middle and Upper Clansayesian. In 1981, GARCIA-HERNANDEZ, distinguished a certain hierarchy between these species and concluded that some were

valuable for defining a biozone while others were limited to various horizons within one or more biozones.

The repartition of species by PASCAL (1984) agrees with that of PEYBERNES. However, in the majority of cases, the vertical distribution of the index forms is larger and shows some overlapping. For this reason PASCAL does not use a formal biozonation in his work. PASCAL puts *Simplorbitolina chauvei* and *Simplorbitolina manasi* (in the absence of *Simplorbitolina conulus*) together with *Pseudochoffatella cuvillieri* into the same chronological interval and mentions their coexistence in the Clansayesian. However, this does not agree with N'DA LOUKOU (1984), who puts *Pseudochoffatella cuvillieri* into the Upper Gargasian and dates the beginning of the Clansayesian with the first appearance of *Mesorbitolina texana*. N'DA LOUKOU's scheme was adopted by ARNAUD-VANNEAU (1986).

The chronological interpretation of these previously established biozonations and, which is of less importance, of individual distributions assigned to the taxa by various authors, is different in the Iberic and the Pyreneo-Aquitanic regions. While many different biozonation concepts exist for the Upper Aptian, there is general agreement regarding the Albian; this is exemplified by the vertical range of the succession *Simplorbitolina manasi*, *Simplorbitolina conulus* and *Neorbitolinopsis conulus* respectively represented in the Lower Albian p.p., the Upper and/or Middle Albian, and the Upper Albian (REY et al., 1977; BERTHOU and SCHROEDER, 1978; PEYBERNES, 1979; GARCIA-HERNANDEZ, 1981; ARNAUD-VANNEAU et al., 1985).

3.2. Biostratigraphical description and biochronological interpretation

In this chapter, the main taxa recognized in the lithological units and subunits of the Sierra del Carce are presented. The units/subunits are dated according to the general biostratigraphic framework discussed before.

Formation I

Lower unit (Ia). – The lower subunit (Ia1) is characterized by the association of: *Palorbitolina lenticularis* (BLUMENBACH), *Orbitolinopsis cuvillieri* MOULLADE, *O. buccifer* ARNAUD-VANNEAU & THIEULOUY, *O. briacensis* ARNAUD-VANNEAU, *Dictyoconus? vercorii* ARNAUD-VANNEAU, *Reclodictyoconus? giganteus* SCHROEDER, *Choffatella decipiens* SCHLUMBERGER, *Debarina hahounerensis* FOURCADE et al., and *Neotrocholina aff. aptiensis* (IOCHEVA). In the southeast of France this assemblage indicates the Lower Aptian (MASSE, 1976; ARNAUD-VANNEAU, 1980). The middle subunit (Ia2) contains in its lower part elements of the preceding association. In its upper part *Iraquia simplex* has its first appearance together with a rudist fauna of *Offneria* sp., *Caprina douvillei* PAQUIER and *Pachytraga paradoxa* (PICTET and CAMPICHE). This rudist fauna is characteristic for the Lower Aptian (MASSE, 1976–1985). In the upper subunit (Ia3) the Dictyoconinae are represented exclusively by *Iraquia simplex*. *Choffa-*

tella decipiens is still present; the rudists are dominated by the genus *Toucasia* associated locally with *Monopleura*, *Matheronia*, very scarce primitive radiolitids and *Horiopleura* cf. *baylei* PAQUIER. This unit can be dated as Lower Aptian, too.

Upper unit (Ib). – The lower subunit (Ib1) contains *Praeorbitolina wienandsi* SCHROEDER and *Mesorbitolina parva*. We consider this association as uppermost Lower Aptian in age. The rudists associated are *Agriopleura* sp. and *Horiopleura* cf. *baylei*. The upper subunit (Ib2) includes in its middle part *Mesorbitolina parva* and *Dictyoconus? pachymarginalis* SCHROEDER, and at the top *Mesorbitolina minuta* (DOUGLASS). According to studies on the stratigraphical distribution of this species, we have assigned a Lower Gargasian age to this sequence.

Formation II

Lower unit IIa. – The lower subunit (IIa1) is characterized by *Orbitolinopsis reticulata*, associated with scarce *Orbitolinopsis aquitanica* SCHROEDER & POIGNANT which are of Upper Gargasian age. Typical *Eoradiolites* are associated with this microfauna as well as *Polyconites* cf. *verneuili* (BAYLE) and *Horiopleura lamberti* BAYLE and COQUAND. The middle subunit (IIa2) lacks a characteristic microfauna. The rudists are dominated by *Pseudotoucasia* cf. *santanderensis* DOUVILLÉ. The upper subunit (IIa3) is well characterized by the presence of *Pseudochoffatella cuvillieri* associated with *Mesorbitolina texana*, relatively evolved radiolitids and forms belonging to the *Horiopleura-Polyconites* group. This fauna is can be dated as Upper Gargasian (Clansayesian pp.?).

Middle unit IIb. – Whereas the Lower subunit (IIb1) contains a insignificant microfauna, the overlying subunit IIb2 is characterized by *Simplorbitolina manasi* associated with Radiolitidae (*Eoradiolites* and *Praeradiolites*) and with the group *Horiopleura – Polyconites*; this suggests a Clansayesian pp. – Lower Albian age. *Simplorbitolina conulus*, defining the period from Lower Albian pp. to Middle Albian appears first in the upper subunit (IIb3).

Upper unit IIc. – In the lower subunit (IIc1) *Simplorbitolina conulus* continues. *Hensonina lenticularis* (HENSON) appears in the middle part of this subunit. The middle subunit (IIc2) contains a similar microfauna. *Neorbitolinopsis conulus* and *Neoiraquia* sp. cf. *convexa* DANILOVA are recorded in the upper subunit (IIc3) accompanied by the previous species. Rudists are mainly represented by costulated monopleurids (*Agriopleura? darderi* ASTRE) associated with evolved *Eoradiolites* and numerous *Polyconites*. According to recent studies, the sub-assembly IIc can be attributed to the Upper Albian p.p.

4. Discussion of the stratigraphical distribution of principal taxa

4.1. Calcareous Algae

Among the dasycladaceans we have found *Helioporella cylindrica* SOKAC and NIKLER. This form is well represented in the Outer Dinarids of Montenegro

(SOKAC and NIKLER, 1973) and occurs exclusively in the Bedoulian. In the Upper Aptian-Albian, *Cylindroporella ivanovici* (SOKAC) appears which has a wide stratigraphic distribution. This form, which is the type species of the genus *Korkyrella* SOKAC and VELIC 1981, as redefined by SOKAC in 1987, is assigned to the genus *Cylindroporella* JOHNSON, (MASSE and LUPERTO-SINNI, studies in progress.) It closely resembles *Cylindroporella? barnesii* JOHNSON but differs from this species by its external mace-like morphology. Its sterile and fertile parts are clearly differentiated; furthermore, the fertile ampoulae are much more numerous. SOKAC and VELIC originally included this species into *Cylindroporella? texana* JOHNSON; however, although the morphology is very similar, it can be distinguished by its general organization, which conforms to the genus *Cylindroporella*. We have observed rare specimens of *Montiella? cf. elitzae* (BAKALOVA) as well, hitherto only known from Hauterivian to Bedoulian beds. *Carpathoporella fontis* (PATRULIUS) and forms like *Neomeris* which pose specific determination problems and others of uncertain taxonomic status such as *Terquemella*, may be added. Finally, various types of the latter, some of which can be compared with the calcified cysts of *Triploporella*, have been recorded. The scarcity of dasycladaceans in the Upper Aptian-Albian interval is not surprising. This is the case in the entire perimediterranean area (MASSE, in press). It is rather astonishing that dasycladaceans are so rare in the Bedoulian. At this time, the general ecological conditions appear much more favourable. This may be concluded from the common occurrence of benthic foraminifera such as Dictyoconinae and Miliolidae and calcified Chlorophyceae of the genus *Boueina*. The last-mentioned genus, represented by various types, is also very frequent in the Upper Aptian-Albian.

Together with these taxa, some species of wide stratigraphic range occur. These include *Marinella lugeoni* PFENDER, *Polystrata alba* PFENDER, *Permocalculus*, as well as diverse porostromatic structures: *Cayeuxia*, *Bacinella-Lithocodium* and *Girvanella*.

4.2. Foraminifera

Our analysis of the studied interval adds a number of new aspects to previous work on the Iberic region. Recent progress in the micropalaeontology of eocretaceous Miliolidae (see mainly the works of NEAGU, 1984–1986 and ARNAUD-VANNEAU, 1980) has enabled us to examine the stratigraphic distribution and inventory of this family; however, our results have to be considered as provisional. The majority of the forms – *Cornuloculina tenuae* NEAGU, *Moesiloculina danubiana* NEAGU, *Massilina cf. ostroviana* Neagu, *Rumanoloculina cf. robusta* NEAGU and *Istriloculina eliptica* IOCHEVA – have a distribution which covers the Barremian-Bedoulian interval. Nevertheless the following should be remarked:

– In accordance with the observations of N'DA LOUKOU (1984), *Derventina filipescai* NEAGU does not extend beyond the limit of the Bedoulian-Gargasian.

– The Miliolidae assemblage changed significantly in the Upper Albian; because a detailed taxonomic review of these forms is lacking, this observation is mainly subjective and needs further evaluation.

Referring to the Orbitolinidae, five points have to be noted:

1. We did not distinguish the different morphotypes of *Iraqia simplex*: This name comprises all types agreeing with the original description of HENSON (1984), as well as those designated by BASSOULLET and MOULLADE (1962) under the name *Iraqia rubiensis*.

2. In the stratigraphic succession, *Simplorbitolina conulus* precedes *Neorbitolinopsis conulus*; this agrees with the observations of our predecessors (see mainly the review of R. SCHROEDER in ARNAUD-VANNEAU et al., 1985). Until now it was generally accepted that these two species were excluding each other in their stratigraphic range. *Simplorbitolina* was thought to occur essentially in the Lower to Middle Albian, *Neorbitolinopsis conulus* in the Upper Albian. We have observed the two species together in the uppermost beds of formation II (Upper Albian pp.). This confirms PEYBERNES (1979) who has pointed out the possibility of a coexistence of both species and has emphasized their close evolutionary relationship. The same observations can be made regarding the coexistence of *Simplorbitolina manasi* and *Simplorbitolina conulus* as suggested by PASCAL (1984).

3. The presence of the genus *Praeorbitolina* together with *Mesorbitolina parva* in the same level, already reported by PASCAL (1984) in the Cantabrian area, is confirmed here.

4. The horizon with *Praeorbitolina* and *Mesorbitolina*, which precedes the *Iraqia simplex* biozone in the Western Prebetic zone (GARCIA-HERNANDEZ, 1981) and in the meridional Iberic zone (ARIAS et al., 1987), appears to be inverted in the Sierra del Carche. We think this is due to local ecological reasons: *Iraqia* is closely connected to the facies with Requieniidae, while the *Praeorbitolina-Mesorbitolina* association is usually found in facies without rudists.

5. *Mesorbitolina texana* appears simultaneously with *Pseudochoffatella cuvillieri*. This raises questions regarding the value of both species for defining the Upper Gargasian in relation to the Clansayesian in carbonate platform facies. This species, vaguely defined by ROEMER (1849) and revised by DOUGLASS (1960) and SCHROEDER in 1979, has been the object of numerous interpretations. The name *Mesorbitolina texana* has been used for “*Mesorbitolina*” with sub- and supra-embryonic zones showing a well developed network of septa (DOUGLASS, 1960). MOULLADE and SAINT-MARC (1975) considered under this denomination forms with hemispheric proloculi, flat bases, and quite large size. For SCHROEDER (1979), who has revised the specimens collected and figured by ROEMER, *O. texana* has a sub-spheric, small to medium size “protoconch” with a generally flattened upper part.

Consequently, the forms mentioned by DOUGLASS, 1960 and MOULLADE and SAINT-MARC, 1975, such as *O. (M.) texana* and *O. (M.) minuta* DOUGLASS, belong after SCHROEDER respectively to *O. (M.) subconcava* (LEYMERIE) and *O. (M.) texana* ROEMER.

The results of the review of SCHROEDER with respect to *M. texana* appear to be correct. However, SCHROEDER's invalidation of *M. minuta* DOUGLASS is not clear, as it is based on the characteristics of the embryonal system and not on the structure of the marginal zone; the taxonomical importance of the latter structure was emphasized by DOUGLASS. Thus the identity of the taxa *O. texana* and *O. minuta* is not yet well demonstrated. After SCHROEDER's attempt to rehabilitate the concept of *O. (M.) subconca* LEYMERIE, PEYBERNES (1982) published a review of the type material. PEYBERNES showed that it was impossible to give formal validity to this taxon and proposed to designate *O. leymeriei* as neotype of *O. subconca* as it was assigned by SCHROEDER (PEYBERNES, 1982). However, after this author *O. leymeriei* does not include the forms with hemispheric embryos and flat bases (pro "*O. subconca*", sensu SCHROEDER and "*Orbitolina* sp. A" sensu FOURCADE and RAULT 1973) and could not be related to *O. texana*.

This opinion is in contradiction with the data presented in SCHROEDER's review in 1979. Recognizing these nomenclatural difficulties and considering the work of various authors on the Iberic region and the southwest of France, we have placed the mesorbitolinids with embryos, showing numerous chamberlets, into two groups:

- *O. (M.) minuta* comprises forms with subspheric embryos which are in agreement with the description of DOUGLASS. It could include, p.p., *O. (M.) texana* ROEMER, sensu SCHROEDER's review in 1979.

- *O. (M.) texana* for the forms with hemispheric embryos and a flat base, which obviously do not correspond to the *O. (M.) texana* "type" but to the *M. leymeriei* PEYBERNES - "*Orbitolina*" *pervia* DOUGLASS group, not yet reviewed in detail.

Finally it must be noted that we haven't found the genus *Archaeoalveolina* in the Upper Aptian-Albian interval, as recorded in the Balears (AZEMA et al., 1979) nor *Coskinolinella*, well known in the Aquitanic-Pyreneic area and its Cantabrian extension (ARNAUD-VANNEAU et al., 1985).

4.3. Rudists

Rudists are well represented in the whole succession and show a characteristic vertical distribution.

Caprinidae: *Offneria* sp. (large form with developed canals all around the valves and therefore attributed to the group *O. rhodanica* PAQUIER), and *Caprina douvillei*, are restricted to the Bedoulian like *Pachytraga paradoxa*. This stratigraphic position agrees with that known from the southeast of France (MASSE, 1976). No Caprinidae are present in the Upper Aptian and in most of the Albian; the genus *Caprina* re-appears at the end of the Albian. It is represented by *C. choffati* DOUVILLÉ in the basal part of the dolomites, overlying the studied succession (see p. 4).

Radiolitidae, represented mainly by *Eoradiolites*, increase in number notably in the middle of the Gargasian (levels with *Orbitolinopsis reticulata*,

O. aquitanica and *Mesorbitolina minuta*). These forms are small with thin and only partially cellular shells. In the Upper Gargasian larger forms with well developed cellular structures occur. Other forms of *Eoradiolites* with relatively large size and thick, cellular shells are recorded from the Clansayesian and the Albian; they are associated with *Praeradiolites*. As the general systematic framework of this group of primitive Radiolitidae is unsatisfactory we have voluntarily abstained from attributing these diverse forms to species described in the literature. A detailed taxonomic work is needed.

Like the Radiolitidae the *Polyconites-Horiopleura* group, identified in the uppermost Bedoulian and represented here by small forms, shows considerable development in the Upper Gargasian; *Horiopleura cf. lamberti* and *Polyconites* of the *verneuili* groups are very common and persist into the Clansayesian-Albian.

Monopleuridae are present in the whole succession, although they generally play a minor role from a quantitative point of view. Nevertheless they are particularly abundant in the Middle and Upper Albian. Costulated tubular forms belonging to the *Agriopleura? darderi* group form important biostromes. Requieridae are dominated by the genus *Toucasia* which is widely distributed abroad. *Pseudotoucasia* develops in the middle part of the Gargasien. *Pseudotoucasia santanderensis* is very abundant in both, the Upper Gargasian and the Clansayesian.

It becomes evident from this brief description, that the Sierra del Carche locality is essential for the knowledge of the Spanish Aptian-Albian rudists; until now, these were poorly known and stratigraphically only partially evaluated. The possibility of analyzing the evolution of primitive Radiolitidae within a precise biostratigraphic framework is exceptional in this area. Finally, our analysis suggests a certain number of modifications regarding the vertical partitions proposed by palaeontologists who have worked in the Aquitanic-Pyreneic domain and the revisions by PEYBERNES, in 1979. The stratigraphic appearance of the principal Gargasian-Albian taxa is generally younger than previously accepted.

5. Conclusions

The studied succession covers a time interval from the Lower Aptian p.p. to the Upper Albian p.p. It is divided into two main formations, each subdivided respectively into two and three units. Five subunits are recognized in the lower formation and nine in the upper, each showing distinct facies associations. Based essentially on foraminifera the time interval is subdivided into 10 biozones, whereas rudists are used as complementary indices. These biozones are defined by:

- the total range of a single species,
- the total range of a group of taxa (cenozone).

In addition, the limits of some zones are defined by the appearance of a particular taxon which may pass the boundary of the time interval (for example: *Mesorbitolina*).

The following biozones have been recorded:

1. *Orbitolinopsis cuvillieri* and *Rectodictyoconus? giganteus*, together with the *Caprina-Offneria-Pachytraga* group.

2. *Iraqia simplex*.

3. *Praeorbitolina-Mesorbitolina*.

In zones 2 and 3 the first Radiolitidae and primitive *Horiopleura* appear.

4. *Dictyoconus pachymarginalis*, with the initial appearance of *Mesorbitolina minuta*.

5. *Orbitolinopsis reticulata* and *O. aquitanica*.

In zones 4 and 5 large *Polyconites*, *Horiopleura* and *Pseudotoucasia* develop together with Radiolitidae.

6. *Pseudochoffatella cuvillieri*. Initial appearance of *Mesorbitolina texana*.

7. *Simplorbitolina manasi*. *Praeradiolites* appears together with *Hensonina lenticularis*.

8. *Simplorbitolina manasi* and *Simplorbitolina conulus*.

In zones 6, 7 and 8, Radiolitidae of large size develop.

9. *Simplorbitolina conulus* and *Neorbitolinopsis conulus*.

10. *Neorbitolinopsis conulus* and *Neoiraquia*.

In zones 9 and 10, Radiolitidae and *Agriopleura? darderi* develop, forming biostromes.

This biozonation framework lacks the *Coskinolinella* and *Archaeoalveolina* species which may be considered as valuable index fossils, as well as *Simplorbitolina chauvei*.

Some of the recorded taxa are linked to the northwestern part of the "European continent", especially to the "Iberic plate" and adjacent regions (i.e. of the Aquitaine). Many species are known from European and African regions or from both. Consequently, most of the proposed biozones are valuable for biostratigraphical correlations within the Tethyan realm.

Acknowledgements

We gratefully acknowledge the determination of the Barremian ammonites by the Rvd. G. CONTE of the University of Marseille.

We also acknowledge the help of Miss B. BARTOLOMÉ and Miss R. OJEDA who kindly typed the manuscript, of Mr. J. L. GONZALEZ-PACHÓN who printed the photographs, of Mr. J. L. GONZALES-GALÁN and Mr. G. HERRERO who made the thin sections and Mr. C. SANCHEZ who drew the illustrations.

This study was supported by C.S.I.C.-C.A.I.Y.T. 452 project and also by the Spanish-French Action n. 90/168.

References

- ARIAS, C., MASSE, J. P., and VILAS, L. (1987): Modalités d'installation et de développement des plates-formes carbonatées urgoniennes à la charnière des domaines ibérique et bétique (Espagne meridionale) durant l'Aptien inférieur. – Mém. Géol. Univ. Dijon, **11**: 213–223.
- ARNAUD-VANNEAU, A. (1980): Micropaleontologie, paleoécologie et sédimentologie d'une plate-forme carbonatée de la marge passive de la Tethys. – Geol. Alpine. Grenoble, **11**: 874 p.
- ARNAUD-VANNEAU, A. (1986): Episodes transgressifs et renouvellements des Foraminifères benthiques sur les plates-formes du Crétacé inférieur du Sud de la France. – Bull. Centres Rech. Explor.-Prod. Elf-Aquitaine, **10/2**: 405–420.
- ARNAUD-VANNEAU, A., CHERCHI, A., CHIOCCHINI, M., DE CASTRO, P., FOURCADE, E., HAMAOU, M., LUPERTO SINNI, E., NEUMANN, H., PRESTAT, B., and SCHROEDER, R. (1985): Les grands Foraminifères du Crétacé moyen de la région méditerranéenne. – Géobios. Lyon. Mem. spec., **7**: 160 p.
- AZEMA, J. (1977): Etude géologique des zones externes des Cordillères bétiques aux confins des provinces d'Alicante et de Murcie (Espagne). – Thèse Sciences Univ. Paris VI, 393 pp.
- AZEMA, J., CHABRIER, G., CHAUVE, P., and FOURCADE, E. (1979): Nouvelles données stratigraphiques sur le Jurassique et le Crétacé du Nord-Ouest d'Ibiza (Balears, Espagne). – Geologica Rom., **18**: 1–21.
- BAENA, J. (1981): Mapa Geológico de España E. 1/50.000. n° 869, Jumilla. IGME. Madrid.
- BASSOULET, J. P., and MOULLADE, M. (1962): Les Orbitolinidae du Crétacé inférieur de la Sierra du Montsec, Province de Lèrida (Espagne). – Rev. Micropaleont., **5/2**: 104–114.
- BERTHOU, P. Y., and SCHROEDER, R. (1978): Les Orbitolinidae et Alveolinidae de l'Albien supérieur-Cenomanien inférieur et le problème de la limite Albien-Cénomanien dans le sud-ouest de la région de Lisbonne (Portugal). – Cahiers Micropaleont., Paris, **3**: 51–104.
- BUSNARDO, R., CHAMPETIER, Y., FOURCADE, E., et MOULLADE, M. (1968): Etude stratigraphique des faciès à Orbitolinidés et à Rudistes de la Sierra Mariola (province d'Alicante, Espagne). – Géobios, **1**: 165–185.
- CHAMPETIER, Y., et MOULLADE, M. (1968): Sur la présence de Barrémien et d'Aptien à Orbitolinidae dans la partie septentrionale de la feuille d'Alcira (prov. de Valence, Espagne). – C. R. Somm. Soc. Géol. France, **1**: 12–14.
- DOUGLASS, R. C. (1960): The foraminiferal genus Orbitolina in North America. – Geol. Surv., Prof. pap., **333**: 52 p.
- FOURCADE, E. (1970): Le Jurassique et le Crétacé aux confins des Chaînes Bétiques et Ibériques (SE de l'Espagne). Thèse Sciences Univ. Paris VI, 468 pp.
- FOURCADE, E., JEREZ, L., RODRIGUEZ, T., and JAFFREZO, M. (1972): El Jurásico terminal y el Cretácico inferior de la Sierra de la Muela (provincia de Murcia). Consideraciones sobre las biozonas con Foraminíferos del Albense-Aptense del Sureste de España. – Rev. Esp. Micropaleont. No extraordinario, 215–248.
- FOURCADE, E., et RAOULT, J. F. (1973): Crétacé du Kef Hahouner et position stratigraphique d'«*Ovalveolina reicheli* P. de CASTRO (série septentrionale du môle néritique du Constantinois, Algérie) – Rev. Micropaléont., **15/4**: 227–246.
- GARCIA-HERNANDEZ, M. (1978): El Jurásico terminal y el Cretácico inferior en las Sierras de Cazorra y del Segura (zona Prebética). – Tesis Doct. Universidad de Granada. 344 p.

- GARCIA-HERNANDEZ, M. (1981): Biozonation du Crétacé inférieur à l'aide des Foraminifères benthiques et des algues Dasycladacées dans le Prébetique Occidental (Cordillères bétiques, Espagne). – *Géobios*, **14**: 261–267.
- GARCIA-HERNANDEZ, M., LOPEZ GARRIDO, A. C., RIVAS, P., SANZ DE GALDEANO, C., and VERA, J. A. (1980): Mesozoic Paleogeographic evolution of the External Zones of the Betic Cordillera. – *Geol. Mijnbouw*, **59**: 155–168.
- HENSON, F. R. S. (1948): Larger imperforate Foraminifera of South-Western Asia, Families Lituolidae, Orbitolinidae and Meandropsinidae. – *British Museum (Nat. Hist.) London*, 127 p.
- MASSE, J. P. (1976): Les calcaires urgoniens de Provence (Valanginien-Aptien inférieur): stratigraphie, paléontologie; les paléoenvironnements et leur évolution. Thèse Sciences. Marseille, 445 p.
- MASSE, J. P. (1985): Paléobiographie des Rudistes du domaine périméditerranéen à l'Aptien inférieur. – *Bull. Soc. géol. France*, (8), **1**: 715–721.
- MASSE, J. P. (in lit.): Relations entre modifications biologiques et phénomènes géologiques sur les plates-formes carbonatées du domaine péri-méditerranéen au passage Bedoulien-Gargasien. *Géobios*.
- MOULLADE, M., et SAINT-MARC, P. (1975): Les «Mésorbitolines»: révision taxonomique, importance stratigraphique et paléobiogéographique. – *Bull. Soc. géol. France*, (7), **XVII/5**: 828–842.
- N'DA LOUKOU, V. (1984): L'Urgonien des Pyrénées Occidentales. Thèse Doctorat 3^e cycle, Univ. de Pau, 318 p.
- NEAGU, TH. (1984): Nouvelles données sur la morphologie du test, sur la systématique et la nomenclature des Miliolidés agatisthegues du Mésozoïque. – *Rev. Española Micropaleont.*, **16**: 75–90.
- NEAGU, TH. (1986): Barremian Lower Aptian Miliolid Fauna in Southern Dobrogea (Romania). – *Rev. Española Micropaleont.*, **28**: 313–348.
- PASCAL, A. (1984): Les Systèmes biosédimentaires urgoniens (Aptien-Albien) sur la marge Nord Ibérique. – Thèse Sciences Dijon, 561 p.
- PEYBERNES, B. (1976): Le Jurassique et le Crétacé inférieur des Pyrénées franco-espagnoles entre la Garonne et la Méditerranée. – Thèse Univ. Toulouse, 459 pp.
- PEYBERNES, B. (1979): L'Urgonien des Pyrénées; essai de synthèse. – *Géobios. Mém. spec.*, **3**: 79–87.
- PEYBERNES, B. (1982): Les Orbitolinidés Crétacés d'Afrique: essai de synthèse. – *Cah. de Micropaleont.*, **2**: 13–28.
- REY, J., BILOTTE, M., et PEYBERNES, B. (1977): Analyse biostratigraphique et paléontologique de l'Albien marin d'Estremadura (Portugal). – *Géobios*, **10/3**: 369–393.
- RODRIGUEZ ESTRELLA, T. (1979): Geología e Hidrogeología del sector de Alcaraz-Lietor-Yeste (prov. de Albacete). – *Mem. IGME.*, **97**. (I y II): 566 pp.
- ROEMER, F. (1849): Texas. Bonn, 464 p.
- SCHROEDER, R. (1979): Les Orbitolines de l'Aptien: définition, origine et évolution. Colloque sur l'Urgonien des Pays Méditerranéens. Grenoble. – *Géobios, Mém. sp.*, **3**: 289–299.
- SOKAC, B. (1987): On some controversial Dasyclad genera and species and their stratigraphic position in the Lower Cretaceous deposits of the Dinarides. – *Geol. Vjesnik. Zagreb*, **40**: 9–38.
- SOKAC, B., and NIKLER, L. (1973): Calcareous algae from the Lower Cretaceous of the environs of Niksic, Crna. Gora (Montenegro). – *Paleont. Jugosl.*, **13**: 57 p.
- SOKAC, B., and VELIC, I. (1981): *Korkyrella* n. gen. (Dasycladaceae) from the Upper Barremian and Lower Aptian of the island of Korcula. – *Paleont. Jugosl.*, **24**: 1–12.

Plate I

Fig. 1 & 2: *Iraqia simplex* (HENSON).

1. Oblique vertical section.

2. Horizontal section.

Fig. 3 & 6: *Simplorbitolina manasi* CIRY and RAT.

3. Axial section.

6. Horizontal section.

Fig. 4, 5 & 10: *Simplorbitolina conulus* SCHROEDER.

4. Vertical section.

5. Horizontal section.

10. Axial section.

Fig. 7: *Neorbitolinopsis conulus* (DOUVILLÉ).

Horizontal section.

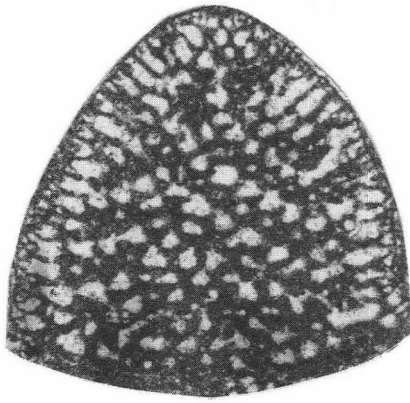
Fig. 8: *Neoiraquia convexa* DANILOVA.

Axial section.

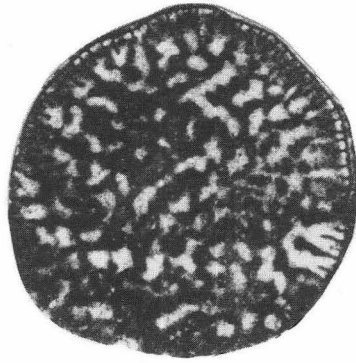
Fig. 9 & 11: *Neoiraquia* cf. *convexa* DANILOVA.

Oblique vertical sections.

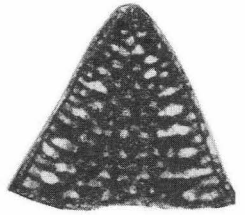
Magnification for all sections x 40.



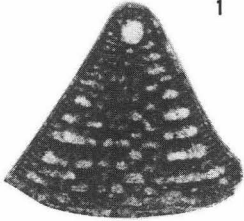
1



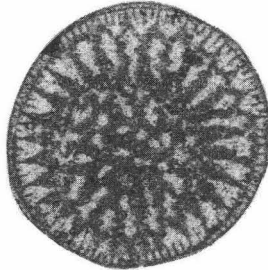
2



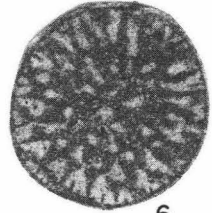
3



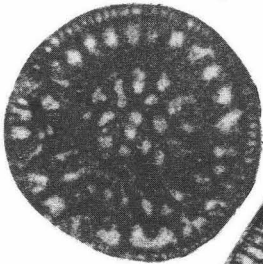
4



5



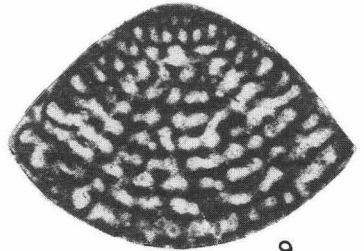
6



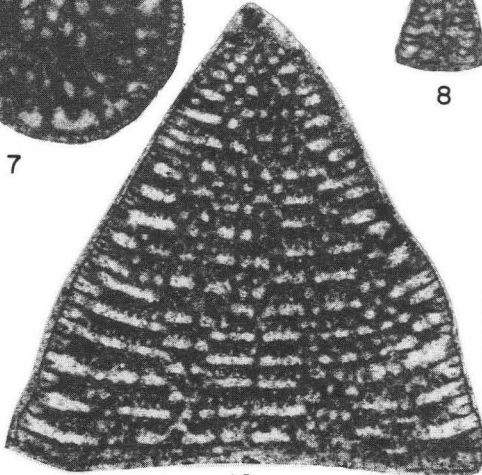
7



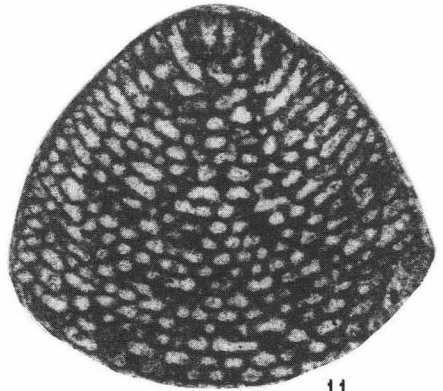
8



9



10



11

Plate II

- Fig. 1 & 2: *Rectodictyoconus ? giganteus* SCHROEDER
1. Horizontal oblique section.
2. Vertical oblique section.
- Fig. 3: *Orbitolinopsis cuwillieri* MOULLADE.
Vertical section.
- Fig. 4: *Orbitolinopsis briacensis* ARNAUD-VANNEAU.
Vertical section.
- Fig. 5: *Orbitolinopsis buccifer* ARNAUD-VANNEAU and THIEULOUY.
Oblique section.
- Fig. 6: *Dictyoconus ? vercorii* ARNAUD-VANNEAU.
Oblique vertical section.
- Fig. 7: *Dictyoconus ? pachymarginalis* SCHROEDER.
Oblique vertical section.
- Fig. 8: *Orbitolinopsis aquitanica* SCHROEDER and POIGNANT.
Oblique vertical section.
- Fig. 9: *Orbitolinopsis reticulata* MOULLADE.
Oblique vertical section.
- Fig. 10: *Palorbitolina lenticularis* (BLUMENBACH).
Apical oblique section showing the macrospheric embryonic apparatus.
- Fig. 11: *Praeorbitolina wienandsi* SCHROEDER.
Apical oblique section showing the macrospheric embryonic apparatus.
- Fig. 12: *Mesorbitolina parva* (DOUGLASS).
Subaxial oblique section showing the macrospheric embryonic apparatus.
- Fig. 13: *Mesorbitolina texana* (ROEMER).
Axial section.

Magnification for all sections x 40.

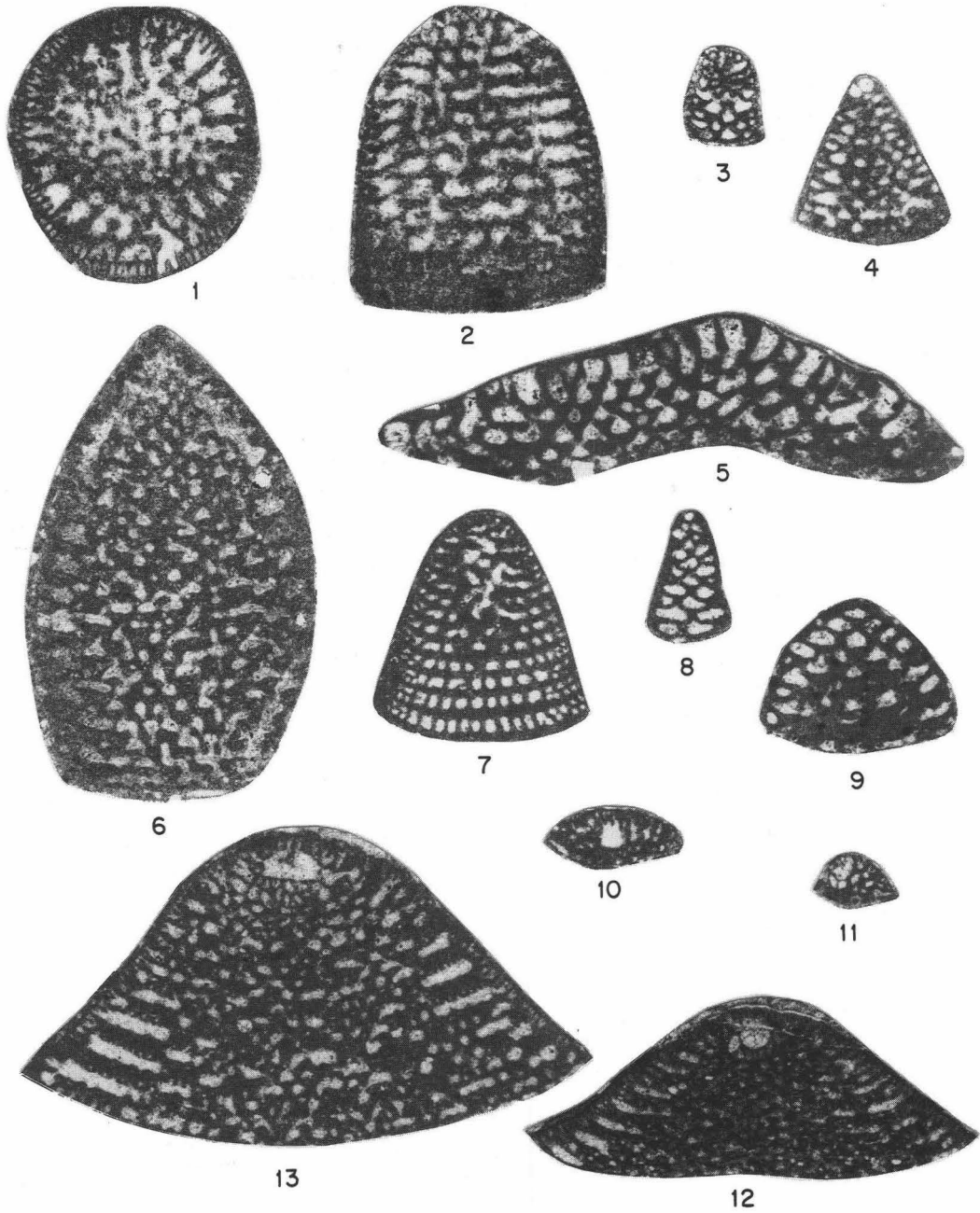


Plate III

- Fig. 1: *Pseudochoffatella cuvillieri* DELOFFRE (x 20)
Subaxial section.
- Fig. 2: *Neomeris* sp. (x 50)
Transverse section of a thallus fragment.
- Fig. 3: *Helioporella cylindrica* SOKAC and NIKLER (x 40)
Transverse section of a thallus fragment.
- Fig. 4: *Boueina* (x 40)
Longitudinal section of a thallus fragment.
- Fig. 5, 6 & 7: *Cylindroporella ivanovici* (SOKAC) (x 50)
5. Transverse section of the fertile part.
6. Transverse section of the sterile basal part.
7. Longitudinal section of the basal part.
- Fig. 8: *Charentia nana* ARNAUD-VANNEAU (x 50)
Subaxial section.
- Fig. 9: *Charentia cuvillieri* NEUMANN (x 40)
Equatorial transverse section.
- Fig. 10: *Vercorsella scarcellai* (DE CASTRO) (x 50)
Oblique vertical section.
- Fig. 11: *Glomospira urgoniana* ARNAUD-VANNEAU (x 50)
Transverse section.
- Fig. 12: *Carpathoporella fontis* (PATRULIUS) (x 50)
Transverse section.
- Fig. 13: *Derventina filipescui* NEAGU (x 50)
Subaxial section.
- Fig. 14: *Nautiloculina bronnmanni* ARNAUD-VANNEAU and PEYBERNES (x 50)
Subaxial section.
- Fig. 15: *Neotrocholina* aff. *aptiensis* (IOCHEVA) (x 50)
Axial section.
- Fig. 16: *Cuneolina* gr. *pavonia* D'ORB. (x 50)
Axial section.
- Fig. 17: *Choffatella decipiens* SCHLUMBERGER (x 50)
Subaxial section.
- Fig. 18: *Montiella* cf. *elitzae* (BAKALOVA) (x 40)
Longitudinal section.

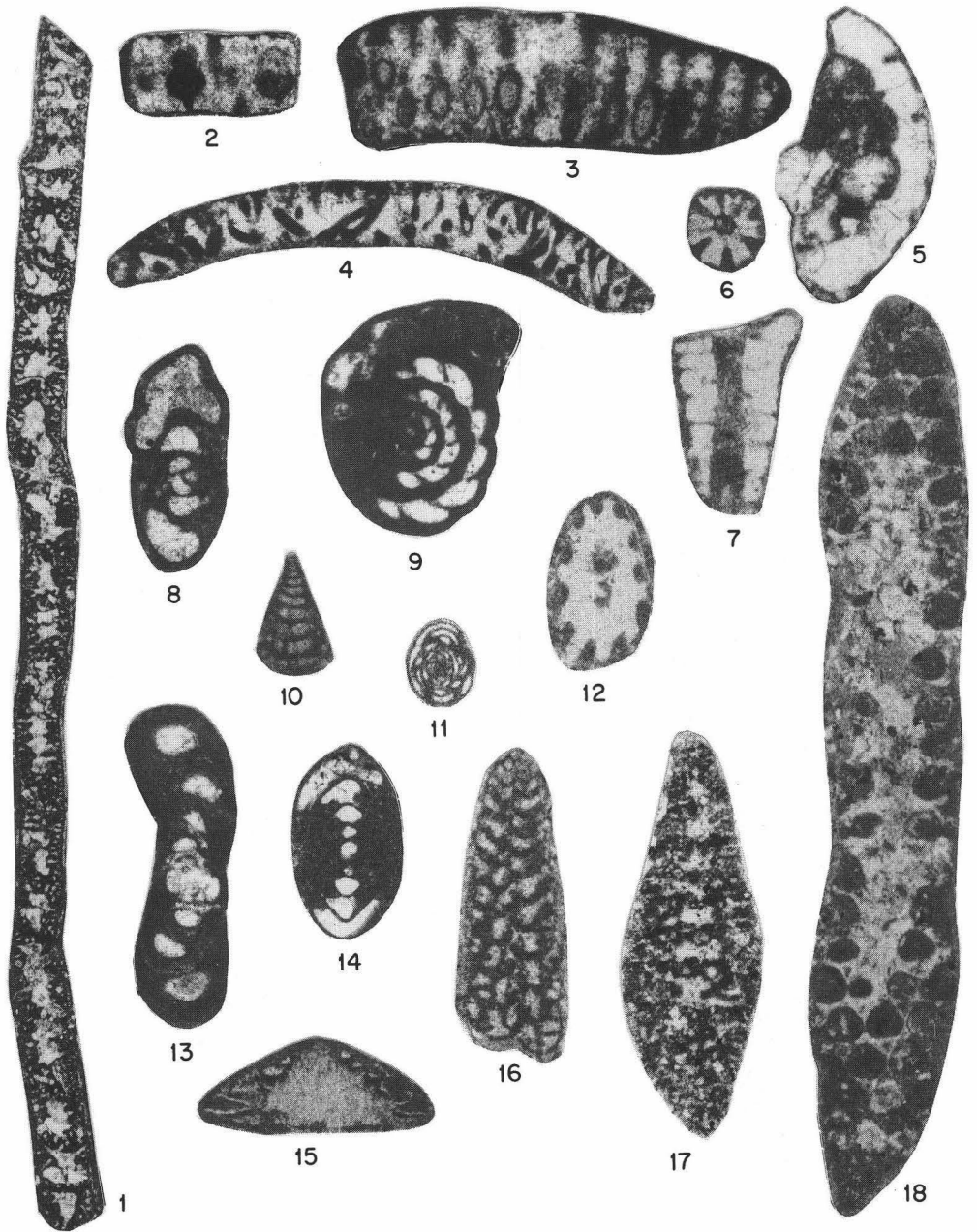


Plate IV

Fig. 1: *Pseudotoucasia santanderensis* (DOUVILLE)

Transverse section of a two valves specimen.

p. m. p. – posterior myophoral plate,

u. v. – upper valve,

l. v. – lower valve.

Fig. 2: *Horiopleura* sp. (primitive form).

Radial section of a two valves specimen.

a. m. p. – anterior myophoral plate,

p. m. p. – posterior myophoral plate (without accessory cavity).

Fig. 3: *Pachytraga paradoxa* (PICTET and CAMPICHE)

Transverse section of the lower valve.

p. a. c. – posterior accessory cavity,

c. – anterior palleal canals.

Fig. 4: *Offneria* sp. (gr. *rhodanica* PAQUIER)

Transverse oblique section of the lower valve (notice the development of palleal canals on the ventral side).

Fig. 5: *Caprina douvillei* PAQUIER

Transverse section of the upper valve (notice the pyriform palleal canals developed on the ventral side).

p. a. c. – posterior accessory cavity.

Fig. 6: *Agriopleura ? darderi* (ASTRE)

Transverse section of a cluster of lower valves with well expressed outer costal ornamentation.

Fig. 7: *Eoradiolites* sp.

Transverse section of a cluster of lower valves.

Fig. 8: *Eoradiolites* sp.

Transverse section of the lower valve.

L. – ligamental ridge, m. – myophore (of the upper valve),

S.-E. – prominent siphonal bands.

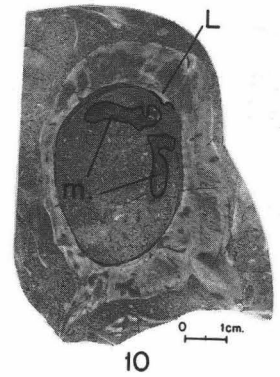
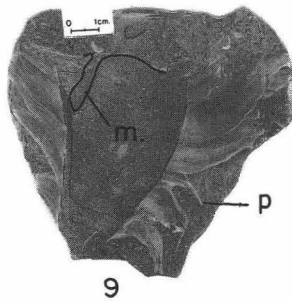
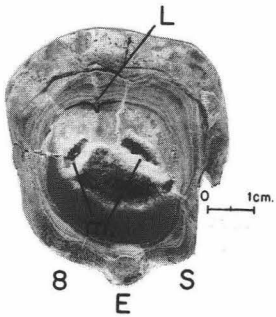
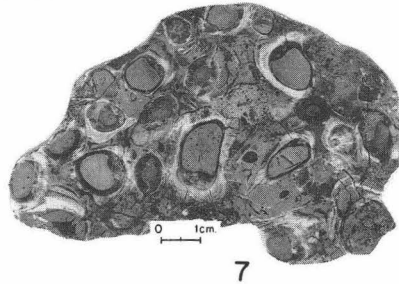
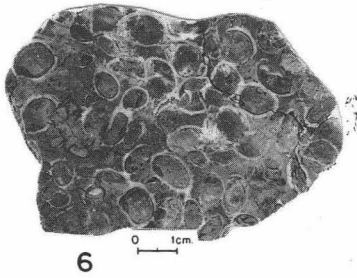
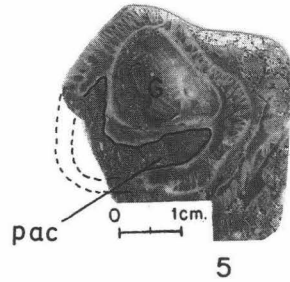
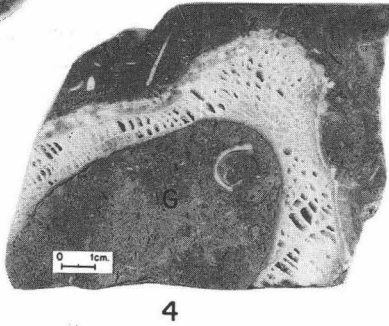
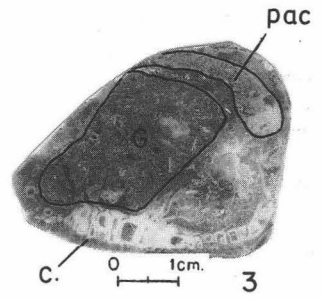
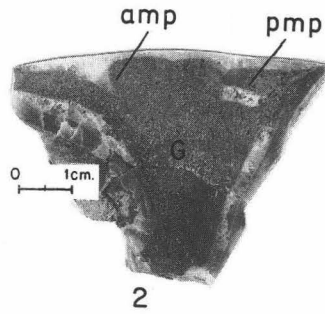
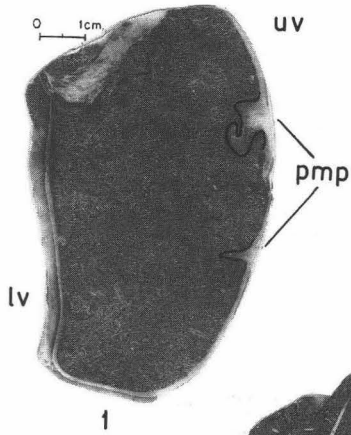
Fig. 9 & 10: *Praeradiolites* sp.

9. Radial section of a two valves specimen. Notice the deflected outer plates (p) and the myophore of the upper valve (m).

10. Transverse section of the lower valve showing the great development of the outer plates on the ventral side and the myophoral apparatus (of the upper valve).

L. – ligamental ridge, m. – myophores.

For all the sections: G. – body cavity.



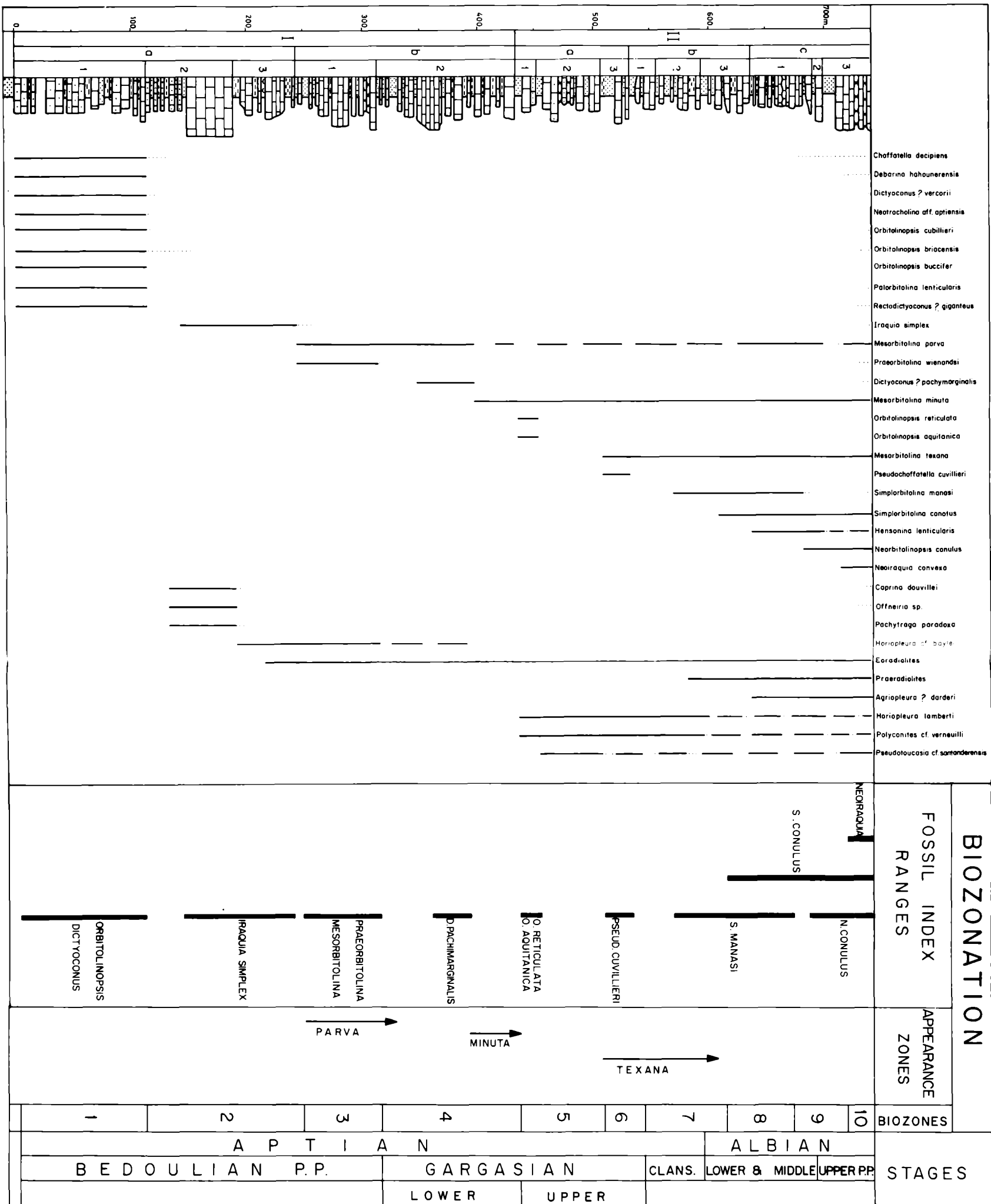


Fig. 2: Lithological and biostratigraphical subdivision of the Sierra del Carbe sequence.