

Carboniferous auloporids from the Iberian Peninsula: palaeoecology, diversity, and spatio-temporal distribution

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Abstract

Auloporid corals are common in the Palaeozoic and very frequent in the Carboniferous buildups of the Iberian Peninsula. The aim of this study is to analyze the diversity of these corals through a taxonomical recognition of the species and morphotypes that occur in the Iberian Peninsula. Eighteen sections have been sampled between the Ossa-Morena (Mississippian) and Cantabrian (Pennsylvanian) zones dated as upper Viséan to early Kasimovian. In addition, other localities where auloporids occur and are cited in the literature have been also used for this study. The taxonomical identification has been carried out using the criteria proposed by Tchudinova (1980) with little modifications. Thus, eighteen morphotypes and two species belonging to nine nominal genera have been identified (*Multithecopora* sp. A-H, *Syringopora* sp. A-B, *Aulopora* sp. A-B, *Cladochonus* sp. A-B, *Syringoaalcyon* sp., *Roemeripora* sp., *Sinopora* sp., *Mastopora?* sp., *Multithecopora hontoriense* and *Neomultithecopora cantabrica*). Through a classical microfacies study, the environments where the auloporids lived have been identified, as well as the growth patterns and the features of sedimentation. Finally, a preliminary biostratigraphic range chart for the Carboniferous auloporoids from the Iberian Peninsula has been achieved.

Keywords: Iberia, Ossa-Morena Zone, Cantabrian Zone, Auloporid corals, Carboniferous

Resumen

Los corales aulopóridos son muy comunes en el Paleozoico y muy frecuentes en las bioconstrucciones del Carbonífero de la Península Ibérica. Con el objetivo de analizar la diversidad de estos corales, se ha llevado a cabo un detallado estudio de los morfotipos y especies de aulopóridos carboníferos que aparecen en la Península Ibérica. Para ello se han estudiado 18 secciones repartidas entre la Zona de Ossa-Morena (Missisípico,) y la Zona Cantábrica (Pennsilvánico), con edades comprendidas entre el Visense superior y el Kasimovien-se inferior. Así mismo para este estudio se han tenido en cuenta otros aulopóridos ya identificados en trabajos previos. La identificación taxonómica se ha realizado siguiendo los criterios propuestos por Tchudinova (1980) con algunas modificaciones. De esta manera se han identificado dieciocho morfotipos y dos especies que pertenecen a nueve géneros (*Multithecopora* sp A-H, *Syringopora* sp A-B, *Aulopora* sp A-B, *Cladochonus* sp A-B, *Syringoaalcyon* sp, *Roemeripora* sp, *Sinopora* sp, *Mastopora?* sp, *Multithecopora hontoriense* and *Neomultithecopora cantabrica*). Mediante un estudio clásico de las microfacies asociadas a los aulopóridos de la Península Ibérica se han identificado los ambientes y características de crecimiento o depósito. Por último se ha realizado una tabla bioestratigráfica preliminar con los datos de los que se dispone actualmente.

Palabras clave: Iberia, Zona de Ossa-Morena, Zona Cantábrica, Corales aulopóridos, Carbonífero

1. Introduction and background

1.1. Introduction

Auloporida Sokolov, 1947 is an order of tabulate corals that are very abundant during the Palaeozoic Era. Their dis-

tribution ranges from Early Ordovician to Late Permian (Hill, 1981). Auloporids are both primary and secondary builders in the Carboniferous and had an important role along with the algae and others corals in the development of reef limestones (Said *et al.*, 2010; Poty, 2010; Aretz and Herbig, 2010). Wahlman (2002) stated that auloporoids are closely related

to chaetetids in his chaetetid-buildups and Minwegen (2001) described the same relationship in the buildups of the Cantabrian Zone, referring to this association as 'chaetetid-coral reef mounds' (*Korallen-Chaetetiden-Reefmounds*).

Although this group is common in the record, there are few palaeontological studies on Carboniferous auloporids in the Iberian Peninsula. In a general way, this group has been frequently cited, but not described, in palaeontological and geological studies of the Carboniferous of the Iberian Peninsula as auloporid, syringoporid or tabulate corals.

This article represents a compendium of the variety and diversity of Carboniferous auloporid taxa found in the Iberian Peninsula, and the different type of facies and environments in which they grew. The stratigraphic distributions as well as the growth-patterns used by auloporid corals are also objectives of this paper. An exhaustive sampling and identification of the auloporid corals of the Iberian Peninsula in eighteen sections was made to achieve this goal. These sections are spread through the Ossa-Morena (Mississippian) and Cantabrian (Pennsylvanian) zones (Fig. 1) dated as late Viséan to early Kasimovian. Additionally, other information obtained from the literature is also included in this work. The criteria used for the identification and characterization of the genera were those proposed by Tchudinova (1980) and are analysed below.

1.2. Background

Auloporids have been cited in Mississippian (Ossa-Morena Zone) materials: Cózar *et al.* (2007), and Cózar and Rodríguez (1999) cited the presence of tabulate corals in reference to Auloporida in Peñarroya-2 section, Córdoba (Spain). Cózar and Rodríguez (2000), Cózar and Rodríguez (2001) and Rodríguez and Rodríguez-Curt (2002) cited the occurrence of tabulate corals in reference to Auloporida in Antolín-1 section, Antolín-3 section and Sierra Boyera section, Córdoba (Spain). Cózar *et al.* (2007) described the Fuenteobejuna section and found abundant tabulate corals which correspond with Auloporida in Córdoba (Spain). Rodríguez *et al.* (1992) and Rodríguez (1996) identified *Syringopora*, *Pleurosyphonella* and other tabulate corals in the Cerro de los Santos, Cerro Almeña and El Torreón sections from the Carboniferous Basin of Los Santos de Maimona, Badajoz (Spain).

Cózar and Rodríguez (2001) found tabulate corals in the Camino del Águila section, which correspond with remains of Auloporida. Gómez-Herguedas and Rodríguez (2008) found tabulate corals that were identified as syringoporids and/or auloporids in the La Cornuda section, Córdoba (Spain).

Within the Betic Cordillera, auloporid corals were cited by Herbig (1984) in the Marbella Conglomerates, which are a subunit of the Malaguide Complex, Málaga (Spain). The auloporids occur within post-Viséan carbonate pebbles.

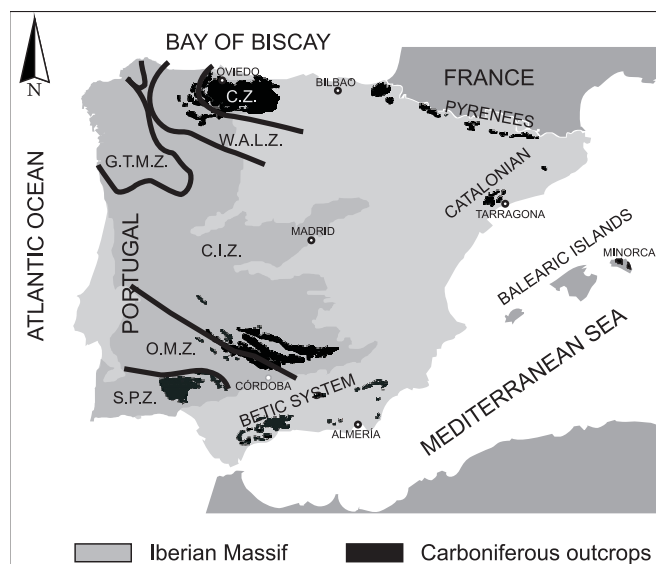


Fig.-1.- Synthetic map showing the distribution of the main Carboniferous outcrops of the Iberian Peninsula. (Cantabrian Zone, C.Z.; West-Asturian-Leonese Zone, W.A.L.Z.; Galicia-Tras os Montes, G.T.M.Z.; Central-Iberian Zone, C.I.Z.; Ossa-Morena Zone, O.M.Z. and South Portuguese Zone, S.P.Z.) Modified from Colmenero *et al.* (2002).

Numerous outcrops yielded auloporoids in the Pennsylvanian (Cantabrian-Zone). Winkler Prins (1971) described the type section of the Valdeteja Formation, in the Barcaliente Valley, León (Spain) and found some tabulate corals, citing *Cladochonus* sp. and *Paleofavosites* sp. Later Eichmüller (1985) described additional sections of the Valdeteja Formation and found numerous samples of a syringoporid coral that was classified as *Sinopora*. Recently, Villa *et al.* (2001) analyzed the biostratigraphic sequence of this section and described some facies containing auloporid corals.

van de Graaff (1971a) cited small colonies of auloporid corals in growth-position related to chaetetids in the Piedrasluengas Limestone, Palencia (Spain).

van Loon (1971) mentioned syringoporoid corals together with other fossil remains in the Pando Limestone section, at the Pando Pass and in the road to Prioro, León (Spain). Later, Fernández and Barba (1992) identified auloporoid corals in the Pando Pass.

The only taxonomical study on auloporids in the Spanish record was presented by Rodríguez and Ramírez (1987). These authors described the taxonomical characteristics of two genera and three new species of auloporids that occur in the La Playa de la Huelga section, Asturias (Spain) and interpreted the environments of growth. Later, this section was studied by Minwegen (2001), who identified the same genera. Similarly, the transect of San Antolín-La Huelga was described by Bahamonde *et al.* (2008), who also recognized syringoporid corals.

Minwegen (2001) studied the microfabrics and building organisms dominant during the Carboniferous in several sec-

tions of the Cantabrian Zone as indicated above. This author recognized auloporid corals associated with chaetetids in the Villanueva section, Asturias (Spain). Likewise she recognized syringoporoids in the Piedrasluengas limestone as well as *Neomultithecopora* in the Fuente De section, Cantabria (Spain).

The Fuente De section (*sensu* Minwegen, 2001) was also studied by Martínez-Chacón *et al.* (2001) and Merino-Tomé *et al.* (2009), who identified the genus *Neomultithecopora*, forming small buildups associated with chaetetids, in Cantabria (Spain).

Rodríguez *et al.* (1997) identified some taxa of rugose corals in a section near Ribadesella town, Asturias (Spain), where numerous incrustations of auloporid corals occur on the rugose coral skeletons.

Coronado and Rodríguez (2009) recognized syringoporoid corals in the algal-mounds of Cosgaya Formation in Cantabria (Spain) where they occur associated with calcareous algae, chaetetids and rugose corals.

Corrochano *et al.*, (in press) found syringoporid corals in the Lena Group within the Levinco Formation, León (Spain) and Corrochano *et al.* (2009) identified syringoporid corals in the Bachende Limestone in León (Spain) also included in the Lena Group.

2. Geological settings

The outcrops sampled belong to the Carboniferous rocks of the Iberian Peninsula (Fig. 1). These materials crop out mainly in the Iberian Massif (Lotze, 1945; Julivert, 1971), which occupies almost half of the Iberian Peninsula and corresponds with the European zone of the Variscan Belt. There are additionally a number of smaller Carboniferous outcrops, separated by a Mesozoic and Cenozoic cover, exposed in the Iberian Range, Pyrenees, Catalanian Coastal Ranges, Minorca and Betic Cordillera (Colmenero *et al.*, 2002). See figures 2 and 3 for the location of the eighteen studied and sampled sections in the Ossa-Morena and Cantabrian Zones of the Iberian Massif.

2.1. Ossa-Morena Zone

The Ossa-Morena Zone is located in the southwestern part of the Iberian Massif, and contains two marine Mississippian basins: the Guadiato Area and the Los Santos de Maimona Coal Basin (Wagner, 2004). Nine sections have been sampled in both basins.

The Guadiato Area is situated in Córdoba province and is a large and complex area in SW Spain (Fig. 2) that comprises Mississippian siliciclastic and limestone rocks. It is divided into three bands (Cózar and Rodríguez, 1999): 1) Fresnedoso Unit, composed mainly of Viséan siliciclastic rocks, 2) San Antonio-La Juliana Unit, composed of Serpukhovian siliciclastic and limestone rocks, and 3) Sierra del Castillo Unit, composed mainly of Viséan limestone rocks. Most palaeontological and stratigraphical studies were focused on the Viséan

units. This is especially marked for studies on rugose corals, (Rodríguez 1985; Rodríguez and Falces, 1996; Rodríguez *et al.*, 2001; Rodríguez and Somerville, 2007; Gómez-Herguedas and Rodríguez, 2008).

Seven sections have been sampled in the Guadiato Area (Córdoba province): La Adelfilla, Sierra de la Estrella, El Collado, Antolín, Fuenteobejuna, San Antonio and La Cornuda (Fig. 2).

Only two sections (Los Santos de Maimona and Cerro Almeña) have been sampled in *Los Santos de Maimona Coal Basin* that is located in the Badajoz province, between the towns of Los Santos de Maimona, Fuente del Maestre, and Feria. The Carboniferous outcrops form a narrow strip 11 km SE-NW and a width of 1 to 3 km, NE-SW (Fig. 2) and is formed by siliciclastic and carbonate materials, and small volcanic bodies, with a Mississippian age (Rodríguez *et al.*, 1992).

2.2. Cantabrian Zone

The Cantabrian Zone is the most northern part of the Iberian Massif (Lotze, 1945), located in the north-west of the Iberian Peninsula. In this area, five zones can be distinguished from a structural point of view, with boundaries set by major thrusts. These are, from west to east: Fold-and-Thrust region (Somiedo-Correcillas, Sobia-Bodón and Aramo units), Central Carboniferous Coal Basin, Thrust Region (Ponga Unit), Picos de Europa Unit, and Pisuerga-Carrión Unit (Fig. 3). Overall, they show a vergence towards the east or the north, with the western units overthrusting the eastern ones. The Pisuerga-Carrión Region or Unit, in the innermost part, is overthrust by all the surrounding units.

Nine sections have been sampled in different units of the Cantabrian Zone (Fig. 3): Manto del Esla (Prioro section, León province); Manto del Ponga (Ribadesella and Playa de la Huelga sections, Asturias province); Sobia-Bodón (Valdeteja section and Las Majadas section, León province); Pisuerga-Carrión (Las Ilces section in Cantabria province, Piedrasluengas, Este de Camasobres, Celada de Robledo Sur and Pico Guillermo sections in Palencia province).

3. Material of study and methods

Eighteen sections have been sampled searching for auloporid corals. The sampling consisted in the collection of complete colonies, fragments of colonies or fragments of corallites in facies associated with buildups in all of the sections, except in Ribadesella. Ten solitary rugose corals were sampled in this section, because auloporid corals only occur encrusting the rugosans.

520 thin-sections of auloporid corals have been prepared to study the inner characters. The specimens from Ribadesella were partly covered with marls and clays. For this reason, ten corals were cleaned with an 8% sodium hexametaphosphate solution during 18 hours to remove the sediment. Later, three thin-sections were made, two of them to observe the inner

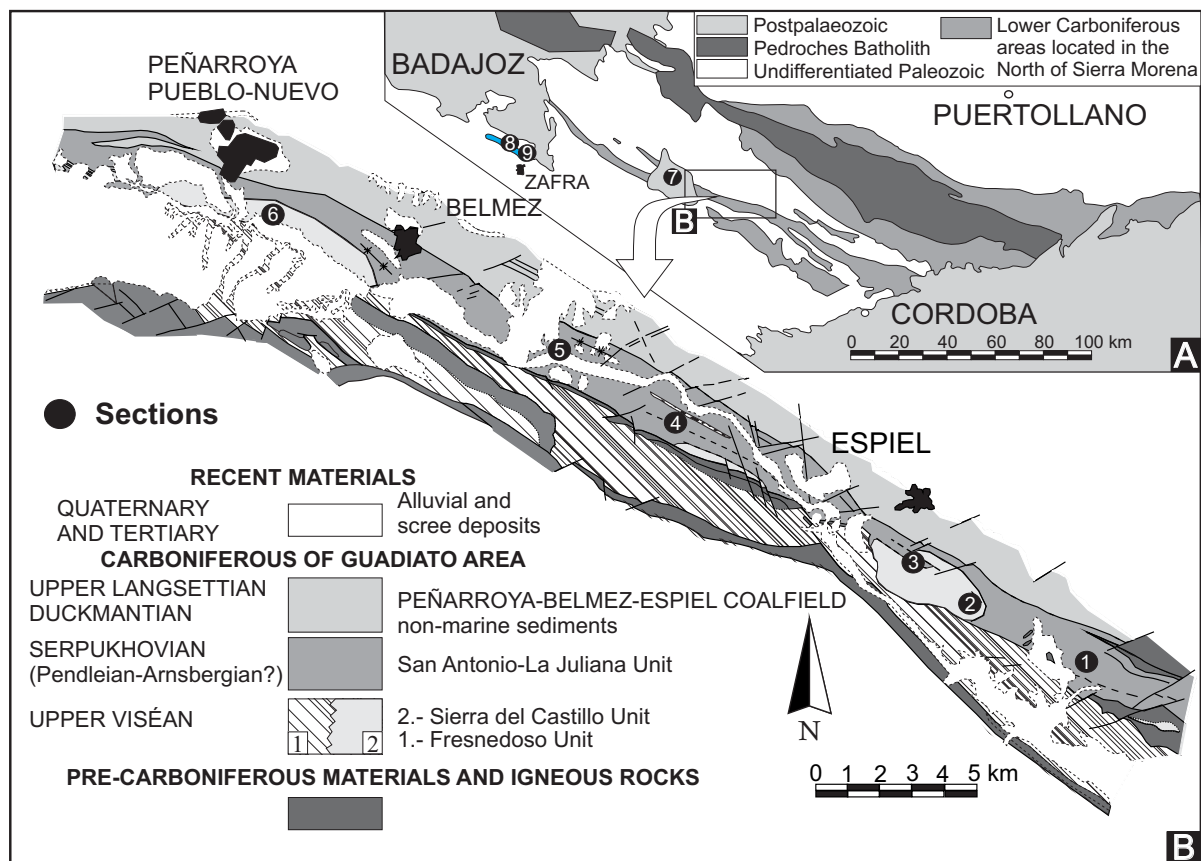


Fig.-2.- A) Early Carboniferous outcrops (upper Tournaisian to Arnsbergian) in the northern Sierra Morena. B) Synthetic map of the main geological units of the Guadiato Area. Location of the sampled sections. 1) La Adelfilla; 2) Sierra de la Estrella; 3) El Collado; 4) La Cornuda; 5) San Antonio; 6) Antolín; 7) Fuenteobjuna 8) Cerro Almeña; 9) Los Santos de Maimona. Modified from Cózar and Rodríguez (1999).

characters. In addition, some colonies have been cut and polished to observe the growth stages of the colonies.

Likewise, additional occurrences of auloporids have been identified with references in the literature (Minwegen, 2001; Merino Tomé *et al.*, 2009).

4. Descriptions

4.1. Localities

The sections mentioned in this chapter have been described in detail in previous papers. Consequently, we will not describe them in detail, but will provide short reports on their most representative lithologies and palaeontological content. Temporal distributions of sections are displayed in Fig. 4.

Ossa-Morena Zone:

La Adelfilla, Fuenteobjuna and San Antonio. (San Antonio-La Juliana Unit). Described and figured by Cózar *et al.* (2007) and Cózar and Rodríguez (2004). These localities correspond to Viséan olistoliths in Serpukhovian olistostromes. La Adelfilla shows several imbricated olistoliths. Its thickness is about 40 m thick. It consists of bioclastic massive limestones, brecciated limestones and oolitic limestones. The sec-

tion has been dated from the microfauna as late Viséan (Brigantian). The Fuenteobjuna section is 140 m thick, mostly composed of limestones, shales and polymictic breccias in the upper part. The section has been dated from microfauna and the microflora as late Viséan (late Asbian to early Brigantian). San Antonio section consists of limestones interbedded with shales and marls. The limestones are wackestones and grainstones. The section has been dated from the foraminiferal assemblage as early Serpukhovian (Pendelian). The facies that yielded corals are bioclastic limestones that are irregularly distributed in the olistoliths. They are coarse grained and corals are related to a diverse assemblage of invertebrates and algae. The original environment for those sections was open marine, shallow, agitated water (Cózar and Rodríguez, 1999).

Sierra de la Estrella. (Sierra del Castillo Unit). Described and figured by Cózar *et al.* (2003). It consists of a 234 m thick succession of bioclastic and massive limestones with interbedded marls. The auloporids from Sierra de la Estrella occur in well-bedded biostromal limestones at the top of microbial mounds. They represent the capping beds of the mounds, when they reached shallow waters. The section has been dated from foraminiferal assemblage as Zone 15 of Mamet, 1974 (middle part of the late Viséan, Asbian).

El Collado. (Sierra del Castillo Unit). Described and figured by Cózar (2004). This section comprises more than 150

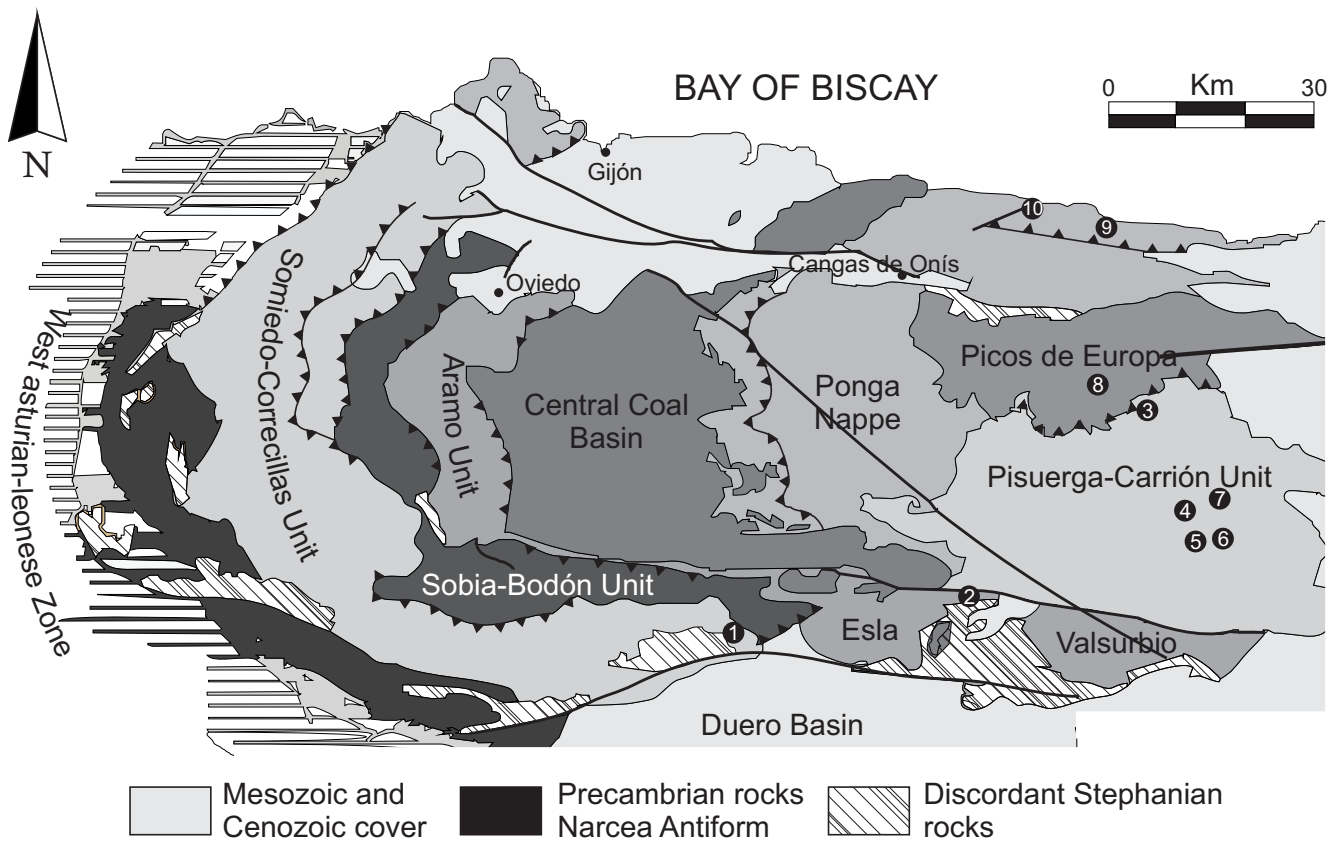


Fig. 3.- Synthetic map of the main geological units of the Cantabrian Zone. Location of the sampled sections. 1) Valdeteja; 2) Prioro; 3) Las Ilces; 4) Piedrasluengas; 5) Este de Camasobres; 6) Celada de Roblecedo; 7) Pico Guillermo; 8) Morra de Lechugales; 9) Playa de la Huelga; 10) Ribadesella. Modified from Pérez-Estaún *et al.* (2004).

metres of cyclic sedimentation of limestones and marls, in a shallow-water platform. The section has been dated from the foraminiferal assemblage as late Viséan (Asbian-Brigantian). The beds containing auloporids correspond to storm beds that reworked a rich assemblage dominated by colonial rugose corals.

Antolín. (Sierra del Castillo Unit). Described and figured by Cózar and Rodríguez (2000). This section comprises limestone debris 15 m thick in a mainly siliciclastic rhythmic sedimentation. It is typical from proximal turbidites. This section has been dated as late Viséan (Asbian-Brigantian). The reworked limestones originated in patch reefs located in the border of the talus (Rodríguez and Rodríguez-Curt, 2002).

La Cornuda. (San Antonio-La Juliana Unit). Described and figured by Gómez-Herguedas and Rodríguez (2008). This section is the only Serpukhovian autochthonous outcrop that yielded auloporids in Sierra Morena. It consists of limestones, calcareous sandstones and conglomerates 500 m thick. The section has been dated from foraminiferal assemblage as early Serpukhovian zones 17 and 18 (Pendleian). Auloporids encrusted rugose corals in shallow-water, coral-algal-microbial mounds (Gómez-Herguedas and Rodríguez, 2008).

Los Santos de Maimona. (Los Santos de Maimona Coal Basin). Described and figured by Rodríguez *et al.* (1992). Consist of 35 m of marls, limestones and marly limestones.

The section has been dated as late Viséan, zone 15 (Asbian). Auloporoids in Los Santos occur in well-bedded biostromal limestones that have been regarded as a reef-flat (Rodríguez, 1996). They are one of the main building organisms together with gigantoproductid brachiopods and rugose corals.

Cerro Almeña. (Los Santos de Maimona Coal Basin). Described and figured by Rodríguez *et al.* (1992). It consists of 90 m of alternating limestones, marly limestones and shales. This section has been dated as late Viséan, Zone 15 and 16 (Asbian-Brigantian substage). Well-bedded to massive bioclastic limestones contain common reworked fragments of auloporoids and some entire colonies at the top of the beds. They lived in calcareous shoals and are accompanied by a diverse assemblage containing different invertebrates, foraminifers and algae.

Cantabrian Zone:

Valdeteja and Las Majadas (Valdeteja Formation, Sobia-Bodón Unit). Calcareous succession up to 700 m thick cropping out in the Somiedo-Correcillas, Sobia-Bodón, northern part of the Central Asturian Coalfield, Ponga Nappe, and Picos de Europa structural units of the Cantabrian Zone. The Valdeteja Formation was first described by Winkler Prins (1971), who identified the auloporid genus *Cladochonus*.

Eichmüller (1985) described different sections and outcrops of Valdeteja Formation and identified mounds built by calcareous algae and reef mounds containing the auloporoid coral *Sinopora* sp.

The Valdeteja Formation has been dated as early Bashkirian-early Moscovian (Villa *et al.*, 2001).

Las Ilces (Cosgaya Formation, Pisuega-Carrión Unit). Described and figured by Coronado and Rodríguez (2009). It consists of a calcareous section 35 m thick, composed of limestones, which occasionally alternate black shales and marls. The Cosgaya Formation is composed of bioclastic limestones that show abundant algae and corals and locally form mounds (bioherms?). Those mounds are conspicuous at Las Ilces Section. Auloporoids are common in the mounds and in the surrounding facies. The age of the sections was established by fusulinids as late Bashkirian (Coronado, 2008).

Piedrasluengas (Piedrasluengas Formation, Pisuega-Carrión Unit). This section comprises 300 m of limestones and marls. The Piedrasluengas Limestone, as was first defined by van de Graaff (1971a), has a early Moscovian age (Vereiskian-Kashirskian), and provides a facies model for most of the Carboniferous limestones in the Cantabrian Mountains. A boundstone of auloporoids and chaetetids has been identified in the level 16 of van de Graaff (1971a), which Mingewen (2001) denominated as a biostrome of chaetetids with syringoporids and rugose corals and which was sampled for this study.

Ribadesella section (Calizas del Cuera Formation, Picos de Europa Unit). This section was first described by Rodríguez *et al.* (1997) and Fernández (1995). In this quarry subhorizontal marls and limestones crop out. The section begins with 8-10 m of silty limestones and marls containing common disseminated solitary and colonial *Rugosa* and chaetetids, and scarce auloporids. This interval is overlain by 10-12 m of massive well-bedded limestone containing less abundant corals, which extends to the top of the quarry. Chaetetids are usually represented by large colonies encrusting brachiopods, rugose corals and tabulate corals. Most of them show a sub-spherical shape. Auloporids were less abundant and usually grew on lateral surfaces of large solitary corals whereas the rugose corals are very abundant and show little or no transportation. The presence of fusulinids in these beds establishes an Early Moscovian age (Rodríguez *et al.*, 1997).

The Vergaño Formation (Pisuega Carrión Unit) was defined by van de Graaff (1971b) as having a lower part of cross-stratified sandstones—shales with thin interbedded layers of mudstone and sandstone, limestones, and a turbidite bed. Three members of limestone can be recognized in this formation, Socavón Limestone (Podolskian), Cotarraso Limestone (Podolskian-Myachkovian) and the Sierra Corisa Limestone member (Myachkovian). These limestone members form three superstructures denominated as the Casavegas Syncline, Redondo Syncline and Castillería Syncline (Wagner *et al.*, 1983; Wagner 2009).

van de Graaff (1971b) described the facies from the Vergaño Formation and mentioned the presence of auloporid cor-

als in the limestones facies from Pico Guillermo, Peña Abismo, Cabramocha, Vergaño, Celada de Roblecedo, Tremaya, Casavegas, Peña Tres Mares, and Peña Agujas sections.

Three sections were sampled from this study: Celada de Roblecedo Sur, Pico Guillermo and Este de Camasobres.

Celada de Roblecedo Sur: This section is located in the Celada de Roblecedo Anticline between the Redondo Syncline and the Castillería Syncline. It is Late Moscovian (Myachkovian horizon) in age.

Este de Camasobres: Located in the Casavegas Syncline and corresponds with a small section described by Boll (1985) where abundant rugose corals occur with auloporids and chaetetids. It is Middle Moscovian (Kashirian-early Podolskian horizons) in age.

Pico Guillermo: Located in the Redondo Syncline. It is a large calcareous olistolith that was described by van de Graaff (1971b) and contains small colonies of auloporid corals in growth position. It is Middle Moscovian (Kashirian-early Podolskian) in age.

Prioro limestones (Pando Formation, Esla Nappe): The synorogenic sediments of the Esla Nappe form a succession that exceeds 5 km in thickness in some sectors of the nappe, but generally presents strong changes of thickness, some discordances and lateral changes of facies, as a consequence of the synsedimentary tectonic activity (Alonso, 1989). In the first stage (Bashkirian-Moscovian) the succession has a marine character with deposits of talus (turbidites, olistostromes, shales with pebbles, etc). In this succession, a carbonate lithosome denominated as the Mesao Limestone (van Loon, 1971) is conspicuous. It consists of an alternation of limestones and calcareous mudstones. Bioclastic limestones occur as well as biogenic banks. The biogenic banks are mainly constructed by algae, but corals, brachiopods, crinoids, and fusulinids are almost always present. The bioclastic limestones consist mainly of transported crinoidal fragments, but brachiopods, corals, fusulinids, and even plant remains occur as well. These materials were dated as from fusulinid assemblage as Westphalian C (early Podolskian) by van Loon (1971).

The biogenic banks have been sampled for this study both in the south flank and in the north flank of the Pando Syncline where the thickness of the limestones is much greater.

Playa de la Huelga (Calizas del Cuera, Picos de Europa Unit): This section is exposed along the cliffs of eastern Asturias from San Antolin Beach to the village of Hontoria. Villa (1995) dated the levels sampled in this work as early Podolskian – late Myachkovian. Rodríguez (1984) studied the coral faunas, mainly focused in the *Rugosa* specimens. In a later taxonomical study focused in tabulates, Rodríguez and Ramírez (1987) described three new taxa that occur in the Playa de la Huelga section. Two cerioid-phaceloid forms assigned to *Neomultithecopora cantabrica* and *N. submassiva*, and a phaceloid-bushy form denominated as *Multithecopora hontoriense*. The Pennsylvanian materials that provided the subject of the study (interval of latest Podolskian or earliest Myachkovian age) are composed of ca. 100 m of massive

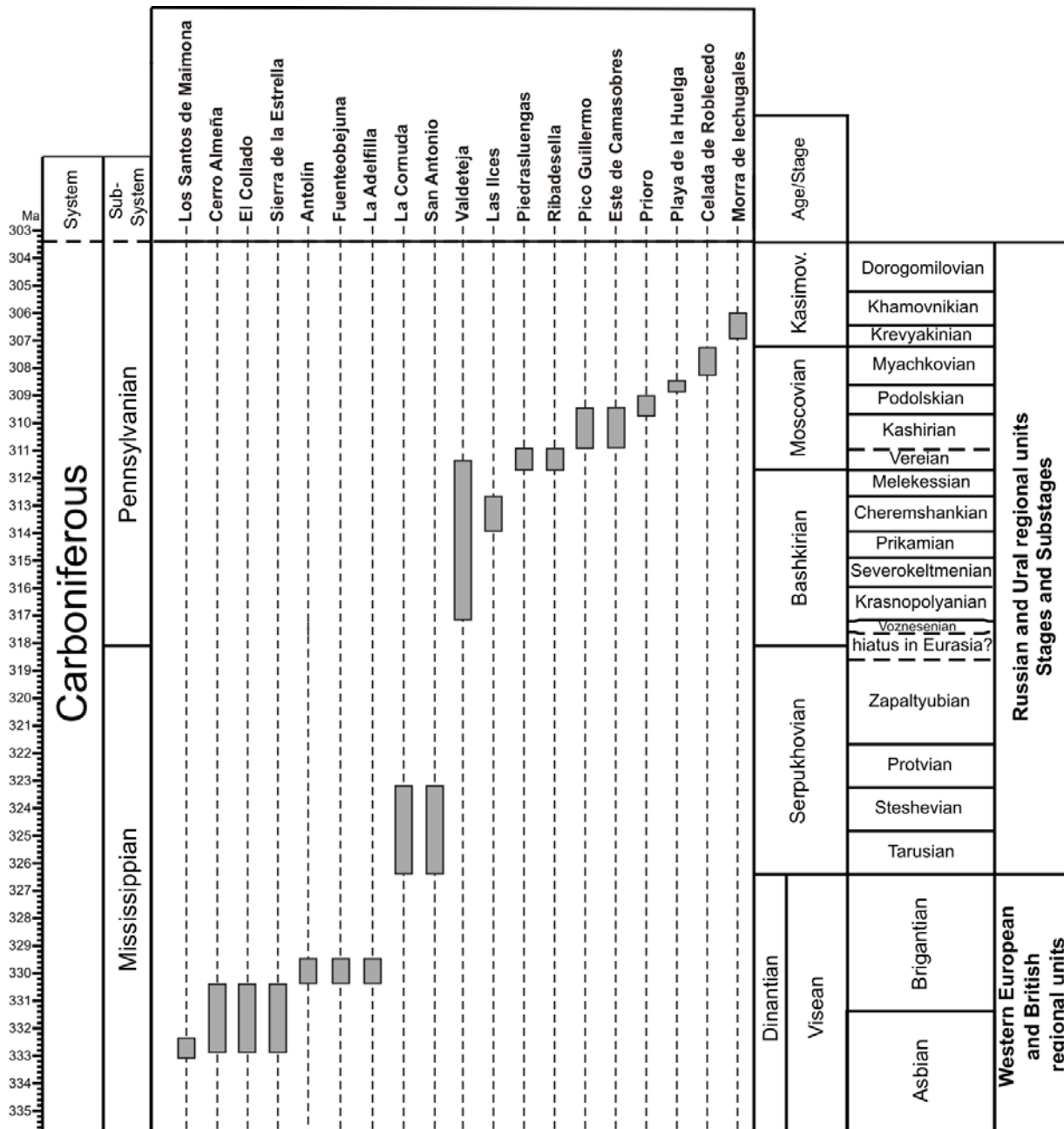


Fig. 4.- Temporal distribution of the carboniferous sections sampled in Iberian Peninsula.

bioclastic limestones, which present interbedded marls and shales and occasionally sandstones. Minwegen (2001), described the microfacies and bioconstructions found in Playa de la Huelga section (Hontoria *in sensu* Minwegen, 2001). She described the bioconstructed facies as reef-mound facies. These beds are dominated by syringoporoid masses in growth position, associated with bryozoa, abundant brachiopods, calcareous algae, chaetetids, and rugose corals.

In addition, syringoporoids cited and figured in the Picos de Europa Unit, at Morra de Lechugales section in Cantabria province (Minwegen, 2001; Martínez-Chacón *et al.*, 2001; Merino-Tomé *et al.*, 2009) have been also identified from the bibliography. The specimens sampled in the Cantabrian

zone range from early Bashkirian to late Moscovian in age. The inclusion of the Morra de Lechugales section extends the record to early Kasimovian.

4.2. Introduction to Auloporida

Two superfamilies were identified in the record for Auloporida Sokolov, 1947 order; Auloporidae Milne-Edwards and Haime, 1851 and Syringoporidae de Fromentel, 1861; twenty families were recognized, of which twelve have been recorded in the Carboniferous period: Auloporidae Milne-Edwards and Haime, 1851; Pyrgiidae, de Fromentel, 1861; Romingeriidae, Sokolov, 1950; Aulocystidae, Sokolov, 1950; Sinopo-

ridae, Sokolov, 1955; ?Khmeriidae, Montanaro-Gallitelli, 1954; Syringoporidae, de Fromentel, 1861; Tetraporellidae, Sokolov, 1950; Multithecoporidae, Sokolov, 1950; Roemeridae, Počta, 1904; Thecostegitidae, de Fromentel, 1861 and Gorskyitidae Lin, 1963.

Auloporida formed arbustive or fruticose colonies with proximal corallites commonly prostrate or adherent to other biogenic or inorganic remains; may have erect corallites (fasciculate) or branched (dendroid) and more rarely cerioid. They show diverse forms: tubular, horned, cylindrical or prismatic. This order could show mural pores or connecting tubuli (e.g. Syringoporicae); the septa are represented by longitudinal rows of commonly fine spines, and the tabulae are very sparse or even absent to numerous, complete or incomplete, with a syrinx in most Syringoporicae. The increase is lateral and commonly basal (cf. Hill, 1981).

4.3. Systematics and classification

There are no useful common criteria to establish the main features for the auloporid taxonomy to different levels. Those features depend on the subjectivity of the author and the superfamily involved. In Auloporicae the most commonly used criterion is the general morphology, the growth habit and, to a lesser degree, the presence and morphology of tabulae and septal spines. In Syringoporicae, more diverse criteria have been used. Nelson (1977) used four parameters in the taxonomy of syringoporid corals; two of which are the corallite diameter and the frequency of corallites (number of corallites that occur within a certain area). This author suggests that these parameters are very important in defining species and that both are, more or less, independent of the environment. Nelson (1977) suggests also two other parameters, the type of tabular pattern and the wall thickness, which are significant in defining genera. Other authors, such as Nowinski (1991) and Niko (1998), have employed the frequency or distance between corallites. Tchudinova (1975), Sando (1984) and Nowinski (1991) used not only the corallite diameter and the distance between corallites, but also the wall thickness, diameter of connecting tubes, distance between connecting tubes, distance between tabulae, diameter of axial canal or lumen and the amount of septal spines. These additional characters also were used by Rodríguez and Ramirez (1987) along with the diameter of corallite and thickness. These criteria could be used in those genera that present abundant tabulae and connecting structures, but cannot be used as a systematic feature in all auloporid genera.

Tchudinova (1980) presented a study on the morphogenesis of Syringoporidae, which shows a series of characters that occur in different genera through time. These are: microstructure of corallite wall, presence of lamellar or fibrous sclerenchyme and presence of septal spines, connecting elements and tabulae.

In this study we follow the taxonomical characters proposed by Tchudinova (1980): microstructure, septal spines,

and tabulae, together with the corallite diameter, lumen diameter, and their relationship (diameter/lumen), which helps in the identification of some genera such as *Multithecopora* and *Sinopora*. The frequency or space between corallites, as suggested by Nelson (1977), is an acceptable criterion for use in Syringoporidae, but not in Multithecoporidae and Sinoporidae, because these families show plasticity in growth and the substrate and environment control the growth of the colonies. The morphology of the colony and the morphology of the corallite only have been considered for the Auloporicae taxa. The kind of septal spines used by Tchudinova (1980) are also used in Scleractinian corals and compiled by Hill (1981). However, in our opinion, this criterion could cause some problems in the classification of tabulate corals. For this reason, we use quantitative criteria (abundant, common or scarce), distribution (sparse, in rows or random) and form (acute or blunt) to describe the septal spines. Occasionally, septal spines are very scarce or absent, but the wall presents undulations in the sclerenchyme as septal projections.

Sando (1984) undertook a biostratigraphic study on syringoporid corals from the Western Interior Region, USA and he grouped all the syringoporoids in morphogroups. In the absence of previous taxonomical studies, this methodology has been used in this study, subdividing the genera into morphotypes. Due to the plastic morphology and growth habit of auloporidae, these morphotypes may be species or subspecies (ecophenotypes) or groups of species, and need to be analyzed deeper in the future.

The Carboniferous auloporids of the Iberian Peninsula include nine nominal genera and have been divided into 18 morphotypes and two species, which are based on the morphologic criteria documented above (Table 1).

4.3.1. Mississippian taxa

The Mississippian samples have been located in the Ossa-Morena Zone, and five genera have been identified: *Multithecopora* Yoh, 1927; *Syringopora* Goldfuss, 1826; *Syringocalcyon* Termier and Termier, 1945; *Cladochonus* McCoy, 1847 and *Roemeripora* Kraicz, 1934. Table 1 shows the main taxonomical characters of each genus identified.

Multithecopora is the most frequent genus in the Iberian Peninsula. We have identified four morphotypes in the Ossa-Morena Zone: *Multithecopora* sp. A, sp. B, sp. C and sp. H.

Multithecopora sp. A shows a larger size than the other Mississippian morphotypes of *Multithecopora* (avg. 1.96 mm –range 1.47-2.85 mm in diameter; Table 1) and presents well developed septal spines, which show acute morphology (Fig. 5). This morphotype is present in five sections of the Ossa-Morena Zone (Antolín-1, Sierra de la Estrella, Fuentebejuna, Los Santos de Maimona and El Collado sections) ranging in age from middle-late Asbian to early Brigantian.

Multithecopora sp. B is quite similar to *Multithecopora* sp. A, but differs in the diameter (1.06 mm versus 1.96 mm). This morphotype occurs in the Antolín-1 and Fuentebe-

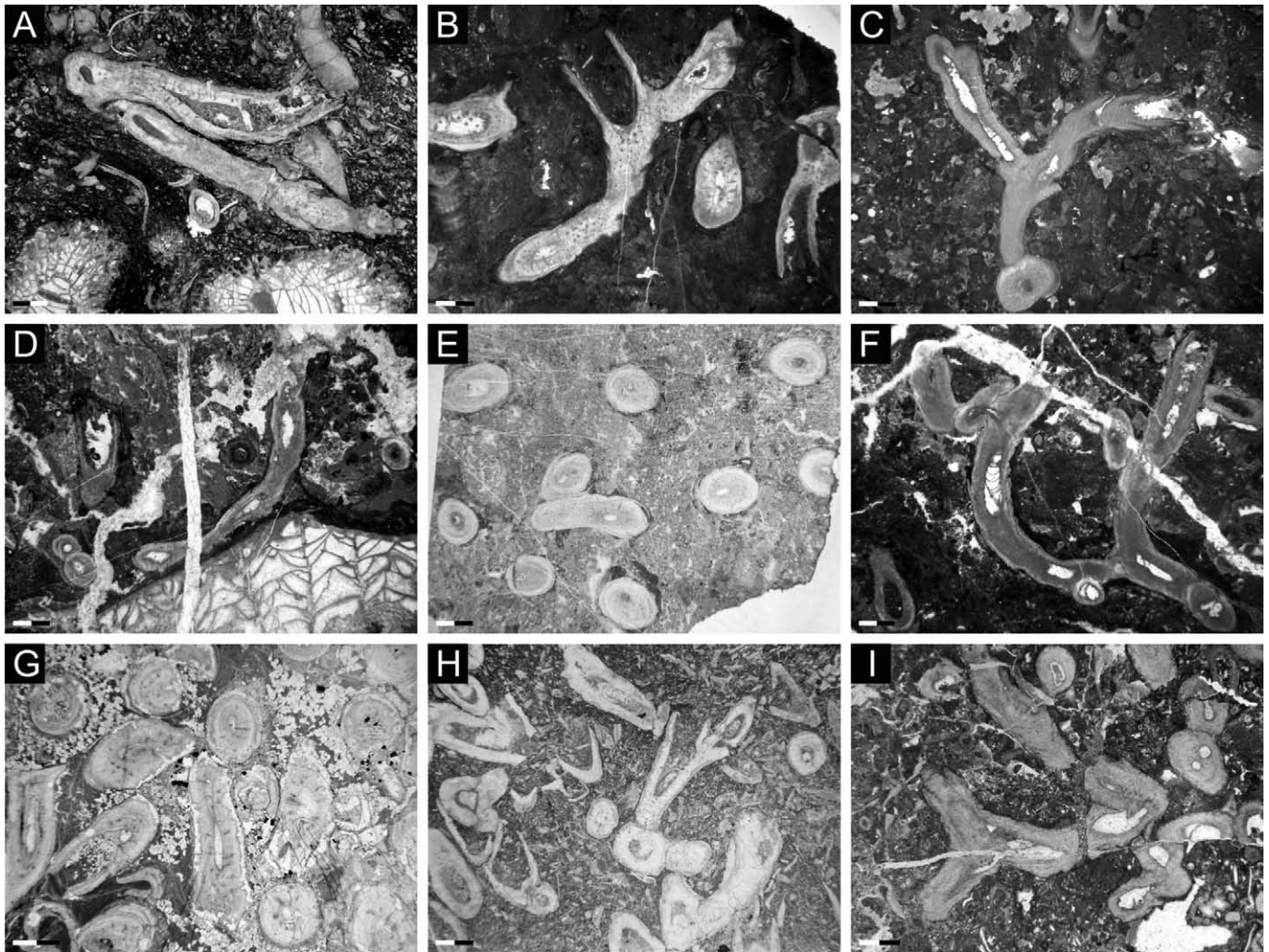


Fig. 5.- *Multithecopora* sp. A. A) Fragments of corallites in storm beds from El Collado Section. B-C) Branched corallites from Antolín section on thrombolitic-microbial texture. Note the growth of automicrite around the corals and the pseudostromatactoid cavities in B. D-F) Sierra de la Estrella section. D) Encrusting habit of *Multithecopora* sp. A on a rugosan. E-F) Phaceloid development, parallel with an initial reptant growth. G) *Multithecopora* sp. A in Los Santos de Maimona section growing in a reef-flat facies. Note the dolomite development around the corallites. H) Reworked facies in Los Santos de Maimona section. Note the fragmentation and abrasion of the corallites. I) *Multithecopora* sp. A in shallow-water facies from Fuenteovejuna section. Note the brecciation and the reworked corallites. Scale bar is 2 mm.

juna sections and has a early-middle Brigantian distribution (Fig.6A-B).

Multithecopora sp. C shows a more bushy growth than the previous morphotypes, forms better developed colonies, and the corallites present less septal spines (Fig. 6C-D). This morphotype occurs in the early Brigantian from El Collado (zone 16 of Mamet, 1974). *Multithecopora* sp. A, B and C occur only in the Viséan.

Multithecopora sp. H shows a phaceloid growth habit and encrusting on rugose corals. Their characteristics are common in *Multithecopora* genera: the diameter/lumen rate and the dimensions, the presence of septal spines, and a colonial development forming small bushy colonies (Fig. 6E-F). This morphotype is known only from the Serpukhovian (Pendleian Stage, Table 2).

Another significant genus in the Viséan recorded from the Ossa-Morena Zone is *Syringopora*. Two morphotypes have

been recognized: *Syringopora* sp. A and *Syringopora* sp. B. Both morphotypes show the main characteristics of *Syringopora*. The differences between them are that *Syringopora* sp. B is larger than *Syringopora* sp. A, and has a higher lumen diameter. *Syringopora* sp. B shows a fasciculate development, with less density of corallites and branched colonies (Fig. 7A-D). *Syringopora* sp. A shows a palisade development with a high density of corallites (Fig. 7E-F). The morphology of the corallites of *Syringopora* sp. A is more irregular than that of the morphotype B, which present a more cylindrical development. *Syringopora* sp. A occurs only in the Los Santos de Maimona Basin and in Los Santos and Cerro Almeña sections of late Viséan (middle-late Asbian) age. Whereas *Syringopora* sp. B occurs in the Guadiato Area, and more specifically in the Antolín and La Adelfilla sections and is of late Viséan (early Brigantian) age.

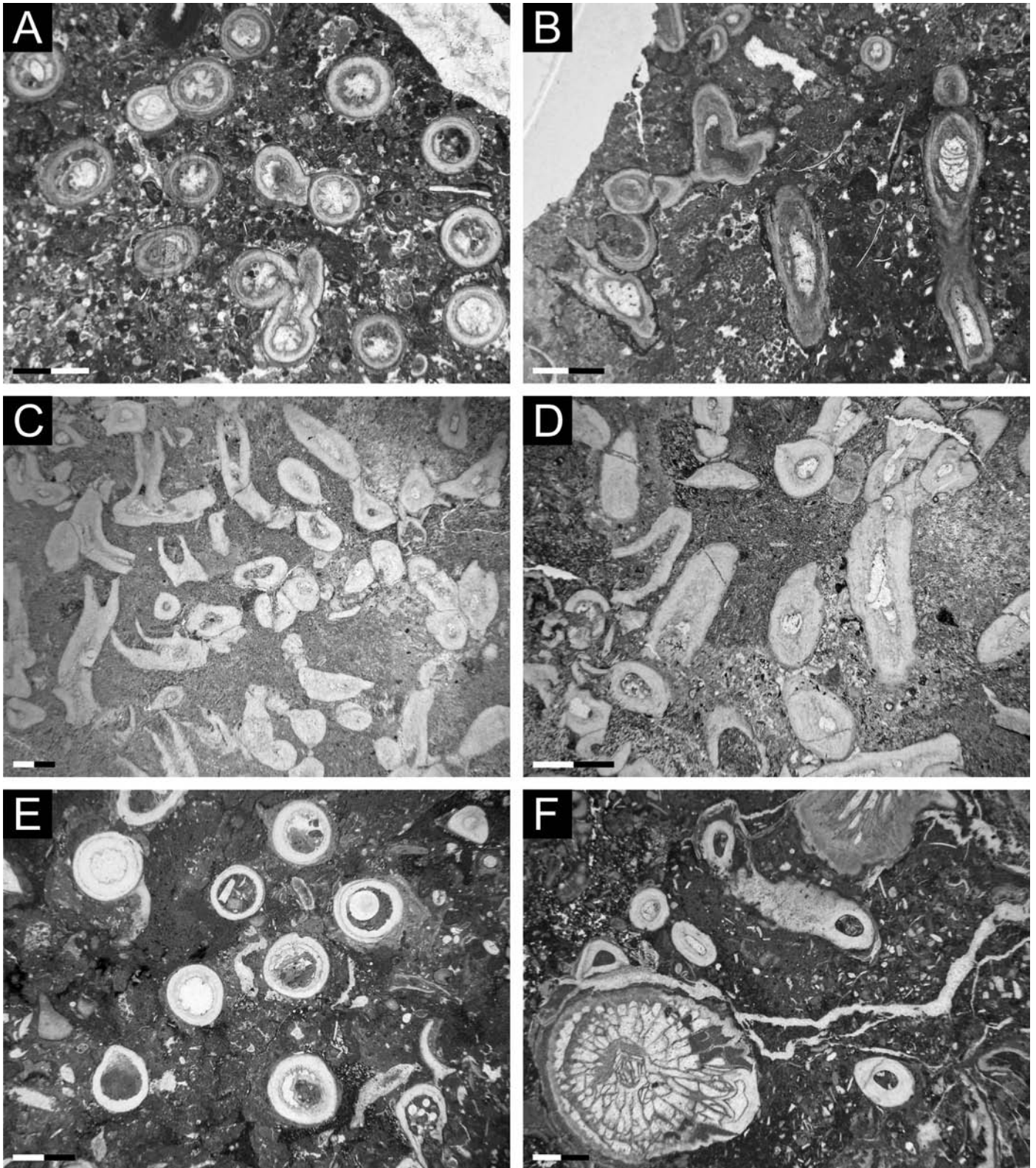


Fig. 6.- A-B) *Multithecopora* sp. B in Fuenteovejuna section. Note the abundance and acute development of the septal spines in A and the presence of incomplete tabulae in B. C-D) *Multithecopora* sp. C corallites in El Collado section. Note that some branches are reworked and transported whereas others are in growth position, like in D. E-F) *Multithecopora* sp. H in La Cornuda section. E) Note the small and scarce septal spines and the parallel (phaceloid) development of the corallites. This illustration shows a superficial section of the calices. F) This morphotype is encrusting a rugose coral. Scale bar is 2 mm.

Syringalcyon is another common genus in Ossa-Morena. It has been recorded in the Los Santos de Maimona and Cerro Almeña sections with a distribution of Asbian-Brigantian. This genus presents distinctive epithelial scales and shows characteristics very similar to *Syringopora* (Fig. 7G-I). For this reason some authors such as Hill (1981) and Tourneur *et al.* (1995) identified it with *Syringopora*. Its distribution is middle Asbian. The epithelial scales of the samples of Los Santos de Maimona Coal Basin do not show a dense packing and are thinner than those described in the literature.

Roemeripora sp. occurs only in the Fuentebejuna section as massive cerioid colonies, where the corallites show a dense packing with prismatic and irregular forms, with abundant septal spines and connecting tubuli (Fig. 8E-F). It occurs from late Asbian to early Brigantian (Cózar *et al.*, 2007).

Cladochonus sp. A is one of the two morphotypes (A and B) that occurs in the Iberian Peninsula. It shows an initial tubular

development with a secondary globular enlargement and “diaphragms” between corallites as well as the lack of tabulae and spines (Fig. 9C-D). This morphotype occurs in the lower levels of the El Collado section, which is uppermost Asbian in age (Zone 15 of Mamet, 1974 biostratigraphy).

4.3.2. Pennsylvanian taxa

On the other hand, the Pennsylvanian samples collected in the Cantabrian Zone yielded six nominal genera: *Multithecopora* Yoh, 1927; *Neomultithecopora* Lin, 1963; *Sinopora* Sokolov, 1955; *Cladochonus* McCoy, 1847, *Aulopora* Goldfuss, 1829 and *Mastopora*? Sokolov, 1952. Table 1 shows the main taxonomical characters of each genus identified in this zone.

Four morphotypes and one nominal species of *Multithecopora* have been recognized in the Cantabrian Zone: *Multi-*

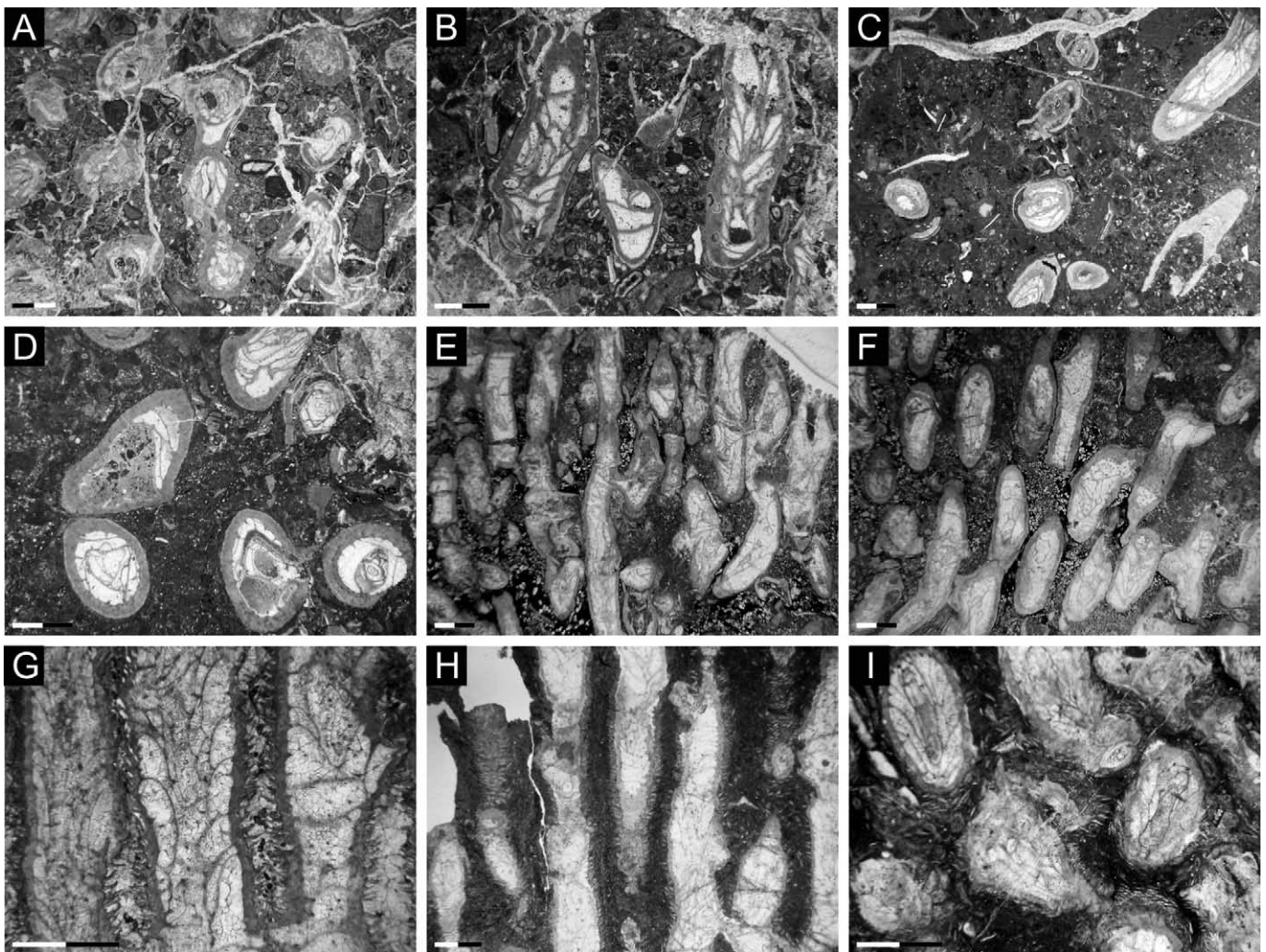


Fig. 7.- A-B) *Syringopora* sp. B from La Aldelfilla section in a matrix with cortoids and peloids. C-D) Branched development of *Syringopora* sp. B from Antolín section in microbial texture. E-F) *Syringopora* sp. A from Los Santos de Maimona section. Note the palisade development of the colony. G-I) *Syringalcyon* sp. G) Detail of the epithelial scales on the corallites of Cerro Almeña section. Note the sparite cement between the corallites in reef-flat facies. H-I) *Syringalcyon* sp. from Los Santos de Maimona section. Note the dense packing of the epithelial scales around the corallites in I and the growth in palisade of this morphotype in H. Scale bar is 2 mm.

thecopora sp. D, *Multithecopora* sp. E, *Multithecopora* sp. F, *Multithecopora* sp. G, and *Multithecopora hontoriense* Rodríguez and Ramírez, 1987.

Multithecopora sp. D shows phaceloid colonies composed of small corallites that show septal projections and have a well-developed inner fibrous domain or an alternation of fibrous and lamellar domains. The growth pattern is prostrate in early stages, but later the corallites develop an erect growth, with subsequent budding in some cases (Fig. 10A-B). This morphotype occurs in the Valdeteja section at higher levels than the “*Cladochonus* band” of Winkler Prins (1971), which could occur from early Bashkirian? to early Moscovian rocks (Villa *et al.*, 2001), but it is more probable that it occurs in a middle Bashkirian to early Moscovian (Tashatinian – Vereian) horizon.

Multithecopora sp. E shows diameter and septal projections similar to the previous morphotype but presents some differences, such as the microstructure (only three domains, mainly lamellar), and the growth habit (phaceloid and bushy). This morphotype grows encrusting other organisms, such as rugose corals or *Chaetetes*. The corallite length is very short, showing an open calyx almost from the beginning of the offsetting (Fig. 10C-F). This morphotype occurs in two sections in the Cantabrian Zone; in the Las Ilces section, middle Bashkirian in age (Tashatinian horizon, Coronado, 2008) and in the Piedrasluengas section, early Moscovian in age (Vereian horizon, van der Graaff, 1971a).

Multithecopora sp. F is similar to the previous morphotype; the differences are in the growth habit; this morphotype is reptant or rarely bushy, shows a smaller diameter and smaller septal protrusions (Fig. 11A-B). This morphotype only occurs in the Este de Camasobres section that is late Moscovian in age (Kashirian horizon, van der Graaff (1971b), Westphalian C *sensu* Boll, 1985).

Multithecopora sp. G shows a bushy development of the colonies and a smaller diameter than previous morphotypes. This morphotype presents scarce septal spines that are small and short (Fig. 11C-D). The colonies are composed of many corallites and grew encrusting on chaetetids and other bioclasts. This morphotype only occurs in the Prioro section that is late Moscovian in age (Podolskian – early Myachkovian).

Multithecopora hontoriense presents a larger diameter than other *Multithecopora* of the Cantabrian Zone; they built erect, densely packed or branching, bushy colonies (Fig. 12A-H). The corallites show scarce septal spines but frequent septal projections that offer an undulating microstructure. This morphotype presents fibrous inner and outer layers and, sometimes, a thin fibrous middle layer. It is present in two sections of the late Moscovian. It occurs in the Pico Guillermo section that is Kashirian-Podolskian in age and in the Playa de la Huelva section that is Podolskian-Myachkovian in age.

The taxon *Neomultithecopora cantabrica* shows phaceloid to submassive colonies with lateral increase. The

corallites show circular to prismatic sections, sometimes sharing the wall with neighbouring corallites (Fig. 8A-D). This taxon shows a thick wall with abundant septal spines and frequently connecting tubuli. The tabulae are variable in shape (curved, horizontal or infundibuliform). This genus is similar to *Multithecopora* in the structure of the wall. It shows alternating fibrous and lamellar layers with higher development of the lamellar layers. This species occurs in two sections, in the Playa de la Huelva, where it occurs associated with chaetetids and rugose corals and in the Prioro section, where it appears associated with chaetetids and *Multithecopora* sp. G and has an late Moscovian (Podolskian-Myachkovian) age.

Sinopora also occurs in the Celada de Robledo section and shows a bushy colonial morphology with cylindrical corallites similar to *Multithecopora*, but with deeper calices and absent septal spines. The tabulae are rare (scarce or absent) and concave (Fig. 11E-F). The age of this morphotype is late Moscovian (Myachkovian).

Cladochonus sp. B occurs in the Valdeteja section. This morphotype presents the classical features of this genus, as compiled by Hill (1981) and later Stasinska (1982): coral prostrate, which in distal parts presents erect branches that seem forked, with a characteristic growth in zigzag, inner “diaphragms” between corallites as well as the lack of the septal apparatus, and scarce curved tabulae (Fig. 9A-B). The level of *Cladochonus* is early Bashkirian in age (Akavasian horizon, Villa *et al.*, 2001).

Aulopora is represented by two morphotypes (*Aulopora* sp. A, sp. B), which occur in the same locality (Ribadesella section, early Moscovian, Vereian horizon). Both *Aulopora* morphotypes show adherent colonies with cornute corallites joined in anastomosing chains; the calices show a conical shape, basal-lateral increase, and moderately thick walls (Fig. 13).

Aulopora sp. A shows a thick wall similar to *Multithecoporidae*, but it does not show septal spines and the microstructure is poorly preserved. However, a fibrous domain and an inner and thicker homogeneous lamellar domain are distinguished (Fig. 13A-B). The tabulae are curved (concave and convex) and frequent.

Aulopora sp. B shows a more open calyx lumen and thinner wall than *Aulopora* sp. A. Septal spines are absent and tabulae are infundibuliform as in *Syringopora*. The microstructure is composed of an outer fibrous layer more developed than that in *Aulopora* sp. A (Fig. 13C-F).

Two colonies of *Mastopora?* sp. show reptant and densely packed colonies, which form continuous encrusting sheets. Occasionally, it may form a globular shape, when the successive sheets are joined. Although the collected samples do not display the typical mammilliform shape of *Mastopora* corallites, the growth habit and the presence of sheet-like structures point to this genus. Two colonies have been sampled in the Playa de la Huelva section. The calices are raised and present a small aperture and thick walls, but the relation-

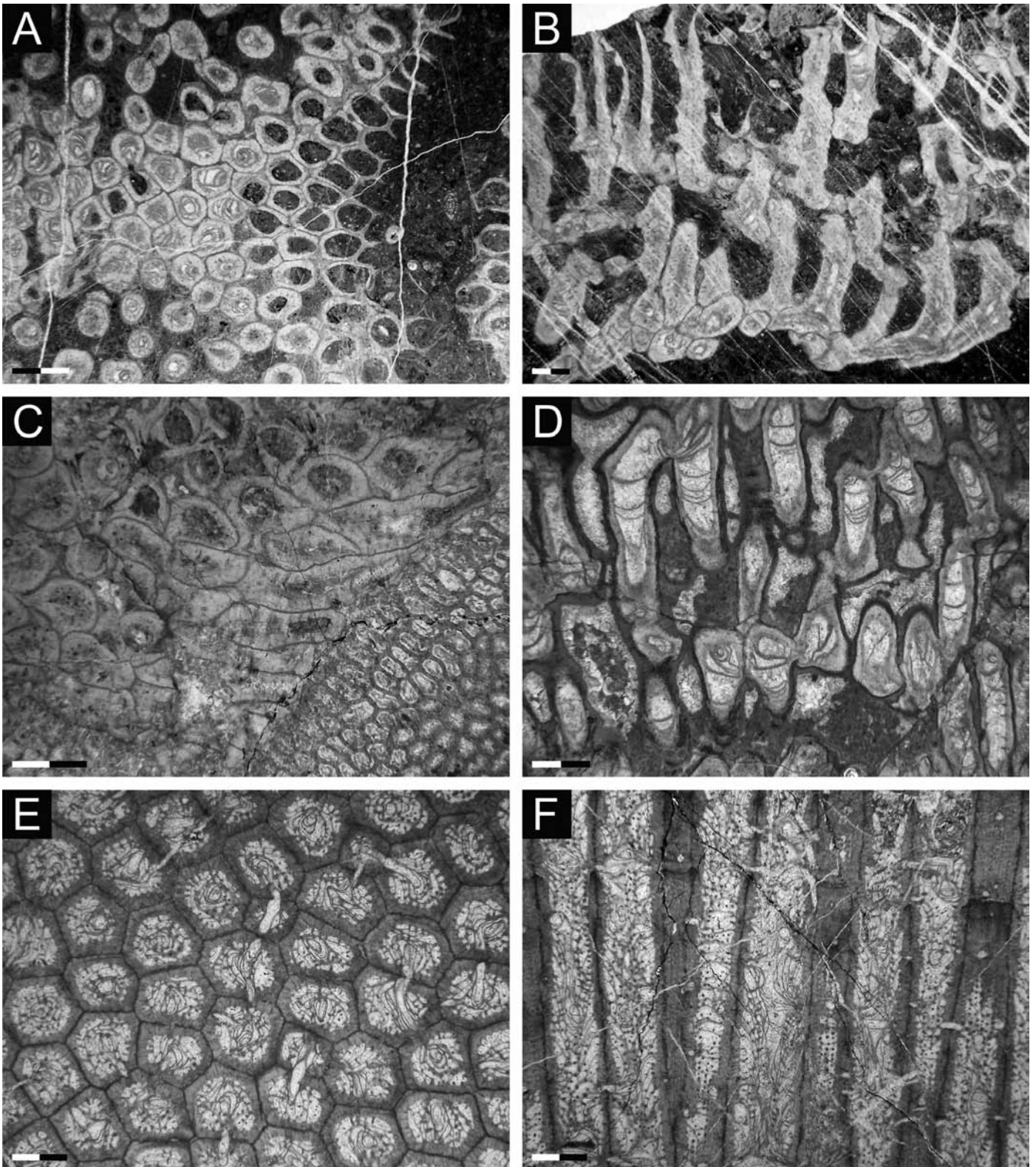


Fig. 8.- A-D) *Neomultithecopora cantabrica* Rodríguez and Ramírez, 1987. A-B) Samples from Prioro section. Note the massive-proximal and prismatic habit of the corallites in A. B) Reptant initial development of the colony and the vertical growth later. C-D) Samples from Playa de la Huelga section. C) Note the massive development of the colony that initially is encrusting a chaetetid. D) Phaceloid habit with connecting tubuli between corallites. E-F) *Roemeripora* sp. from Fuenteobejuna section. Note the massive and prismatic development of the corallites and the communication between them through connecting tubuli. Scale bar is 2 mm.

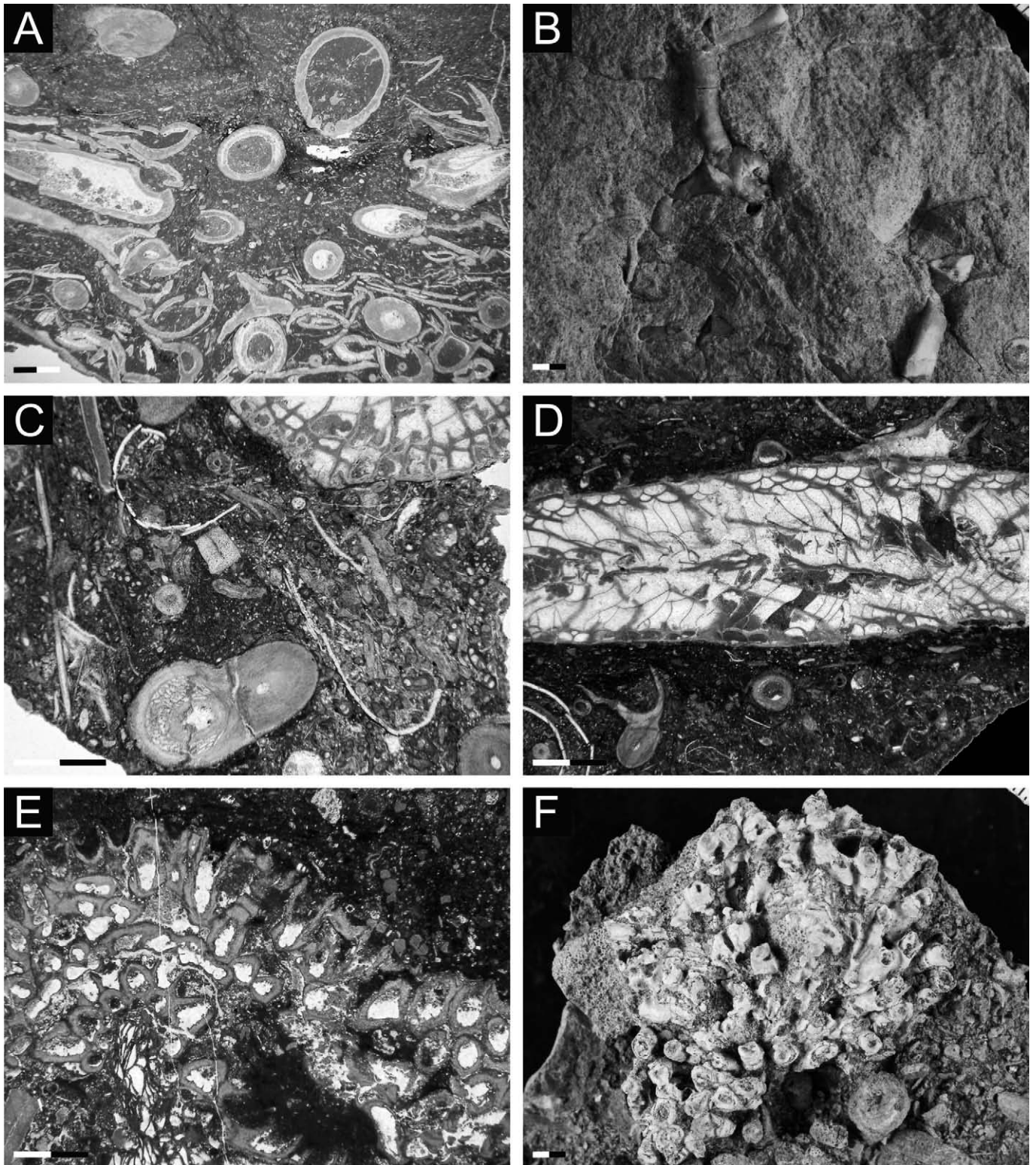


Fig. 9.- A-B) *Cladochonus* sp. B from Valdeteja section. A) *Cladochonus* wackestone with many corallites oriented in the bottom of the strata. B) Detail of zigzag development of three-dimensional sample on the bedding plane. C-D) *Cladochonus* sp. A from El Collado section. C) Note the diaphragm in the inner part of the calyx. D) Detail of *Cladochonus* encrusting a rugose coral in a storm bed. E-F) *Mastopora*? Detail of the colony in thin section. Note the septal spines and the open calices. F) Colony in the calcareous sandstone encrusting and being encrusted by bryozoans. Scale bar is 2 mm.

| Taxa | Locality | Colony morphology | Coralite morphology | Coralite diameter (mm) | Dimensions | | | Septal spines | Tabulae | Connecting structures | L-lamellar, F-fibrous | Microstructure | Observations |
|------------------------------|------------------------|-----------------------------|---|------------------------|---------------------|---------------------|--------------------|---------------------------|-----------------------------------|-----------------------|-----------------------|---|--------------|
| | | | | | Lumen diameter (mm) | Wall thickness (mm) | Diameter/Lumen | | | | | | |
| Multithecopora sp. A | ANT, FOB, SE, COLL, SS | Phaceloid | Cylindrical | X=1.96 (1.47-2.85) | X=0.5 (0.39-0.7) | X=1.4 (1.03-2.4) | X=3.81 (2.47-6.66) | Abundant-Acute | Thin-Scarce-Concave | - | F-L-F | Lamellar with a small inner and extern fibrous development | |
| Multithecopora sp. B | FOB-ANT | Phaceloid | Cylindrical | X=1.06 (0.92-1.34) | X=0.55 (0.36-0.9) | X=0.64 (0.16-1.02) | X=1.99 (1.15-3.48) | Abundant-Acute | Thin-Scarce-Concave | - | F-L-F | Lamellar with a small inner and extern fibrous development | |
| Multithecopora sp. C | Ei Collado | Bushy | Cylindrical | X=1.45 (1.04-2.01) | X=0.63 (0.33-1.21) | X=0.817 (0.20-1.52) | X=2.56 (1.17-4.15) | Common-Scarce | Thin-Scarce-Concave | - | L-F | Lamellar and intern fibrous | |
| Multithecopora sp. D | Valdeleja | Phaceloid | Cylindrical | X=1.79 (1.23-2.10) | X=0.57 (0.27-0.98) | X=1.21 (0.63-1.70) | X=3.62 (1.75-6.9) | Septal projections | Thin-Concave-Concave | - | F-L-F-L-F | Alternate lamellar and fibrous. Inner fibrous highly developed. | |
| Multithecopora sp. E | PLU and IL | Phaceloid-Bushy | Cylindrical - Irregular | X=1.71 (1.24-2.31) | X=0.83 (0.33-1.40) | X=0.96 (0.41-1.40) | X=2.52 (0.98-5.17) | Septal projections | Thin-Irregular | - | F-L-F | Extern and inner fibrous, the inner less developed. | |
| Multithecopora sp. F | ECM | Replant-Bushy | Cylindrical | X=1.39 (1.02-1.79) | X=0.56 (0.34-0.87) | X=0.82 (0.44-1.31) | X=2.66 (1.55-4.18) | Small septal projections | Thin-Irregular | - | F-L-F | Extern and inner fibrous, the inner less developed. | |
| Multithecopora sp. G | Priore (PR) | Bushy | Cylindrical | X=1.44 (0.95-1.79) | X=0.71 (0.25-1.30) | X=0.76 (0.11-1.36) | X=2.60 (0.93-5.54) | Small-Blunt-Scatter | Thin-Scarce-Concave | - | F-L-F | Extern and inner fibrous, the inner less developed. Very irregular. | |
| Multithecopora sp. H | SA-COR | Phaceloid | Cylindrical - Irregular | X=2.33 (1.99-2.82) | X=1.41 (0.60-1.74) | X=0.90 (0.31-1.60) | X=1.76 (1.18-3.66) | Plentiful-Acute | Very scarce-concave | - | F-L | Extern fibrous (in calix) and lamellar. | |
| Multithecopora hontoriense | HO | Replant-Phaceloid | Cylindrical | X=2.25 (1.96-2.73) | X=0.37 (0.26-0.43) | X=1.88 (1.55-2.32) | X=6.08 (1.11-6.26) | Septal projections-Common | Scarce-horizontal-concave | - | F-L-F-L-F | Middle fibrous sometimes not appears. | |
| Sinopora sp. | CRS | Bushy | Cylindrical | X=1.93 (1.58-2.31) | X=1.01 (0.57-1.39) | X=0.90 (0.50-1.52) | X=1.91 (1.42-3.05) | Absent | Absent or concave | - | F-L | Extern fibrous highly developed. | |
| Neomultithecopora cantabrica | HO and PR | Phaceloid, massive-proximal | Irregular to prismatic | X=1.72 (1.44-2.25) | X=1.16 (0.041-1.19) | X=0.55 (0.04-1.19) | X=1.53 (1.03-2.68) | Common-Scarce | Curved-horizontal-infundibuliform | Tubuli | F-L-F | Extern fibrous more developed than inner. Large lamellar. | |
| Roemeripora sp. | FOV | Ceroid | Prismatic-Irregular | X=2.97 (2.27-3.57) | X=1.97 (1.16-2.57) | X=0.99 (0.28-2.20) | X=1.55 (1.13-2.89) | Abundant-Acute | Infundibuliform | Tubuli | L | Lamellar, radial aggregates shape. | |
| Syringopora sp. | SS | Fasciculate | Cylindrical - Irregular | X=2.38 (1.62-2.87) | X=1.79 (1.37-1.99) | X=0.59 (0.150) | X=1.34 (0.91-2.09) | Abundant-in Rows-Acute | Infundibuliform-horizontal | Tubuli | L | Epithelial scales. | |
| Syringopora sp. A | SS | Fasciculate | Cylindrical - Irregular | X=2.76 (2.26-3.31) | X=1.92 (1.36-2.24) | X=0.84 (0.39-1.94) | X=1.47 (1.18-2.42) | Abundant-Scarce-Acute | Infundibuliform-thick | Tubuli | L | With wavy microstructure for septal spines. | |
| Syringopora sp. B | ANT and ADF | Fasciculate | Irregular and Cylindrical | X=2.95 (2.65-3.36) | X=2.11 (1.20-2.43) | X=0.85 (0.51-1.81) | X=1.47 (1.22-2.51) | Abundant-Scarce-Acute | Infundibuliform-thick | Tubuli | L | With wavy microstructure for septal spines. | |
| Cladochonus sp. A | Ei Collado | Prostrate | - | X=1.40 (1.05-2.45) | X=0.35 (0.27-0.5) | X=0.78 (0.25-1.03) | X=4.01 (4-4.9) | Absent | Absent | - | F | Fibers. Poorly preserved | |
| Cladochonus sp. B | Valdeleja | Prostrate in zig-zag | Initially cylindrical, funnel-shape finally | X=2.14 (1.03-4.22) | X=1.21 (0.31-3.38) | X=0.92 (0.68-1.21) | X=2.11 (1.24-3.54) | Absent | Irregular on calyx- curved-Scarce | - | L-F | Lamellar and extern fibrous. Gradual transition between lamellae and fibrous. | |
| Mastopora? sp. | HO | Replant-proximal | Cylindrical | X=1.02(0.64-1.28) | X=0.54 (0.33-0.92) | X=0.47 (0.13-0.90) | X=1.99 (1.26-3.37) | Scarce-Small-Acute | Thick-concave | - | - | Fibrous possible but not observe correctly | |
| Aulopora sp. A | Ribadesella | Replant-dendroid | Funnel-shape | X=0.79 (0.34-0.99) | X=0.58 (0.28-0.75) | X=0.21 (0.09-0.57) | X=1.42 (0.82-2.35) | Absent | Infundibuliform-horizontal | - | - | - | |
| Aulopora sp. B | Ribadesella | Replant-bushy | Funnel-shape | X=0.82 (0.67-1) | X=0.44 (0.3-0.72) | X=0.34 (0.1-0.66) | X=1.82 (1.16-3.15) | Absent | Absent | - | L | Lamellae | |

Table 1.- Main taxonomical characters (modified from Tchudinova, 1980) for the auloporids of the Iberian Peninsula. ANT = Antolin, COLL = El Collado, SE = Sierra de la Estrella, SS = Los Santos de Maimona, FOB = Fuenteobejuna, ADF = Adelfilla, HO = Playa de la Huelga, ECM = Este de Camasobres, CRS = Celada de Robledo, PLU = Piedrasluengas, IL = Las Ilces and PR = Priore.

| Section | Facies and depositional texture | Geometry and lithology | Components | Depositional environment and characteristics | Morphotype | Age |
|--------------------------------------|--|--|--|---|---|--|
| Los Santos de Maimona / Cerro Almeña | Boundstone (Framestone) of Syringoporicae with packstone-wackestone matrix | Biostromal facies (masive limestones and marls) | Rugosans, brachiopods, molluscs, echinoderms, trilobites, endothyrids, textulariids, bryozoans, calcareous algae. | Reef flat. Near to shore. Shallow, highly to moderately agitated water. Above or close to effective fair-weather wave-base. Well-oxygenated, normal marine. | <i>Multithecopora</i> sp. A, <i>Syringopora</i> sp. & <i>Syringopora</i> sp. A | late Viséan (middle-late Asbian) |
| Sierra de la Estrella | Micropeloidal Wackestone-Boundstone (Framestone) of <i>Multithecopora</i> | Massive limestones-mound and breccias | Peloids, micropeloids. Aoujgalids, heterocorals, rugosans, endothyrids, <i>Girvanella</i> , molluscs, crinoids, <i>Tharharella</i> and bryozoans. | Top of mud-mounds and limestone breccias. Shallow to moderately deep subtidal conditions, below fair-weather wave-base. Well-oxygenated, normal marine. | <i>Multithecopora</i> sp. A | late Viséan (late Asbian - early Brigantian) |
| El Collado | Bioclastic wackestone-packstone | Thin beds of limestones in a marls succession. | Bryozoans, bivalves, echinoderms, crinoids, calcareous algae, Aoujgalids, rugose corals, gastropods, trilobites, ostracods and foraminifers. | Shallow carbonate platform. Near to shore. Shallow water, highly to moderate agitate energy. Between wave base and storm base. Well-oxygenated, normal marine. | <i>Multithecopora</i> sp. A & <i>Cladochonus</i> sp. A. | late Viséan (late Asbian - early Brigantian) |
| El Collado | Bioclastic packstone-wackestone | Massive and bedded limestones | Grapestones and peloids. Bryozoans, bivalves, echinoderms, crinoids, calcareous algae, Aoujgalids, rugosans, gastropods, trilobites, ostracods and foraminifers. | Shallow carbonate platform. Near to shore. Shallow water, highly to moderate agitates energy. Between wave base and storm base. Well-oxygenated, normal marine. | <i>Multithecopora</i> sp. C | late Viséan (early Brigantian) |
| Antolin | Micropeloidal Mudstone-Wackestone / Boundstone (Framestone) of <i>Multithecopora</i> with cryptalgal texture (Thrombolitic micrites) / Bioclastic packstone | Massive limestones-mound and breccias | Peloids, micropeloids, ooids. Aoujgalids, heterocorals, rugosans, endothyrids, <i>Girvanella</i> , molluscs, crinoids, <i>Tharharella</i> and bryozoans. | Patch-reef to reef-mounds and talus facies. Shallow to moderately deep subtidal conditions, below fair-weather wave-base. Well-oxygenated, normal marine. | <i>Multithecopora</i> sp. A, <i>Multithecopora</i> sp. B & <i>Syringopora</i> sp. B | late Viséan (early Brigantian) |
| Fuentebejuna | Boundstone of <i>Multithecopora</i> with micritized grains | Massive limestones with breccias | Peloids, micropeloids, ooids, coated grains and lithoclasts. Rugose corals, foraminifers, bryozoans, gastropods, crinoids, brachiopods, Aoujgalids, other calcareous algae, cyanobacteria. | Near to shore. Shallow, highly to moderately agitated water. Above or close to effective fair-weather wave-base. Possibly vadose environment. | <i>Multithecopora</i> sp. A, <i>Multithecopora</i> sp. B & <i>Roemeripora</i> sp. | late Viséan (early Brigantian) |
| La Adelfilla | Rudstone/ Boundstone (bafflestone) of Syringopora / Boundstone (Bafflestone) of rugose corals | Massive bioclastic limestones | Micropeloids, ooids, chaetelids, brachiopods, rugosans, foraminifers, bryozoans, molluscs, echinoderms. | Near to shore. Shallow, highly to moderate agitated water. Between wave base and storm base. Well-oxygenated, normal marine. | <i>Syringopora</i> sp. B | late Viséan (early Brigantian) |
| La Cornuda / San Antonio | Micropeloidal mudstone-wackestone / Boundstone of <i>Multithecopora</i> / Oncoidal packstone | Massive limestone with dome shape | Micropeloids and peloids, small bioclast fragments, rugosans, chaetelids, bryozoans, calcareous algae, cyanobacteria, crinoids, brachiopods, gastropods, and oncoids in some facies. | Mud-mounds to Reef-mounds and associated facies. Near to shore. Shallow, highly to moderate agitate energy. Between wave base and storm base. Well-oxygenated, normal marine. | <i>Multithecopora</i> sp. H | Serpukhovian (Pendleian) |
| Valdeteja | <i>Cladochonus</i> wackestone | Thin beds of marls and limestones | Terrigenous clasts and small fragments of bioclasts, rugosans, other tabulate corals (<i>Pseudofavosites</i>), crinoids and brachiopods remains. | Shallow carbonate platform, with terrigenous influx. Near to shore. Shallow, highly to moderate agitated water. Between wave base and storm base. Well-oxygenated, normal marine. | <i>Cladochonus</i> sp. B | early Bashkirian (Akavasian) |
| Valdeteja - Las Majadas | Boundstone of <i>Multithecopora</i> with peloidal matrix | Massive and bedded limestones | Peloids, micropeloids. <i>Tharharella</i> , calcisphaeras, foraminifers, <i>Donezella</i> , echinoderms, ostracods, trilobites and bryozoans. | Top of mound and associate facies. Shallow-medium carbonate platform. Near to shore. Shallow, highly to moderate agitate water. Between wave base and storm base. Well-oxygenated, normal marine. | <i>Multithecopora</i> sp. D | middle Bashkirian - early Moscovian (Tashatnian-Vereian) |
| Las Ilces | Boundstone of <i>Multithecopora</i> with aoujgalids | Massive limestones-mound and bedded | Peloids, micropeloids, intraclasts. Rugosans, chaetelids, <i>Donezella</i> , <i>Ungdarella</i> , <i>Petschoria</i> , echinoderms, <i>Tharharella</i> , calcisphaeras, foraminifers, ostracods and molluscs. | Reef mound and talus facies in medium to shallow carbonate platform. Near to shore. Shallow, highly to moderate agitated water. Between wave base and storm base. Well-oxygenated, normal marine. | <i>Multithecopora</i> sp. E | late Bashkirian (Tashatnian) |
| Piedrasluengas | Boundstone (Framestone-Bafflestone) of chaetelids and corals | Base of massive limestones | Peloids, micropeloids, oncoids, rugosans, chaetelids, <i>Tharharella</i> , <i>Tubiphytes</i> , beresellids, spicules, calcisphaeras, aoujgalids, foraminifers. | Biostrome development above oolitic grainstone, in shallow carbonate platform. Near to shore. Shallow water, highly to moderate agitated water. Between wave base and storm base. Well-oxygenated, normal marine. | | early Moscovian (Vereian) |
| Ribadesella | Bioclastic wackestone-packstone | Silty limestones and marls predominantly | Peloids, micropeloids in cavities, little bioclasts in matrix. Rugose corals, chaetelids, aoujgalids, crinoids, ostracods, calcisphaera and foraminifers. | Middle-shallow carbonate platform. Near to shore. Shallow, highly to moderate agitate water. Between wave base and storm base. Well oxygenated, normal marine water. | <i>Aulopora</i> sp. A & <i>Aulopora</i> sp. B | early Moscovian (Vereian) |
| Este de Camasobres | Bioclastic wackestone-packstone/Boundstone (bafflestone) of corals (Thrombolitic texture) | Silty limestone to marly limestone | Peloids, micropeloids and automicrite in thrombolitic textures, big intraclasts (microbial), oncoids. Rugosans, calcareous algae (<i>Petschoria</i> , <i>Anthracoarella</i>), <i>Tharharella</i> , gastropoda, ostracods, bryozoa and foraminifers. | Shallow carbonate platform, with terrigenous influx. Near to shore. Shallow water to moderately deep subtidal conditions, highly to moderate agitate energy. Between wave base and storm base. Well-oxygenate, normal marine. | <i>Multithecopora</i> sp. F | middle Moscovian (Kashirian-early Podolskian) |
| Pico Guillermo | Boundstone (bafflestone) of <i>Multithecopora</i> with a packstone matrix / Boundstone (Framestone) of <i>Neomultithecopora</i> / Boundstone (framestone) of chaetelids/ Bioclastic packstone | Massive and bedded limestones | Micropeloids, pseudostromatactic cavities and intraclasts. Chaetelids, rugosans, crinoids, phylloid algae, foraminifers and <i>Tharharella</i> . | Reef-mound (biostromal facies) and associated facies. Near to shore. Shallow, highly to moderate agitated water. Between wave base and storm base. Well-oxygenated, normal marine. | <i>Multithecopora hontoriense</i> | middle Moscovian (Kashirian-early Podolskian) |
| Prioro | Boundstone of aulopods and chaetelids/Trombolitic micrites (cryptalgal texture) with boundstone of aulopods corals | Massive-limestones in the north flank of the syncline and bedded limestones in the south flank | Peloids, intraclasts, micropeloids, breccias, rugosans, chaetelids, <i>Tharharella</i> , echinoderms, gasteropods, spicules, calcareous algae and foraminifers | Mud-mounds and Reef-mounds. Near to shore. Shallow, highly to moderate agitated water. Between wave base and storm base. Well-oxygenated, normal marine. | <i>Multithecopora</i> sp. G & <i>Neomultithecopora cantabrica</i> | late Moscovian (Podolskian) |
| Playa de la Huelga | Boundstones (bafflestone) of <i>Multithecopora</i> with a packstone matrix / Boundstone (Framestone) of <i>Neomultithecopora</i> / Boundstone (framestone) of chaetelids/ Bioclastic packstone | Massive and bedded limestones, marls, calcareous sandstones and breccias | Small bioclastic remains, breccias, rugosans, chaetelids, brachiopods, bryozoa, crinoids, molluscs and foraminifers. | Reef-mound and associated facies. Near to shore. Shallow, highly to moderate agitated water. Between wave base and storm base. Well-oxygenated, normal marine. | <i>Multithecopora hontoriense</i> , <i>Neomultithecopora cantabrica</i> & <i>Mastopora?</i> sp. | late Moscovian (Podolskian-Myachkovian) |
| Celada de Robledo Sur | Boundstone of beresellids / Boundstone of <i>Sinopora</i> | Thin tabular beds of limestones and some massive limestones | Micropeloids, rims and cavities, pseudostromatactic cavities. <i>Tharharella</i> , <i>Anthracoarella</i> , <i>Tubiphytes</i> , chaetelids, foraminifers (textulariids and fusulinids), echinoderms, crinoids, calcisphaera, gastropods, aoujgalids, brachiopods. | Bioherm facies. Near to shore. Shallow, highly to moderate agitated water. Between wave base and storm base. Well-oxygenated, normal marine. | <i>Sinopora</i> sp. | late Moscovian (Myachkovian) |

Table 2.- Localities and microfacies associated with the aulopod corals, geometry and lithology, main components, depositional environment and characteristics, morphotypes and age.

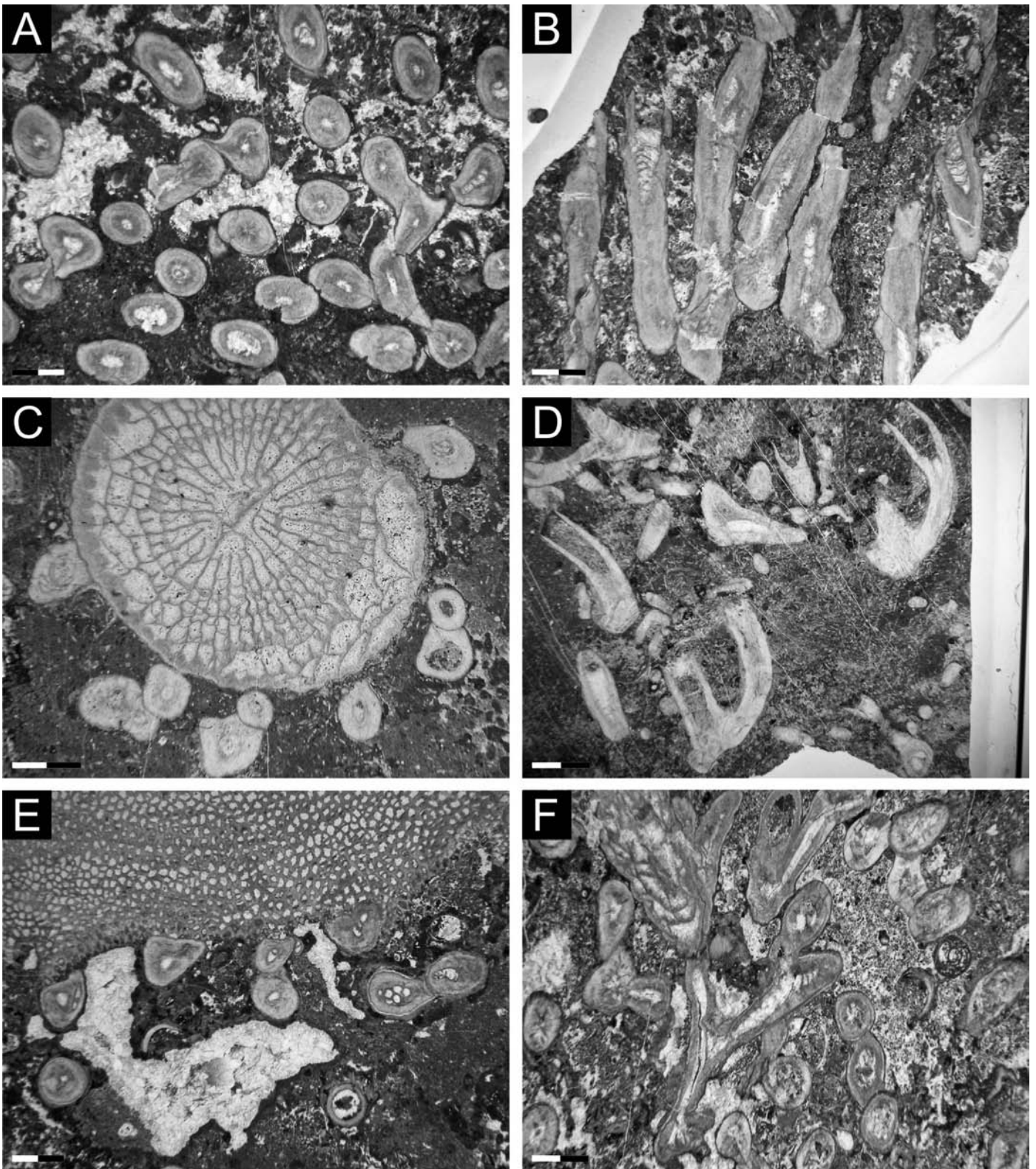


Fig. 10.- A-B) *Multithecopora* sp. D from Valdeteja-Las Majadas sections. Note the vertical and parallel development of the colony in a typical microbial matrix with pseudostromatactoid cavities, peloids and micritic envelope. C-F) *Multithecopora* sp. E. C-D) Samples from Las Ilces section. Note the encrusting habit on a rugosan from C in a microbial facies. D) Strategy of developing a stepped offsetting in response to an aggrading substrate in a *Donezella* core mound. E-F) Samples from Piedrasluengas section. E) Note the encrusting habit on a chaetid in a microbial texture from the bioherm facies. F) Detail of the phaceloid to bushy habit of the colony. Scale bar is 2 mm.

ship (diameter/lumen) is low, because the lumen is usually open (Fig. 9E-F). This morphotype shows scarce, small septal spines, and acute shape and thick concave tabulae. These morphologic criteria suggest that this morphotype belongs to *Mastopora*. The genus *Mastopora* has been found previously only in the Silurian and Devonian, but as the section Playa de la Huelga has been dated as upper Moscovian (Podolskian) we use this genus with question mark.

4.4. Microfacies and palaeoecological characteristics

The sections sampled offer a large variety of environments, microfacies, and associations where the Carboniferous auloporids from the Iberian Peninsula could grow. Table 2 shows a compendium of data of the different microfacies found in studied samples (section, microfacies, geometry and lithology of the beds, components, depositional environment and characteristics derived from the study of the other components, fabrics, morphotypes, and age).

These data show that the dominant microfacies are coral or chaetetid boundstone (*sensu* Dunham, 1962). The bioclastic microfacies (e.g. bioclastic wackestone, packstone or grainstone) are common too, and they formed in a large variety of environments (flanks of buildups, shallow tidal flats or storm beds in inner or medial carbonate platforms).

The predominant host rock in these sections is massive limestone, occasionally with domical shape. Marls and silty limestones are subordinate in some sections. The most common occurrence of auloporoids is in the core of reef mounds, patch-reef and reef systems. Auloporoids also occur in the capping beds of microbial mounds. The bedded limestones instead, are associated with bioclastic microfacies dependent on energetic environments, such as talus facies or storm beds.

The fossil assemblages related to the Auloporida in the Iberian Peninsula are dominated by the presence of crinoids, calcareous algae, chaetetids and other corals. It suggests that those communities are developed in shallow to moderately deep seas that present well-oxygenated and marine normal salinities.

5. Results and Discussion

The Carboniferous Auloporida from the Iberian Peninsula occurs in a large variety of environments and they were related to a wide spectrum of other invertebrate groups (Table 2).

The oldest occurrences are recorded in the upper Viséan (Middle Mississippian) in the Los Santos de Maimona and Cerro Almeña sections. Auloporids occur there in two different environments: reef flat and shallow-water platform. The Auloporids related to reef-flat platforms (Rodríguez *et al.*, 1992; Rodríguez, 1996) show a diverse assemblage dominated by gigantoproductid brachiopods that are the base for the attachment of rugose corals and auloporids (Syringoporidae are the dominant auloporids). Well-preserved build-up beds

alternate with storm beds where corals and brachiopods are reworked. Auloporids occur in growth position at the top of some beds developed in a shallow-water platform (above the wave-base) from Cerro Almeña. Fragments of the same corals occur in the middle part of the beds.

Auloporoids occur in more diverse environments, with Multithecoporidae the dominant auloporids in the Viséan from the Guadiato Basin. They lived at the top of microbial mounds (Sierra de la Estrella Section, Rodríguez-Martínez *et al.*, 2003), in patch reefs (Antolín Section, Rodríguez and Rodríguez-Curt, 2002), and in shallow-water platforms affected by storms (El Collado Section; Fuenteovejuna Section, Cózar *et al.*, 2007; and Adelfilla Section). In all cases they are associated with diverse assemblages that include rugose corals, chaetetids, brachiopods, crinoids, bryozoans, algae, cyanobacteria and foraminifers.

The Serpukhovian rocks from the Guadiato Basin yielded a poor assemblage of auloporoids (San Antonio and La Cornuda sections, Gómez-Herguedas and Rodríguez, 2008) that lived in small mud mounds mainly composed of algae, rugose corals, chaetetids and peloidal wackestone produced by microbial communities.

During the Pennsylvanian there is a change in the benthic communities, but the Multithecoporidae were still present and became dominant components in many environments. Consequently, they occur in many Pennsylvanian localities from the Cantabrian Zone.

Auloporids occur in the Bashkirian and Moscovian, being a main or a secondary component of reef mounds built by them, associated with calcareous algae (*Donezella*, *Anthracoporella* and/or phylloid algae), as well as rugose corals, chaetetids and microbial communities (Las Ilces Section, Coronado and Rodríguez, 2009; Prioro section, van Loon, 1971; Celada de Roblecedo and Pico Guillermo sections (van der Graaff, 1971b). As in the Mississippian, they also occur at the top of microbial and algal mounds and in surrounding facies (Valdeteja Section, Eichmüller, 1985). Auloporoids are also common in shallow-water platforms. They built biostromes associated with rugose corals and chaetetids (Piedras Luengas Section, Minwegen, 2001) and built reefal structures associated also with rugose corals and chaetetids (Playa de la Huelga Section, Minwegen 2001; Bahamonde, 2008). Occasionally, they occur in shallow-water platforms with soft bottom, growing on rugose corals or brachiopods (Playa de la Huelga, Rodríguez and Ramírez, 1987; Ribadesella, Rodríguez *et al.*, 1997 and Este de Camasobres sections).

Most of the Auloporida that are found in these environments belong to the superfamily Syringoporicae, which show phaceloid and more rarely cerioid morphology, with a diverse density of occurrence and growth-directions of corallites. The growth strategies of tabulate corals were analyzed by Scrutton (1997). They depend on the strength of substrate, the competitiveness with other organisms and the environmental conditions during the colony development. The Syringoporicae of the Iberian Peninsula show diverse strategies:

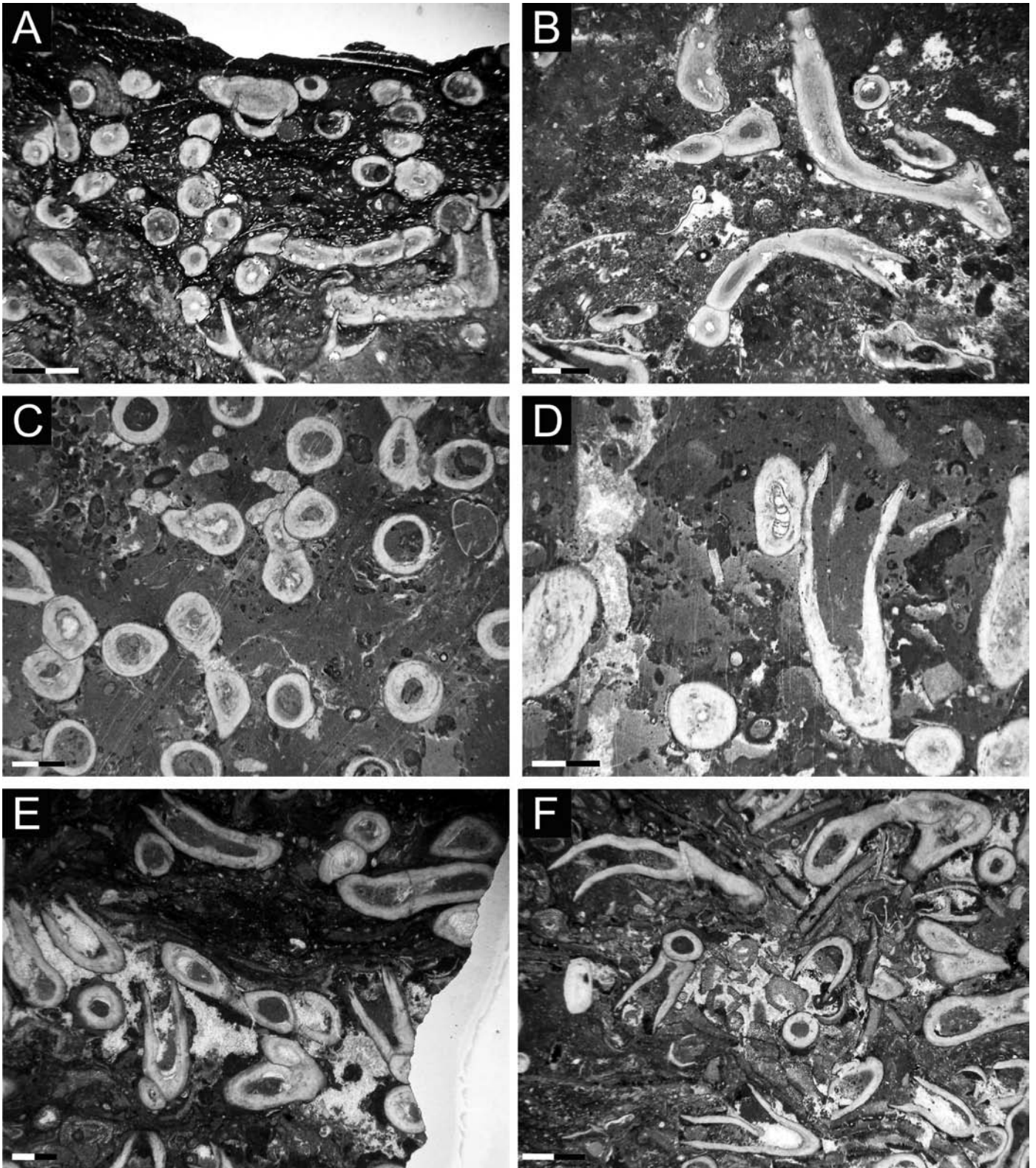


Fig. 11.- A-B) *Multithecopora* sp. F from Este de Camasobres section. A) Detail of the reworked facies where the corallites show fragmentation and abrasion. B) Reptant growth of the corallites in microbial matrix. C-D) *Multithecopora* sp. G from Prioro section. Growth of the colonies in a microbial substrate and presence of open calices with thicker walls. E-F) *Sinopora* sp. from Celada de Robledo section. E) Prostrate and tumbled corallites growing in steps. F) Reworked facies of *Sinopora* with abundant phylloid algae. Scale bar is 2 mm.

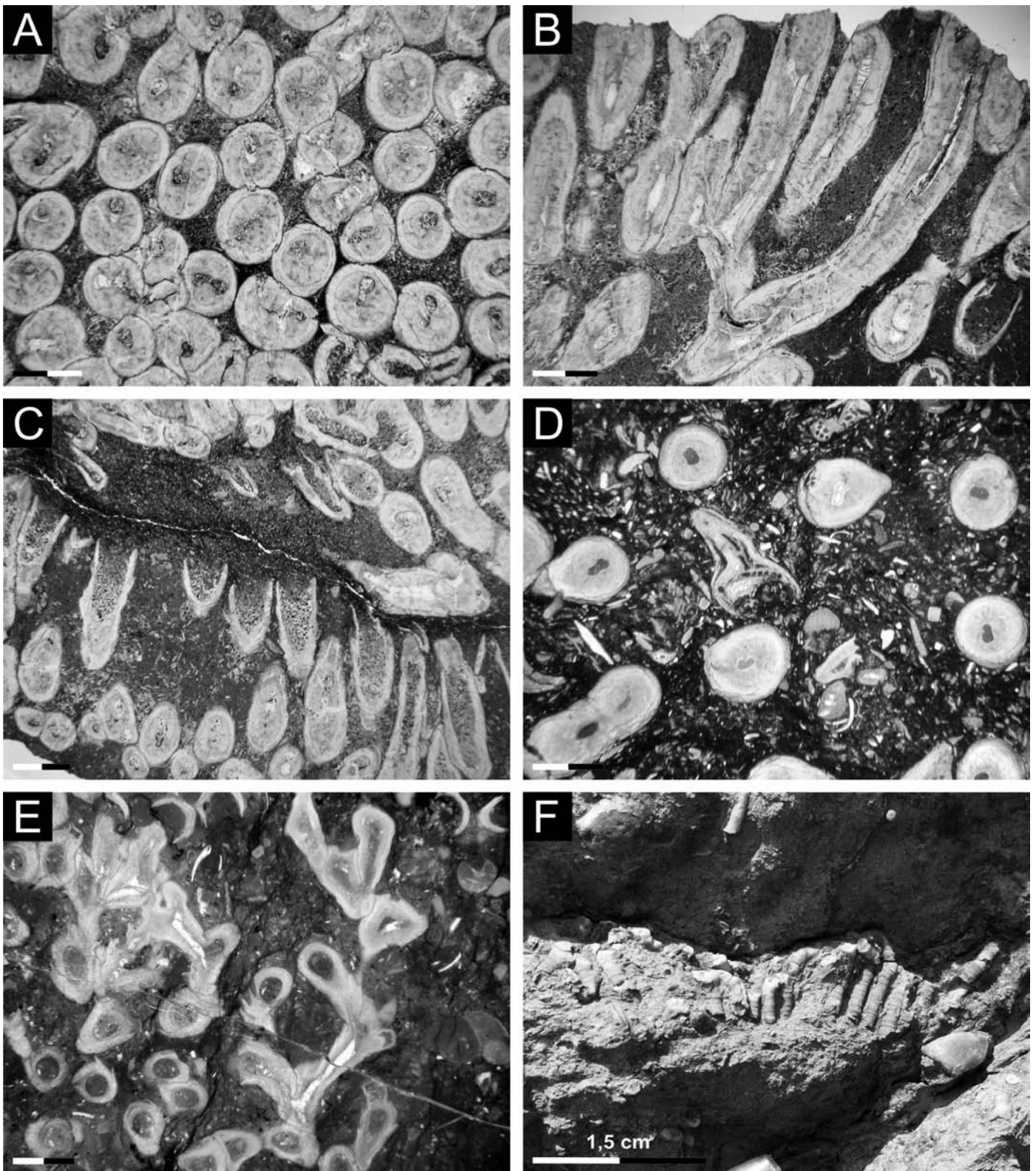


Fig. 12.- *Multithecopora hontoriense* Rodríguez and Ramírez, 1987. A-C) Samples from Pico Guillermo section. Note the phaceloid habit and dense packing of corallites producing a massive colony. C) Stepped offsetting developed in response to an aggrading substrate with vertical corallites in the top and tumbled or prostrate ones in the bottom of the colony. D-F) Samples from Playa de la Huelva section. Note the vertical and parallel development of the colony in D and F. E shows a branched development with a short growth of the corallites. Scale bar is 2 mm.

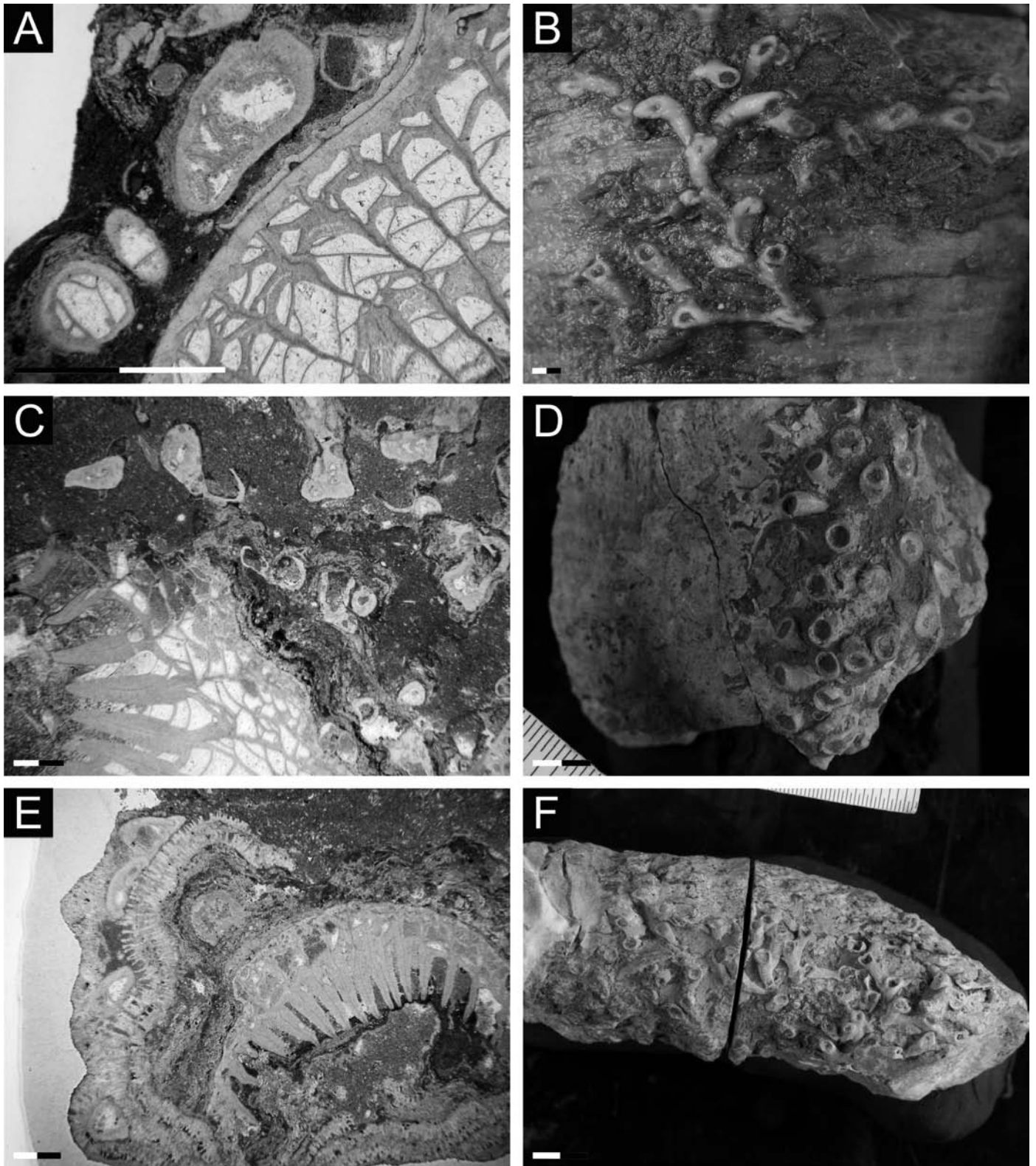


Fig. 13.- A-B) *Aulopora* sp. A from Ribadesella section. A) Detail in thin section of this morphotype. Note the thin infundibuliform tabulae and the incrustation on a rugose coral. B) Note the reptant habit of the corallites growing on a rugosan. C-F) *Aulopora* sp. B from Ribadesella section. C) Detail of the branching bushy habit of a colony. D) Detail in thin section from the corallites; note the differences with *Aulopora* sp. A. E) Encrustation of a chaetetid on a rugosan and *Aulopora* on and between the chaetetid. F) Reptant growth on a rugose coral. Scale bar is 2 mm.

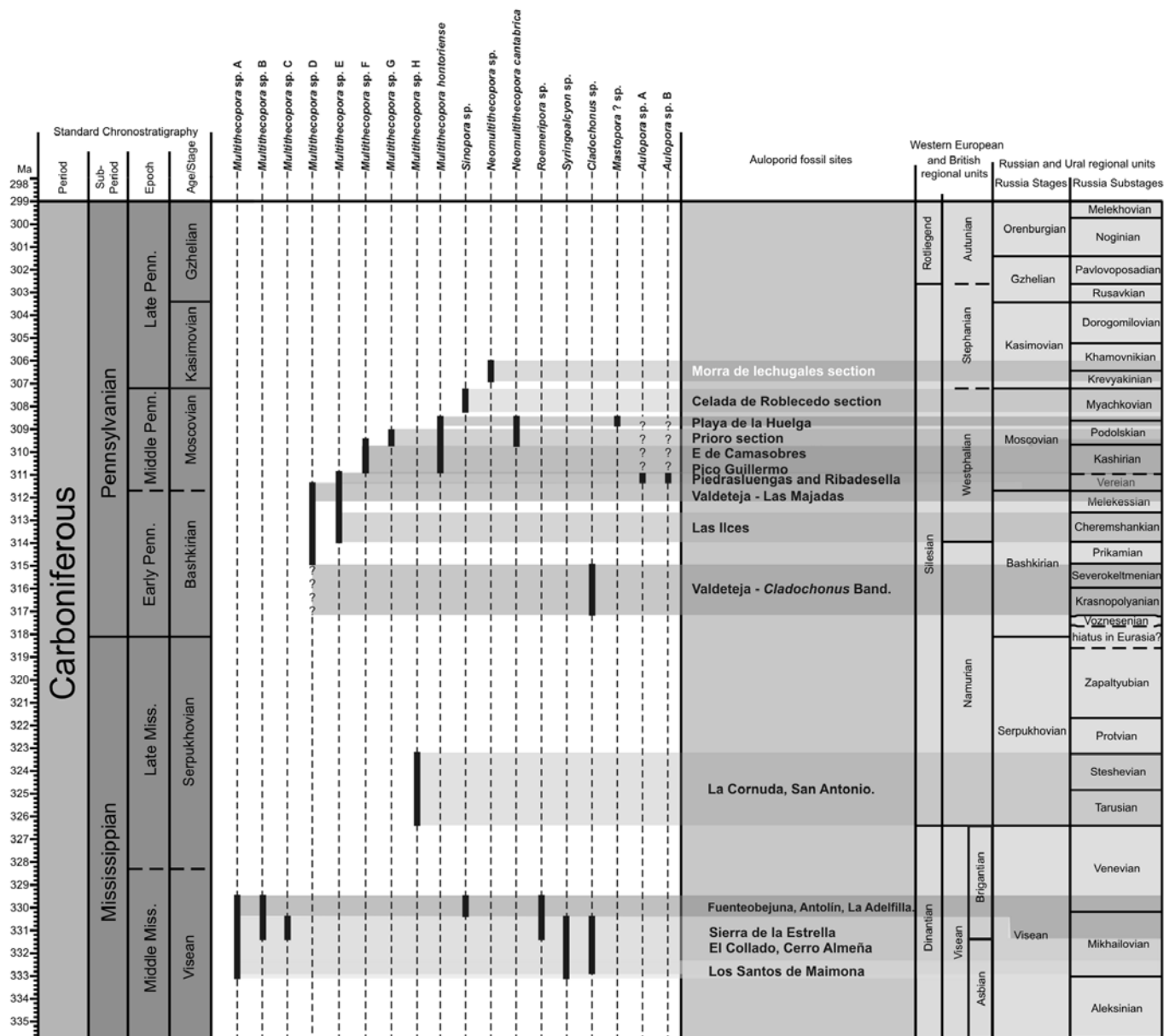


Fig. 14.- Biostratigraphical distribution of the auloporid corals found in the Iberian Peninsula. Note the gap between the upper part of the Mississippian and the lower part of the Pennsylvanian.

Syringopora and *Syringoalcyon* in Los Santos de Maimona and Cerro Almeña Sections show phaceloid (palisade) colonies with the main development in the periphery (Fig. 7 E-I). This strategy is possible because of the presence of hard substrate such as brachiopod shells or rugose corals and protection against high energy of the waves. The vertical growth is unlimited in Cerro Almeña, but limited by the level of low tides in Los Santos de Maimona.

Multithecopora hontoriense from Playa de la Huelga and Pico Guillermo sections shows a similar strategy (Fig. 12. A-B, F). In this case, the corallites are closely packed and show connecting tubuli. These colonies grew on chaetetid colonies. *Roemeripora* from Fuenteovejuna Section (Fig. 8. E-F) and *Neomultithecopora cantabrica* from Playa de la Huelga section share the same strategy and develop massive colonies (Fig. 8. C-D).

Syringopora sp. B, *Multithecopora* sp. A and *Multithecopora* sp. B from Antolín and Sierra de la Estrella sections show a lower density of corallites and branched colonies (Fig. 5. B-C). It is probably due to the substrate. It is composed of peloidal carbonate produced by microbial communities. Due to early lithification, the substrate was firm but not hard, providing less support for the high density of corallites. This strategy is also used by *Multithecopora hontoriense* (Fig. 12. E), *Multithecopora* sp. C, *Multithecopora* sp. H (Playa de la Huelga, Pico Guillermo, El Collado, La Cornuda sections, respectively) and *Neomultithecopora* sp. from Morra de Lechugales section (Merino-Tomé *et al.* 2009). All these morphotypes show bushy colonies with unlimited vertical growth. In the case of *M. hontoriense* and *Neomultithecopora cantabrica*, they grew on chaetetid skeletons and brachiopod shells (Fig. 7. C).

Multithecopora sp. D (Valdeteja section), *Multithecopora* sp. B (Fuenteobejuna section), *Multithecopora* sp. F (Este de Camasobres section), *Neomultithecopora cantabrica* (Prioro and Playa de la Huelga sections) and some specimens of *Multithecopora* sp. A (Sierra de la Estrella) show an initial stage of reptant growth (Fig. 5. E-F; 7. B; Fig. 11. B) followed by an erect growth with corallites vertical and parallel forming typical phaceloid colonies (Fig. 10A-B).

Multithecopora sp. E (Las Ilces and Piedrasluengas sections), *Sinopora* (Celada de Roblecedo Section), *Multithecopora* sp. G (Prioro Section), some colonies of *Multithecopora* sp. F (Este de Camasobres Section) and *Sinopora* (Celada de Roblecedo Section) follow the strategy of developing a stepped offsetting in response to an aggrading substrate (when they grew related to microbial communities) or to competition with other organisms. Well-preserved examples of this strategy are found also in *Multithecopora hontoriense* (Pico Guillermo section) and *Multithecopora* sp. E (Las Ilces section), where the colonies are influenced by the substrate that cut the vertical development and finally is distorted in several bands (Fig. 10. D; Fig. 12. C).

The Auloporicae that do not occur in buildups and show also diverse growth strategies, adapted usually to environments with high energy or high terrigenous influx:

Mastopora? occurs in calcareous sandstones with planar lamination associated with encrusting bryozoans and crinoidal ossicles. It grew in an environment of quite high energy and near shore. It shows reptant growth developing a complete encrusting sheet (Fig. 9F).

Aulopora morphotypes occur mainly in marly facies, associated with rugose corals (Fig. 13A-F) and chaetetids. They grew in columnar profiles (*Aulopora* sp. A) or in branching bushes (*Aulopora* sp. B). All occurrences whatever autochthonous or allochthonous, show evidence of terrigenous influx.

Cladochonus morphotypes show simple lateral branches with a reptant growth habit and zig-zag trajectories (Fig. 8B). Scrutton (1997) regarded this strategy as due to development in a soft substrate.

As explained above, the auloporids from the Iberian Peninsula occur in different habitats, developed diverse strategies and were related to different fossil assemblages. However, there is a typical assemblage, which is repeated in many cases. It is the "Chaetetid-auloporoid-rugose coral buildups" described by West (1988), Minwegen (2001) and Wahlman (2002), as an interrelationship between corals and chaetetids, using each other as substrate and framework. The Pennsylvanian buildups from the Iberian Peninsula show different assemblages of reef-building organisms, including *Donezella*, *Anthracoporella*, *Petschoria*, phylloid algae and bryozoans. Auloporoids are present in all of them, but their most common association includes the presence of chaetetids.

Figure 14 shows the stratigraphical distribution of the morphotypes and species of auloporoid corals studied herein. The auloporoids show many overlaps between the ranges of the

morphotypes in both regions (Ossa-Morena and Cantabrian zones). There is also a reduced representation in the uppermost Mississippian and lowermost Pennsylvanian. In contrast, the record is quite complete in the Viséan and from the Bashkirian to Moscovian. It is due to the scarcity of outcrops and/or the unfavourable environments. As the identification and assignation of new species names is still not completely finished, this is a provisional chart, which will be improved with further studies.

6. Conclusions

Auloporid corals are highly diverse in the Carboniferous of the Iberian Peninsula, mainly in the outcrops of the Ossa-Morena Zone (Mississippian age) and Cantabrian Zone (Pennsylvanian age). The auloporids have been identified following the criteria proposed by Tchudinova in (1980) with some modifications. They have been subdivided into morphotypes and grouped according to common characteristics.

Eighteen morphotypes and two species belonging to nine nominal genera have been identified (*Multithecopora* sp. A-H, *Syringopora* sp. A-B, *Aulopora* sp. A-B, *Cladochonus* sp. A-B, *Syringocalcyon* sp., *Roemeripora* sp., *Sinopora* sp., *Mastopora?* sp., *Multithecopora hontoriense* and *Neomultithecopora cantabrica*).

Syringopora, in the Carboniferous from the Iberian Peninsula is only present in the Mississippian. The dominant genus through the Carboniferous is *Multithecopora*, represented by 8 morphotypes and one species. Forms with pseudocerioid growth habit were derived from phaceloid forms: *Roemeripora* from *Syringopora* in the Mississippian and *Neomultithecopora* from *Multithecopora* in the Pennsylvanian.

The genus *Syringocalcyon*, which is globally very scarce, is quite abundant in the Los Santos de Maimona Basin. The validity of this genus is doubtful and it will be further studied in the future.

These corals inhabited different environments, and show diverse growth strategies. They lived in buildups (reef-mounds, patch-reefs), on microbial mounds, in reef-flats and carbonate shallow platforms). The microfacies study shows that these corals inhabited shallow, well oxygenated waters with normal marine salinity. Those environments allowed the development of diverse communities in which the auloporoids were related to rugose corals, chaetetids, crinoids, brachiopods, algae, foraminifers, molluscs, etc. The biostratigraphic distribution has been established for the proposed morphotypes as a provisional chart, which will be improved with further taxonomic studies.

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