Ovetian cryptic archaeocyaths, lower Cambrian from Las Ermitas (Córdoba, Spain)

Antonio PEREJÓN, Elena MORENO-EIRIS

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Abstract: The record of the archaeocyathan community supports the conclusions that these cryptic organisms were pioneers in crevices into neoproterozoic andesites in Las Ermitas (Pedroche Formation, Ossa-Morena, Spain) during Ovetian time. The different filling phases and the cavity-dwelling biota are described in VENNIN et al. (2003). The archaeocyaths and calcified microbial organisms are major components; we describe here the archaeocyathan taxa from the crevices and breccias. The poriferan cryptic community is composed by coelobiontic forms in life position, including *Dokidocyathus avesiculoides, Nochoroicyathus* sp., *Erismacoscinus* sp., *Neoloculicyathus magnus, Protopharetra gemmata* and *Protopharetra* sp. They were attached to hard substrates, such as calcified microbial or archaeocyathan skeletons during the first phases of filling the cavities and crevices. The last filling phases include common debris skeletons of chancelloriids, hyoliths, brachiopods, trilobites, and reworked *Okulitchicyathus andalusicus.*

The immediately overlying levels of the cavities are breccias, calcimicrobial limestones and lutites with carbonate nodules. The archaeocyathan diversity is high in these platform sediments, 41 taxa in total. We describe here also species from those breccias too, including *Okulitchicyathus andalusicus, Rotundocyathus* sp., *Leptosocyathus?* sp., *Urcyathus?* sp. and the new *Nochoroicyathus simoni.*

The Ovetian cryptic archaeocyathan community from Las Ermitas is composed of *Dokidocyathus* and *Protopharetra,* which mark the first occurrence of cryptic taxa in Atdabanian 1. *Neoloculicyathus* and *Erismacoscinus* are common to others cryptic communities of Atdabanian 1 in the Siberian Platform, but *Okulitchicyathus* was described from the Tommotian. Therefore this Spanish cryptic archaeocyathan assemblage is different from others described from the Atdabanian and these are not obligate cryptobionts because the same taxa appear in the platform sediments outside the cavities.

Forty species in total have been described in the reef complex from Las Ermitas. The cryptic community represents eleven per cent, and the mound community twenty three per cent of the diversity; but in other facies the archaeocyaths represent higher diversity, such as the fifty eight per cent in the nodular and interbiohermal facies, but only eight percent in the breccias.

Universidad Complutense de Madrid, Facultad de Ciencias Geológicas e Instituto de Geología Económica, Departamento y U.E.I. de Paleontología, Ciudad Universitaria c/José Antonio Novais 2, 28040 Madrid, Spain, e-mails: aparqueo@geo.ucm.es, eiris@geo.ucm.es

Key words: Archaeocyaths, cryptic communities, Ovetian, Lower Cambrian, Las Ermitas, Córdoba, Spain

Contents

1. INTRODUCTION

The Córdoba mountain range (SW of the Iberian Peninsula) shows important peaks of rock materials, that compose a morphological highlight over the Guadalquivir plain. The oldest materials are from the Late Proterozoic and the youngest ones are from the Miocene. Las Ermitas hill north of Córdoba has volcano-sedimentary materials from the Upper Proterozoic in its base and these rocks are overlain by a terrigenous-carbonatic succession from the Lower Cambrian, composed mainly of microbial limestones.

MALLADA (1880) considered the existence of Cambrian in this area based on lithological criteria; although it was not until the beginning of the 20th century, when archaeocyaths were cited from Las Ermitas (HERNÁNDEZ-PACHECO, 1902) confirming the supposed age. After that, in 1917, this same author gave names to different taxa of Archaeocyatha, he described them in 1918, but he did not illustrate them. SIMON (1939) elaborated a detailed stratigraphic succession from Las Ermitas, analyzed the distribution of the facies and of the archaeocyaths, and also described and illustrated several taxa.

DEBRENNE & LOTZE (1963) revised the archaeocyathan specimens from Las Ermitas that were in the collections of the German museums and updated their systematic allocations. Starting in 1970, a coordinated study of all the Spanish localities with archaeocyaths began, which included detailed studies of many stratigraphic sections and the descriptions of numerous taxa from all the Spanish Cambrian areas. The studies of PEREJÓN (1971, 1975a,b,c, 1976a,b, 1994), ZAMARREÑO & DEBRENNE (1977), LIÑÁN (1978), MORENO-EIRIS (1987, 1988), MORENO-EIRIS et al. (1995), and FERNÁNDEZ-REMOLAR (1999), have contributed important stratigraphical, sedimentological and paleontological data to the study of the successions from Las Ermitas.

JAMES & KOBLUK (1978), KOBLUK & JAMES (1979), and KOBLUK (1981a,b) were the first that interpreted the existence of cavities in the carbonate sedimentary record of the Lower Cambrian. Such cavities have a biological and sedimentological history of great interest to the interpretation of the sedimentary process of these materials. These cavities preserved the record of the cryptobiota, the processes that affected them, and the organic activity, the contained sediments and the early diagenesis.

The cryptobiota constitute an important part of the organisms that live in present reefs (Reitner, 1993; Reitner et al., 2000), but in the geological record of ancient reefs it could be really difficult to differentiate them from epibenthonic organisms, that lived on the surface of the reefs (Kobluk, 1981a,b). Kobluk & James (1979), Kobluk (1988), Zhuravlev & Wood (1995), and Pratt (2000) have studied and characterized a wide range of cryptobiota in the reef cavities of the Lower Cambrian. In the Las Ermitas reef complex the first phases of the installation of the carbonate platform constitute the crevices into the paleotopography of igneous material, with a system of cavities filled by coelobiotic biota, that was mainly microbes and archaeocyaths (Vennin et al., 2003).

This paper focuses on the detailed systematic study of the association of cryptic archaeocyaths and on their comparison with the taxa in the different facies of the reef complex.

2. GEOLOGICAL SETTING AND STRATIGRAPHY

Lotze (1945) proposed the division of the Variscic Chains of the Iberian Peninsula in six tectonostratigraphical units, according to their structural and sedimentary characteristics. The Córdoba Mountains belong to the Ossa-Morena and its development was conditioned by a rifting phase during the Cambrian (Liñán & Quesada, 1990).

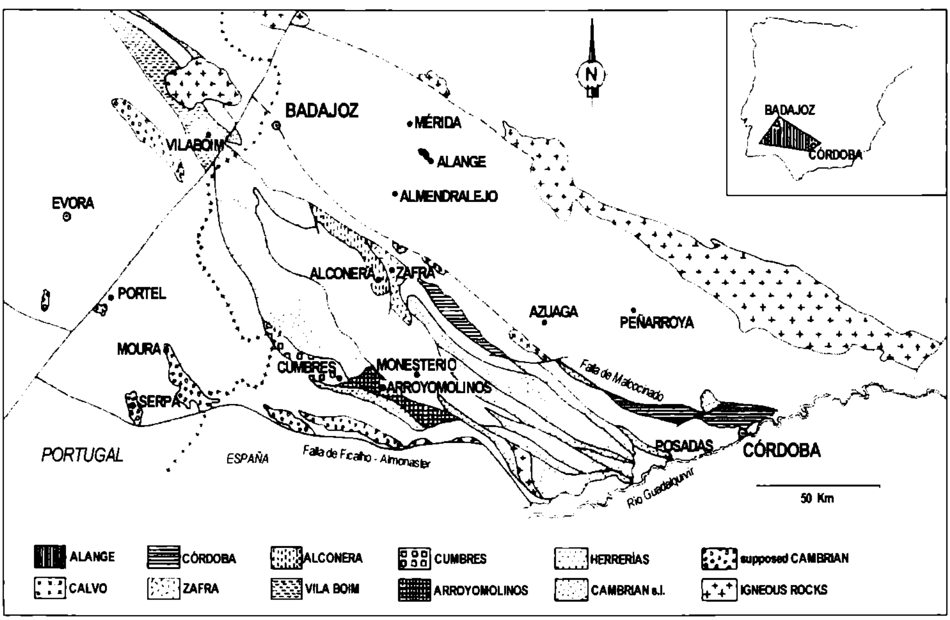

Fig. 1: Tectonostratigraphic units of Ossa-Morena (modified after Liñán & Quesada, 1990).

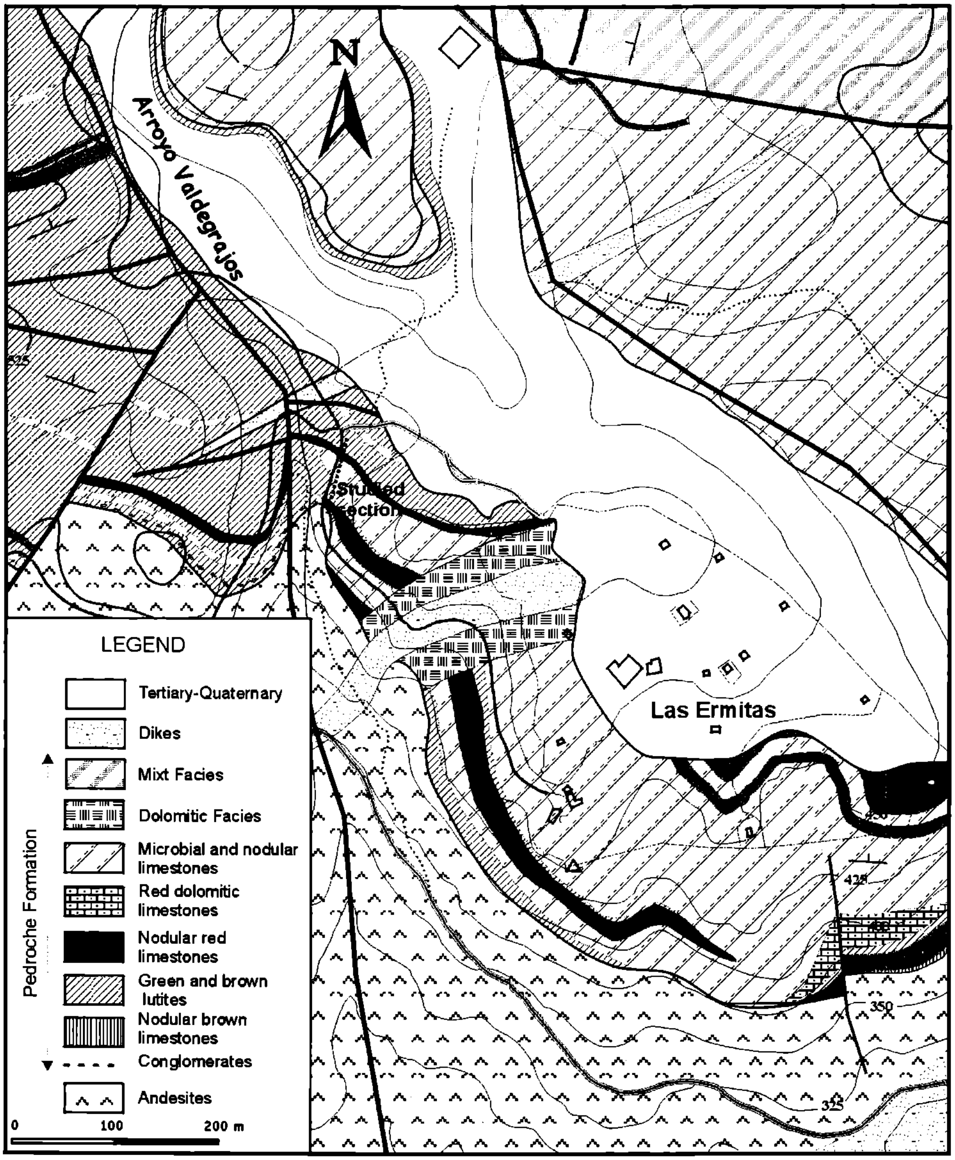

Fig. 2: Detailed geologic map of the studied area (modified after Fernández-Remolar, 1999).

Ossa-Morena is one of the major tectonostratigraphic units (Fig. 1) into which the pre-Hercynian Iberian Massif (Lotze, 1945) has been subdivided. The former contains a complex framework of Paleozoic troughs and platforms that recorded a rifting phase during Cambrian times (Liñán & Quesada, 1990). The oldest sedimentary succession of the Córdoba platform is a volcano-sedimentary group (Liñán, 1974), whose uppermost

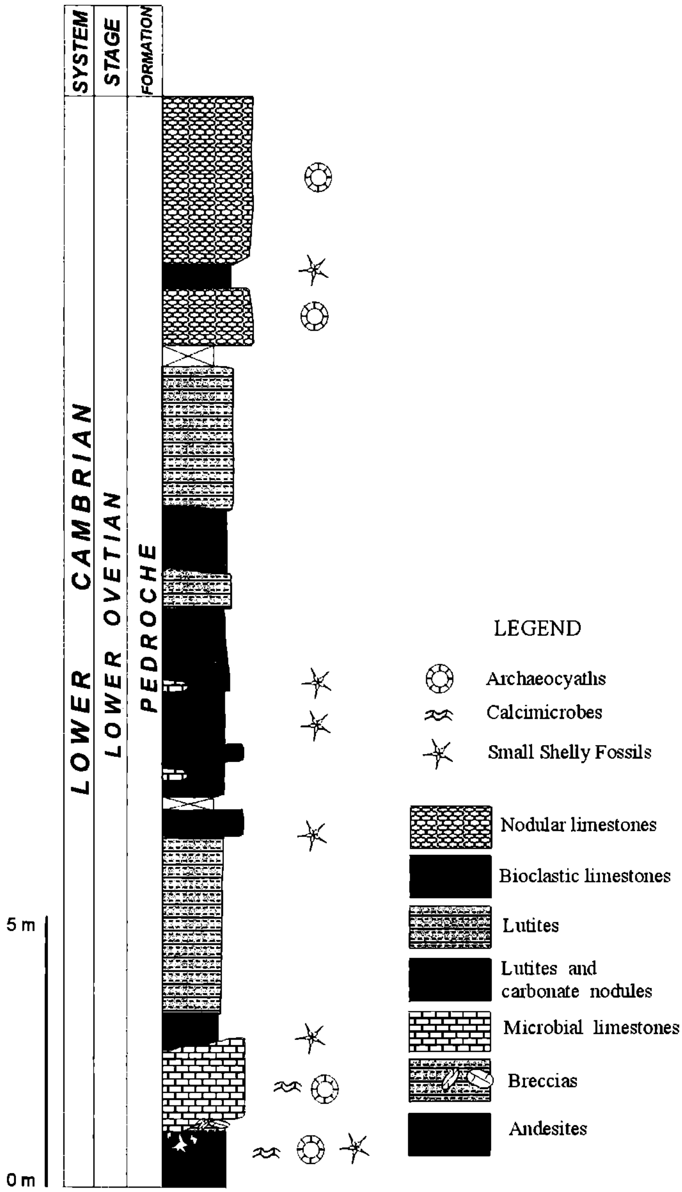

Fig. 3:
Lower Cambrian stratigraphic section of the Las Ermitas (modified after FERNÁNDEZ-REMOLAR, 1999).

part, named the San Jerónimo Formation (ca. 1200 m thick), consists of shales, sandstones and conglomerates interbedded with andesites. The San Jerónimo Formation is unconformably overlain by the Torreárboles Formation, a siliciclastic unit, 0–450 m thick, composed of conglomerates, arkosic sandstones with interbedded shales. The Torreárboles Formation is conformably overlain by the Pedroche Formation (300 m thick), which consists of limestones, shales and rare intercalations of sandstones and dolostones. This formation displays sharp lateral variations in facies and thickness. The Pedroche Formation contains common archaeocyathan buildups, stromatolites, trilobites and shelly fossils indicating an early Ovetian age (Early Cambrian; LIÑÁN et al., 1993), which corresponds to the Iberian zones I, II and III based on archaeocyaths (PEREJÓN, 1986, 1994, 1996; MORENO-EIRIS et al., 1995).

Cambrian deposition began in the Córdoba platform area filling a Neoproterozoic paleorelief. As a whole, a Cordubian – early Ovetian transgressive tendency is recorded in this platform, indicated by the onlapping geometry of the Torreárboles and Pedroche Formations over the andesitic substrate. In the Las Ermitas area (Fig. 2), a giant reef complex belonging to the Pedroche Formation directly overlies the San Jerónimo andesites (ZAMARREÑO & DEBRENNE, 1977; MORENO-EIRIS, 1988), whereas western outcrops permit identification of the unconformity of the San Jerónimo/Torreárboles boundary. A recent enlargement of the Córdoba-Las Ermitas road has permitted the recognition of irregular cavities at the unconformable boundary between the San Jerónimo andesites and the giant reef complex of the Pedroche Formation (Fig. 3).

3. ANALYSIS OF THE TAXA OF THE ARCHAEOCYATHA AND THEIR ROLE IN THE CAVITIES

3.1. Characteristics of the cavities

The cavities and crevices located at the unconformable San Jerónimo/Pedroche boundary in the Las Ermitas area stand out in contrast to surrounding andesites as irregular masses of white limestone encased in greenish, altered andesite. Shapes of individual cavities are an interplay of original fissures and synsedimentary fracturing: they are irregular in shape, commonly up to 2 m deep, and range from 0.2 to 3 m width. There are five distinct filling phases in the more complex cavities. The first and second phases represent complete infills of open cavities, whereas the subsequent ones were tectonically induced, favouring development of vertical and steeply inclined walls. The first phase directly encrusts the walls of cavities with stromatolitic laminae. In the second phase, the microbial-archaeocyathan boundstone, archaeocyaths grew directly on stromatolitic surfaces or attached to other archaeocyathan walls (VENNIN et al., 2003).

3.2. Disposition, growth, and cryptic facies

The Archaeocyatha that lived in the cavities have been preserved in growth position, stuck to walls of the cavities, or hanging from ceilings of the cavities, they also joined with other cryptobionta and with synsedimentary cements. In some cases the cups are encrusted by calcimicrobian covers.

In the cavities the taxonomic diversity of the Archaeocyatha is greater in Facies 2 (microbial-archaeocyathan boundstone), with specimens of *Dokidocyathus avesiculoides*, *Erismacoscinus* sp., *Neoloculicyathus magnus*, *Protopharetra gemmata* and *P.* sp., all in growing position and enclosed in an important calcimicrobian development; in Facies 3 (bioclastic wackestones) diversity is reduced to *Dokidocyathus avesiculoides*, *Nochoroicyathus* sp. 1 and *N.* sp. 2, also in growing position, scattered in a micritic matrix, and Facies 4 (archaeocyathan and bioclastic floatstones) includes only reworked *Okulitchicyathus andalusicus*.

3.3. Relationships between them

Dokidocyathina and Ajacicyathina species are solitary and do not show direct relationships between the different individuals. An important epitheca is developed in a young specimen of Dokidocyathina. Ajacicyathina are commonly altered by calcimicrobes. Specimens of Loculicyathina commonly have a thick crust of *Girvanella* that wraps the cups in their initial stages. Archaeocyathina frequently show chains of individuals with many external buddings hanging from ceilings or walls of the cavities.

3.4. Size

The cups of the Ajacicyathida are small, generally their diameters do not exceed 5 mm and only *D. avesiculoides* reaches 7 mm. Diameters of the Archaeocyathida are bigger, ranging between 5 and 13 mm, and *P. gemmata* and *O. andalusicus* are the biggest ones.

3.5. Taxonomic diversification according to the facies

Analysis of the record of the archaeocyaths in the different facies that are related to the cavities in Las Ermitas shows differences in the biological diversity (Tab. 1).

The special ecological conditions in which the archaeocyaths developed inside the cavities, low light, limited nutrients and space, evoked the low diversity of this association that is formed by seven species of five different genera. All of them also occur in the nodular facies and some of them also occur in the mounds.

In the association that appears in the clasts of the breccias, all the taxa of Ajacicyathina, *Nochoroicyathus simoni* n. sp., *Leptosocyathus?* sp., *Rotundocyathus* sp. and *Urcyathus?* sp, are exclusive of this facies, with a huge range in their sizes between 2 and 7 mm. Among the Loculicyathina only *Okulitchicyathus andalusicus* occurs and it is also the only taxon found in all the facies, where it reaches diameters of more than 8 mm.

Living conditions in which the archaeocyaths developed inside of the microbial mounds were not very favorable, although possibly nutrients were abundant. The association of archaeocyaths was more diverse than that of the cavities, but is poor in relation to the nodular interbiohermal facies. Eight taxa of Ajacicyathida (4 genera with 5 species, and 3 sp.) and seven taxa of Archaeocyathida (5 genera with 4 species, and 3 sp.) are represented. It is notable that the strong diagenesis that has affected the mounds has produced an important recrystalization of the carbonates, which hinders the observation and determination of the archaeocyaths that are part of them.

Archaeocyathan taxa	cavities	breccias	nodular	mounds
Archaeolynthus polaris			X	
Archaeolynthus sp.			X	
Archaeopharetra sp.			X	X
Cordobicyathus deserti			X	X
Coscinocyathus sp.			X	
Dictyocyathus stipatus			X	X
Dictyocyathus sp.			X	X
Dokidocyathus aff. *regularis*			X	
Dokidocyathus avesiculoides	X		X	X
Dokidocyathus sp.			X	X
Eremitacyathus fixus			X	
Erismacoscinus sp.	X		X	
Fallocyathus pedrochei			X	
Leptosocyathus? sp.		X		
Morenicyathus cordobae			X	
Morenicyathus arruzafai			X	
Neoloculicyathus magnus	X		X	X
Nochoroicyathus anabarensis			X	X
Nochoroicyathus cabanasi			X	
Nochoroicyathus cf. *eremitae*			X	
Nochoroicyathus eremitae			X	
Nochoroicyathus simoni nov. sp.		X		
Nochoroicyathus tkatschenkoi			X	X
Nochoroicyathus cf. *umbrella*			X	
Nochoroicyathus valdegrajensis			X	
Nochoroicyathus sp. 1			X	X
Nochoroicyathus sp. 2			X	
Nochoroicyathus sp. 3				
Nochoroicyathus sp.	X		X	X
Okulitchicyathus andalusicus	X	X	X	X
Protopharetra circula			X	X
Protopharetra gemmata	X		X	
Protopharetra grandicaveata			X	
Protopharetra sp.	X		X	X
Retecoscinus guadalquivirensis			X	X
Rotundocyathus sp.		X		
Sibirecyathus sp.			X	
Taylorcyathus sp.			X	
Tumuliolynthus sp.			X	
Urcyathus sp.			X	
Urcyathus? sp.		X		

Tab. 1: Archaeocyathan taxa and their relationship to the different facies from the reef complex of Las Ermitas.

The nodular facies corresponds to the sediments that were generated in areas that surrounded the mounds in the open platform, and which met ideal conditions for the development of communities of Archaeocyatha, that is, a lot of nutrients. That is why this facies registers the most diverse and abundant association of achaeocyaths of the entire reef complex. The assemblage comprises 3 taxa of Monocyathida (2 genera with 1 species, and 2 sp.), 26 taxa of Ajacicyathina (13 genera with 15 species, and 11 sp.) and 8 taxa of Archaeocyathida (4 genera with 5 species, and 3 sp.).

3.6. Relationship of the cryptic taxa of the Atdabanian 1 in Spain with the Siberian Platform

The association of cryptic archaeocyaths of the Siberian Platform during the Atdabanian 1 consists of *Archaeolynthus polaris, Dictyocyathus bobrovi, Dictyosycon gravis, Erismacoscinus oymuranensis, Neoloculicyathus sibiricus, Nochoroicyathus anabarensis* and *Rotundocyathus biohermicus* and so they do not have any species in common with Las Ermitas; only the genera *Neoloculicyathus* and *Erismacoscinus* appear in both communities.

4. SYSTEMATIC PALEONTOLOGY

The studied material is deposited in collections of the Departamento de Paleontología, Universidad Complutense de Madrid and Muséum National d'Histoire Naturelle, París. (MNHN París: 98CE/1 a 10, 13–15, 17; 98CE/C.2.1, C.2.3, C.2.4; Departamento de Paleontología, Universidad Complutense de Madrid: All the other material).

Phylum Porifera GRANT, 1836
Class Archaeocyatha BORNEMANN, 1884
Order Ajacicyathida BEDFORD, R. & BEDFORD, J., 1939
Suborder Dokidocyathina VOLOGDIN, 1957

Superfamily Dokidocyathoidea BEDFORD, R. & BEDFORD, W.R., 1936
Family Dokidocyathidae BEDFORD, R. & BEDFORD, W.R., 1936

Genus *Dokidocyathus* TAYLOR, 1910

Type species: *Dokidocyathus simplicissimus* TAYLOR, 1910

Dokidocyathus avesiculoides (PEREJÓN, 1976)
Plate 1, Fig. A

1976a ?*Bicyathus avesiculoides* PEREJÓN, p. 16; Pl. 7, Figs. 6–9.
1976b ?*Bicyathus avesiculoides* PEREJÓN. PEREJÓN, p. 10; Pl. 1, Figs. 6–9.
1987d ?*Bicyathus avesiculoides* PEREJÓN. MORENO-EIRIS, p. 94; Pl.13, Fig. 4.
1990 *Dokidocyathus avesiculoides* (PEREJÓN). DEBRENNE et al., p. 141.
1999 *Dokidocyathus avesiculoides* (PEREJÓN). MENÉNDEZ et al., p. 74; Pl. 2, Fig. 1.

Studied material: Four specimens in thin section 98CE/C2(0)-1; 98CE1/8B-1; 98CE1/17I-2; 98CE1/17I-4.

Description: Cups with a thickened outer wall and sparse large pores. Inner wall porous. The presence of radial bars in the intervallum is sparse. Most bars originate from the inner wall and they never reach the outer wall.

Dimensions in mm. Cup: D: 2.50 to 7; I: 0.41–2; IK: 0.16–0.33. Outer wall: d: 0.12–0.24; e: 0.12–0.40. Inner wall: d: 0.12–0.24; i: 0.08–0.16; e: 0.08.

Discussion: We have assigned the specimens to the species *avesiculoides* because they show sparse radial elements in the intervallum and the outer wall of the early developmental stages is thickened, with a few dispersed pores. The dimensions and coefficients of these specimens and those of *D. avesiculoides* with equivalent diameters are also similar.

Distribution: Spain: La Tierna, Arroyo Guadalbarbo, Las Ermitas (Córdoba). Early Cambrian. Early Ovetian.

Dokidocyathina gen. et sp. indet.
Pl. 1, Fig. B

Studied material: One specimen in thin section 98CE1/11C-2–1

Description: Cup with thickened outer wall and inner wall porous. Only three porous septa are developed in the intervallum.

Dimensions in mm. Cup: D: 1.20; I: 0.24–0.32; IK: 0.20–0.27. Outer wall: e: 0.08–0.10. Inner wall: d: 0.20; i: 0.08; e: 0.08.

Discussion: We include it in this suborder due to its small diameter and to the structure of the wall and the septa.

Distribution: Spain: Las Ermitas (Córdoba). Early Cambrian. Early Ovetian.

Suborder Ajacicyathina BEDFORD, R. & BEDFORD, J., 1939
Superfamily Bronchocyathoidea BEDFORD, R. & BEDFORD, J., 1936
Family Ajacicyathidae BEDFORD, R. & BEDFORD, J., 1939

Genus *Nochoroicyathus* ZHURAVLEVA, 1951

Type species: *Nochoroicyathus mirabilis* ZHURAVLEVA, 1951

Nochoroicyathus simoni n. sp.
Pl. 1, Figs. C, D

Etymology: Simoni, after Wilhelm Simon, German geologist who in 1939 described several archaeocyathan taxa from Las Ermitas locality.

Holotype: 98CE1/18a4–1 specimen in thin section. Pl. 1, Figs. C, D. Departamento de Paleontología, Universidad Complutense de Madrid.

Description: Cup showing an outer wall with conspicuous bulges, a simple inner wall and an intervallum with porous septa. Irregularly arranged skeletal elements are present in some areas of the intervallum, although in some cases they connect two contiguous septa.

Dimensions in mm. Cup: D: 4.31; I: 1.33; N: 21; ds: 0.33; IK: 0.31; RK: 4.87; IC: 1:4. Outer wall: n: 6–8; d: 0.10; i: 0.02; e: 0.04. Inner

	wall: n: 2–3; d: 0.12; i: 0.04; e: 0.04. Septa: n: 8–10; d: 0.16; i: 0.04; e: 0.02–0.04.
Discussion:	Differences with *N. bulbosus* (Debrenne & Gravestock, 1990) include the absence of spines in the inner wall, the shape of the bulges, and its smaller diameter (4.31 mm against 15 mm in *bulbosus*).
Distribution:	Spain: Las Ermitas (Córdoba). Early Cambrian. Early Ovetian.

Nochoroicyathus sp. 1
Pl. 1, Fig. E

Studied material:	Three specimens in thin section, 98CE1/17I-1; 98CE1/21A-1; 98CE1/21B-2.
Description:	Cups with simple outer wall showing 3 to 5 rows of pores per intersept. Inner wall with 1 or 2 rows of pores per intersept and intervallum with porous septa. Dimensions in mm. Cup: D: 2.76–5.24; I: 0.64–1.12; N: 26 to 38; ds: 0.16–0.40; IK: 0.23–0.21; RK: 4.42–7.25; IC: 1:4 to 1:2.8. Outer wall: n: 3–5; n: 0.08–0.06; i: 0.02; e: 0.02; Inner wall: n: 1–2; d: 0.10–0.16; i: 0.02–0.04; Septa: n: 4–6 to 8; d: 0.08–0.16; i: 0.04; e: 0.02–0.04.
Discussion:	Perejón (1975c) ascribed to *N. anabarensis* (Vologdin, 1937) a large number of specimens from the Cerro de Las Ermitas that, in light of recent data, should be revised. Due to the porosity of the skeletal structures, decrease of the parietal coefficient and the variation of the interval chamber, the studied specimens could be ascribed to the *N. anabarensis* from Las Ermitas, but for the time being we do not include them in any species.
Distribution:	Spain: Las Ermitas (Córdoba). Early Cambrian. Early Ovetian.

Nochoroicyathus sp. 2
Pl. 1, Fig. F

Studied material:	One specimen in thin section 98CE1/17I-3.
Description:	Cup formed by outer wall with 6 to 10 rows of pores per intersept and inner wall with 4 to 6 rows of pores per intersept. Intervallum with porous septa. Dimensions in mm. D: 4.48; I: 1.16; IK: 0.26. Outer wall: n: 6–10; d: 0.06; i: 0.04; e: 0.02–0.03. Inner wall: n: 4–6; d: 0.08; i: 0.02; e: 0.04. Septa: n: 6–8; d: 0.10; i: 0.04; e: 0.02.
Distribution:	Spain: Las Ermitas (Córdoba). Early Cambrian. Early Ovetian.

Genus *Urcyathus* Vologdin, 1940b

Type species: *Urcyathus asteroides* Vologdin, 1940b

Urcyathus? sp.
Pl. 1, Fig. G

Studied material:	One specimen in thin section 98CE1/18a2–1.
Description:	Cup with simple outer wall showing 6 to 10 rows of pores per intersept. Inner wall with irregular grooves and ridges and 3 to 5 rows

of pores per intersept. Intervallum with flat and curved porous septa.

Dimensions in mm. Cup: D: 4.81; I: variable from 1.16 to 1.66; N: 14; ds variable; IK: 0.24–0.35; RK: 2.91; IC variable. Outer wall: n: 6–10; d: 0.06; i: 0.04; e: 0.05. Inner wall: 3–5; d: 0.10; i: 0.04–0.05; e: 0.04. Septa: n: 5–7; d: 0.16; i: 0.08; e: 0.02.

Discussion: The structure of the inner wall in some intersepts is of the type present in *Urcyathus* VOLOGDIN, 1940, although in general it has an irregular structure. We ascribe it with some degree of doubt to the genus *Urcyathus*, differing from all the described species by the structure of the inner wall.

Distribution: Spain: Las Ermitas (Córdoba). Early Cambrian. Early Ovetian.

Genus *Rotundocyathus* VOLOGDIN, 1960

Type species: *Rotundocyathus rotaceus* VOLOGDIN, 1960

Rotundocyathus sp.
Pl. 1, Fig. H

Studied material: Two specimens in thin section 98CE1/18a3–1; 98CE1/18a3–4.

Description: Cups formed by simple outer wall with 3 to 4 rows of pores per intersept. Inner wall with one row of pores per intersept. Intervallum with completely porous septa .

Dimensions in mm. Cup: D: 4.15; I: 1.16; ds: 0.33; IK: 0.28; IC: 1:3.5. Outer wall: n: 3–4; d: 0.08; i: 0.04; e: 0.04. Inner wall: n: 1; d: 0.16; i: 0.04; e: 0.04; Septa: n: 4; d: 0.08; i: 0.04; e: 0.02.

Discussion: Specimens have a structure resembling that of the specimens from Arroyo Pedroche ascribed to *Rotundocyathus* sp. (PEREJÓN, 1989:170–172). They differ from the latter in having a smaller interseptal chamber (IC), and the smaller diameter of the septal pores in cups of similar diameters.

Distribution: Spain: Las Ermitas (Córdoba). Early Cambrian. Early Ovetian.

Genus *Leptosocyathus* VOLOGDIN, 1937

Type species: *Leptosocyathus curviseptum* VOLOGDIN, 1937

Leptosocyathus? sp.
Pl. 1, Fig. I

Studied material: Two specimens in thin section 98CE1/18a3–2; 98CE1/18a3–3.

Description: Cup fragments where we can observe the porous outer wall and the inner wall with a single pore per intersept covered by a bract. The intervallum has completely porous septa.

Dimensions in mm: Cup: D: >6.50; I: > 1; N: >70; ds: 0.24. Outer wall: n: 3–4; d: 0.06; i: 0.4; e: 0.2–0.3. Inner wall: n: 1; d: 0.20–0.18; i: 0.04; e: 0.04. Septa: e: 0.02.

Discussion: The structure of the inner wall is characteristic of the genus *Leptosocyathus*, but due to the presence of completely porous septa these specimens are ascribed with question to this genus.

Distribution: Spain: Las Ermitas (Córdoba). Early Cambrian. Early Ovetian.

Suborder Erismacoscinina DEBRENNE, ROZANOV & ZHURAVLEV, 1989
Superfamily Salairocyathoidea ZHURAVLEVA, 1956 (In: VOLOGDIN, 1956)
Family Asterocyathidae VOLOGDIN, 1956

Genus *Erismacoscinus* DEBRENNE, 1958

Type species: *Erismacoscinus marocanus* DEBRENNE, 1958

Erismacoscinus sp.
Pl. 2, Fig. A

Studied material: One specimen in thin section 98CE1/11A-1–5.

Description: Cup with a porous thickened outer wall. Inner wall with several rows of pores per intersept. Intervallum with a porous tabula.
Dimensions in mm. Cup: D: 4.00; I: 1.2; N: 12; ds: 0.56; IK: 0.30; RK: 3; IC: 1:2.4. Outer wall: n: 6; d: 0.08; i: 0.08; e: 0.12. Inner wall: n: 2–3; d: 0.12; e: 0.08. Septa: n: 6–8; d: 0.16; i: 0.08; e: 0.08. Tabula: d: 0.08–0.10; e: 0.08.

Discussion: The specimen is included in the genus *Erismacoscinus* because of the development of tabula and because both walls have simple pores. We can not assign it to any species due to its small size and the presence of thickened skeletal structures.

Distribution: Spain: Las Ermitas (Córdoba). Early Cambrian. Early Ovetian.

Order Archaeocyathida OKULITCH, 1935
Suborder Loculicyathina ZHURAVLEVA, 1954
Superfamily Loculicyathoidea ZHURAVLEVA, 1954
Family Loculicyathidae ZHURAVLEVA, 1954

Genus *Neoloculicyathus* VORONIN, 1974

Type species: *Neoloculicyathus primus* VORONIN, 1974

Neoloculicyathus magnus DEBRENNE, 1978
Pl. 2, Figs. B, C

1978 *Neoloculicyathus magnus* DEBRENNE. DEBRENNE & DEBRENNE, p. 106; Pl. 1 Figs. 5–7
1992 *Neoloculicyathus magnus* DEBRENNE. DEBRENNE & ZHURAVLEV, p. 128
1993 *Neoloculicyathus magnus* DEBRENNE. ELICKI & DEBRENNE, pp. 21–22; Pl. 2, Figs. 2, 3; Fig. 11
1995 *Neoloculicyathus magnus* DEBRENNE. DEBRENNE & DEBRENNE, Pl. 2, fig.4
1999 *Neoloculicyathus magnus* DEBRENNE. MENÉNDEZ, MORENO-EIRIS & PEREJÓN, pp. 78–79; Pl. IV, Figs. 1–3

Studied material: Three specimens in thin section 98CE1/11A-1–1; 98CE1/11A-1–2; 98CE1/11C-1–1.

Description: Cups with finely perforated outer wall, although in some cases the wall may be thickened. Inner wall with several rows of pores per intersept. There are regularly arranged porous pseudosepta in the intervallum and the vesicular tissue may be abundant.

Dimensions in mm. Cup: D: 2.32 to 3.70, [>10]; I: 0.83–0.99, [1.5]; N: 6; ds: 0.41, [1.5]; IK: 0.35; RK: 2.58; IC: 1:2, [1:1]. Outer wall: n: 6–8, [6]; d: 0.08–0.16, [0.12]; i: 0.06–0.08, [0.12]; e: 0.04–0.08. Inner wall: n: 2, [6]; d: 0.08, [0.08]; i: 0.08, [0.08]; e: 0.04, [0.08]. Septa: n: 2–4, [4–6]; d: 0.12–0.16, [0.16]; i: 0.04–0.08, [0.08]; e: 0.04, [0.08].

Discussion: We have assigned the studied specimens to the species *N. magnus* because of the porosity of the walls and the similarity of its dimensions and coefficients. They may also be close to *N. primus* VORONIN, 1974, but its incomplete description does not allow a clear decision.

Remarks: The two smaller specimens are thickly encrusted by calcimicrobes (*Girvanella*?). These microbial sheaths act as attaching elements to the cryptal cavity walls. The larger cup fragment does not show signs of encrustation.

Distribution: Morocco: Tiout, Early Cambrian, Atdabanian. Germany: Doberlug, Early Cambrian, Atdabanian. Spain: La Tierna and Puente Romano (Alcolea, Córdoba), Las Ermitas (Córdoba), Early Cambrian, Early Ovetian.

Genus *Okulitchicyathus* ZHURAVLEVA, 1960

Type species: *Ajacicyathus discoformis* ZHURAVLEVA (In: ZHURAVLEVA & ZELENOV, 1955)

Description: Inner wall with several rows of simple pores per intersept; coarsely porous pseudosepta; plate tabulae and synapticulae may be present (DEBRENNE et al., 2002).

Observations: Up to now the genus *Okulitchicyathus* has been described from the Tommotian 1–4 of the Siberian Platform, the Atdabanian 4 of Australia, and the Botomian from the interior of China. DEBRENNE et al. (2002) considered *Alconeracyathus* to be a synonym of *Okulitchicyathus* and therefore their distribution in Spain ranges from the Ovetian to the basal Marianian in Sierra Morena and the Bilbilian in the Cantabrian Mountains (PEREJÓN & MORENO-EIRIS, 2003).

Okulitchicyathus andalusicus (SIMON, 1939)
Pl. 2, Figs. D, H

1917 *Dictyocyathus sampelayanus* HERNÁNDEZ PACHECO, p. 82

1918 *Dictyocyathus sampelayanus* HERNÁNDEZ PACHECO. HERNÁNDEZ PACHECO, p. 692

1933 *Dictyocyathus sampelayanus* HERNÁNDEZ PACHECO. HERNÁNDEZ SAMPELAYO, p. 159, Pl. 2, Fig. 2

1933 *Archaeocyathus marianus* ROEMER, 1878. HERNÁNDEZ SAMPELAYO, p. 158.

1933 *Archaeocyathus ajax* TAYLOR, 1910. HERNÁNDEZ SAMPELAYO, p. 158.
1933 *Archaeocyathus* aff. *profundus* BILLINGS, 1861. HERNÁNDEZ SAMPELAYO, p. 158, Pl. 2, Fig. 3.
1935 *Dictyocyathus sampelayanus* HERNÁNDEZ PACHECO. HERNÁNDEZ SAMPELAYO, p. 477
1935 *Archaeocyathus marianus* ROEMER, 1878. HERNÁNDEZ SAMPELAYO, p. 477, Pl. 6, Fig. 4.
1935 *Archaeocyathus ajax* TAYLOR. HERNÁNDEZ SAMPELAYO, p. 158.
1935 *Archaeocyathus* aff. *profundus* BILLINGS, 1861. HERNÁNDEZ SAMPELAYO, p. 476, Pl. 6, Fig. 5.
1939 *Archaeocyathellus (Archaeofungia) sampelayanus* (HERNÁNDEZ PACHECO). SIMON, p. 77, Pl. 5, Fig. 5
1939 *Archaeocyathellus (Archaeofungia) andalusicus* SIMON, p. 76, Pl. 5, Figs. 1–4.
1959 *Dictyocyathus sampelayanus* HERNÁNDEZ PACHECO. BADILLO, p. 78, Pl. 4.
1959 *Archaeocyathus marianus* ROEMER. BADILLO, p. 80, Pl. 6.
1959 *Archaeocyathus ajax* TAYLOR. BADILLO, p. 81, Pl. 7.
1959 *Archaeocyathus (Ethmophyllum) profundum* (BILLINGS). BADILLO, p. 84, Pl. 10.
1963 *Spirocyathella lata*. VOLOGDIN, 1940. DEBRENNE & LOTZE, p. 137, 5, Figs. 1–5.
1973 *Alconeracyathus melendezi* PEREJÓN, p. 186, Pl. 2, Figs. 3–6.
1976a *Andalusicyathus andalusicus* (SIMON). PEREJÓN, p. 18. Pl. 8, Figs. 3–8; Pl. 9, Figs. 1–9.
1976b *Andalusicyathus andalusicus* (SIMON). PEREJÓN, p. 18. Pl. 4, Figs. 3–8; Pl. 5, Figs. 1–9; Pl. 6, Figs. 1–4.
1976b *Flindersicoscinus tabulatus* BEDFORD & BEDFORD, 1937. PEREJÓN, p. 19. Pl. 6, Figs. 5, 6.
1978 *Urdacyathus pradoanus* PEREJÓN & MORENO, p. 201, Pl. 1 Fig. 2.
1987d *Alconeracyathus melendezi* PEREJÓN. MORENO-EIRIS, p. 742, Pl. 2, Fig. 6.
1989 *Andalusicyathus andalusicus* (SIMON). PEREJÓN, p. 205, Pl. 13, Fig. 1.
1992 *Alconeracyathus andalusicus* (SIMON). DEBRENNE & ZHURAVLEV, p. 119, Pl. 3, Figs. 2, 3.
2002 *Okulitchicyathus andalusicus* (SIMON). DEBRENNE, ZHURAVLEV & KRUSE, p. 1654.

Studied material: Two specimens in thin section 98CE1/18a4–3; 98CE1/19B-1.

Description: Cup with simple basic outer wall showing 2 to 4 rows of pores per intertaenial space. Simple inner wall with two rows of pores between each pair of taeniae. Intervallum with very porous taeniae and synapticulae.

Dimensions in mm. Cup: D: 13.61; I: 3.48; ds: 0.33; IK: 0.26; IC: 1:10.5. Outer wall: n: 2–4; d: 0.08; i: 0.04; e: 0.04. Inner wall: n: 2; d: 0.12; I: 0.04; e: 0.04; Taeniae: very porous; e: 0.04. Synapticles: e: 0.04.

Discussion: The specimens are assigned to this species for their characters, dimensions and coefficients. One of the specimens is recrystallized and its skeletal elements are partially altered to chlorite.

Distribution: Las Ermitas and Arroyo Pedroche (Córdoba), Early Cambrian, Early Ovetian. Alconera (Badajoz), Early Cambrian, earliest Marianian.

Suborden Archaeocyathina OKULITCH, 1935
Superfamily Archaeocyathoidea HINDE, 1889
Family Archaeopharetridae BEDFORD, R. & BEDFORD, W.R., 1936

Genus *Protopharetra* BORNEMANN, 1884

Type species: *Protopharetra polymorpha* BORNEMANN, 1884

Protopharetra gemmata (DEBRENNE, 1964)
Pl. 2, Fig. E

1960 *Volvacyathus proteus* DEBRENNE, p. 118, Fig. B (non *proteus* BORNEMANN, 1886)
1961 *Volvacyathus proteus* DEBRENNE, p. 20–21, Pl. 2, Figs. 1–4; Pl. 5, Figs. 1–6.
1964 *Volvacyathus proteus* DEBRENNE, p. 223, Pl. 41, Figs. 1–4; Pl. 42, Fig. 7.
1964 *Volvacyathus? gemmatus* DEBRENNE, p. 224, Pl. 43, Figs. 5–6.
1964 *Protopharetra bourgini* DEBRENNE, p. 216, Pl. 42, Fig. 1.
1976b *Volvacyathus proteus* DEBRENNE. PEREJÓN, p. 16, Pl. 4, Figs. 1–2.
1989 *Protopharetra bourgini* DEBRENNE. PEREJÓN, p. 199, Pl. 12, Fig. 1.
1992 *Protopharetra gemmata* (DEBRENNE). DEBRENNE & ZHURAVLEV, p. 128.
1993 *Protopharetra gemmata* (DEBRENNE). ELICKI & DEBRENNE, p. 23–24, Pl. 2, Fig. 5.
1995 *Protopharetra gemmata* (DEBRENNE). DEBRENNE & DEBRENNE, Pl. 1, Fig. 4.

Studied material: Two specimens in thin section 98CE1/1A-2; 98CE1/2D-1.

Description: Colonial and solitary cups. Compact outer wall in cups of smaller diameter, and perforated and compound outer wall in the upper part of those with larger diameter. Inner wall with one pore per intertaenial space. Intervallum with taeniae, showing large pores, and synapticulae.

Dimensions in mm. Cup: D: 7.47–3.80; I: 1.20; IK: 0.32; Outer wall: n: ?; d: 0.07; i: 0.015; e: 0.015–0.020. Inner wall: n: 1; e: 0.04. Taeniae: e: 0.04.

Discussion: The specimens are included in this species because of the structure of their walls and for showing a medium density of taeniae in the intervallum.

Distribution: Morocco: Amouslek and Tiout, Early Cambrian, Atdabanian. Germany: Doberlug, Early Cambrian, Atdabanian. Spain: Las Ermitas and Arroyo Pedroche (Córdoba), Early Cambrian, Early Ovetian.

Protopharetra sp.
Pl. 2, Fig. F

Studied material: Five specimens in thin section, 98CE1/8b2–1; 98CE1/2C-1; 98CE1/2C-2; 98CE1/2D-2; 98CE1/2D-3.

Description: Cups with a compact outer wall in specimens of smaller diameter and a porous outer wall in those larger than 10 mm in diameter. Inner wall with a single row of pores per intertaenial space. Intervallum with large perforated taeniae and sparse synapticulae. Whenever vesicular tissue is developed, it is located in the intervallum.

Dimensions in mm. Cup: D: 4.8–11.62; I: 1.60–3.32; ds: 0.58; IK: 0.33–0.28; IC: 1:3.8. Outer wall: d: 0.08; i: 0.04; e: 0.04–0.08. Inner wall: n: 1; d: 0.20; i: 0.04; e: 0.04. Taeniae: e: 0.04.

Discussion: Although the structure of the cups and its dimensions and coefficients are typical of *Protopharetra*, the strong recrystallization of the skeletal structures does not allow a species assignment.

Distribution: Las Ermitas (Córdoba), Early Cambrian, Early Ovetian.

Archaeocyathina gen. et sp. indet.
Pl. 2, Fig. G

Studied material: Thirty-eight specimens in thin section.

Description: Cups with unperforated, and some times thickened, outer wall. Porous inner wall. Intervallum with skeletal elements in various stages of development, orthogonally arranged rods or incipient taeniae with large pores. Vesicular tissue may be located only in the intervallum or throughout the whole cup.

Dimensions in mm. Cup: D: 7–2.08; central cavity d: 1.66–0.64. Outer wall: e: 0.083–0.020; Inner wall: d: 0.58–0.12; i: 0.12–0.08; e: 0.12–0.04. Rods/Taeniae: e: 0.12–0.04.

Discussion: We include these specimens in the suborder Archaeocyathina because they have an unperforated outer wall and an intervallum with poorly defined elements.

Distribution: Las Ermitas (Córdoba), Early Cambrian, Early Ovetian.

5. CONCLUSIONS

The previous sedimentological study of the various biogenic and sedimentary processes that filled the cavities and the breccias of the andesites of the Upper Proterozoic at Las Ermitas (Vennin et al., 2003) has also allowed an analysis of the biological diversity of the archaeocyathan assemblage that was involved in these processes.

The systematic study of the archaeocyaths has allowed the description of eight cryptic taxa and five taxa from the breccias, among them *Nochoroicyathus simoni* n. sp. These taxa have been compared first with the archaeocyathan assemblage in the immediately overlying levels and also with the group of taxa described in the reef complex. Therefore they are not obligate cryptobionts because the same taxa appear in the platform sediments outside the cavities.

The analysis of the taxa in each of the facies leads to the conclusion that only in the nodular facies a considerable taxonomic diversity with 58 % of the total described species exists, while in the mounds they reach 23 %, in the cavities 11%, and in the breccias only 8 %.

The cryptic archaeocyaths are arranged inside of the cavities in growth positions, stuck to the walls, hanging from the ceiling, or they could also join with other cryptobionts and to synsedimentary cements. In the filling facies of the cavities, the cups may be either in growth position or reworked.

From the group of cryptic taxa described in the paper only the genera *Neoloculicyathus* and *Erismacoscinus* also appear in the Siberian Platform during the Atdabanian 1. The known cryptic communities are different in each of the areas in which they developed.

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Plate 1

A: *Dokidocyathus avesiculoides* (PEREJÓN, 1976). Longitudinal section; specimen 98CE1/17I-2; x 7.5

B: Dokidocyathina gen. et sp. indet. Transverse section; specimen 98CE1/11C-2–1; x 28

C, D: *Nochoroicyathus simoni* n. sp.

C: Transverse section; specimen 98CE1/18a-4–1 ; x 7

D: Transverse section, detail of the same specimen as C; x 14

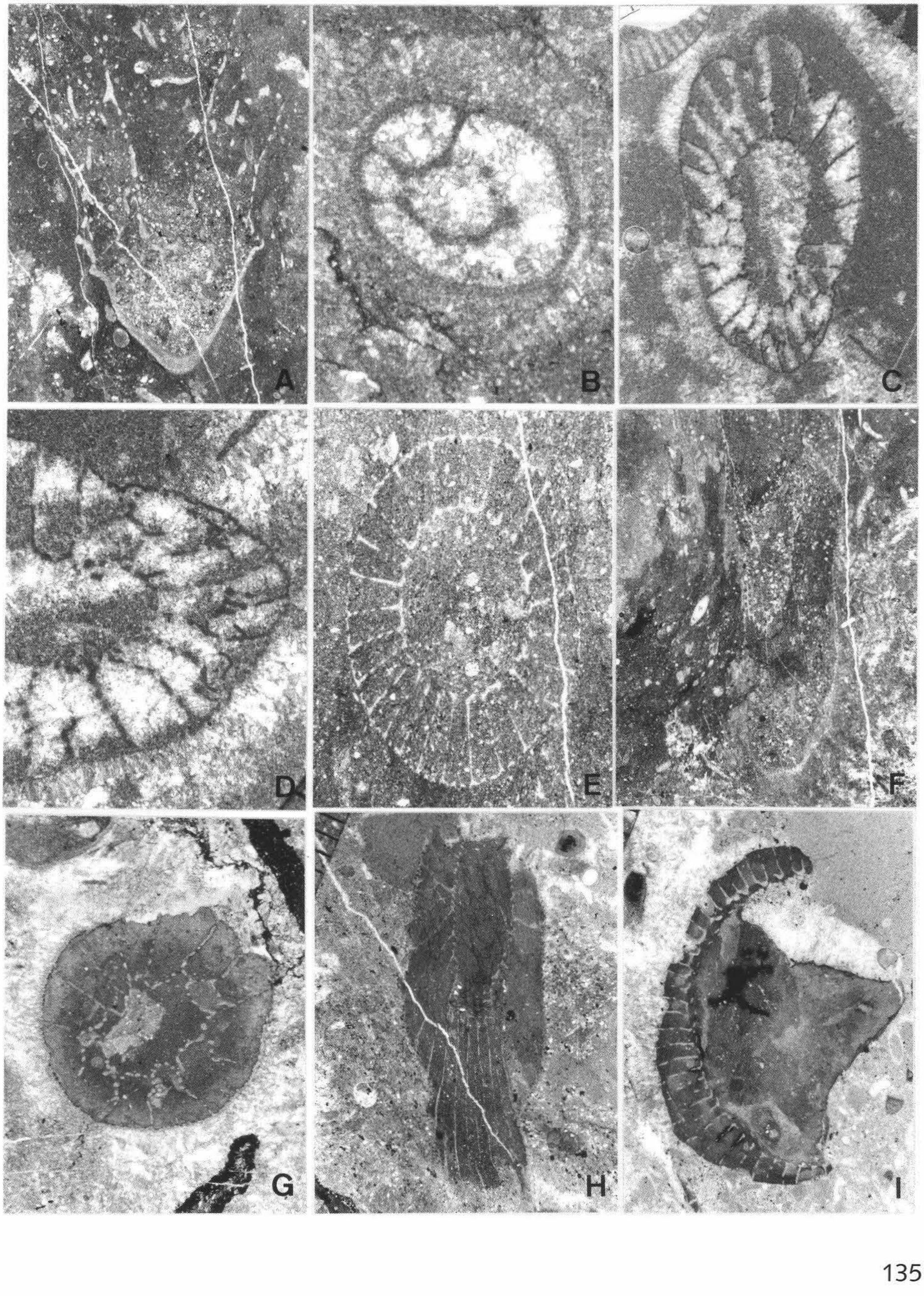
E: *Nochoroicyathus* sp.1. Transverse section; specimen 98CE1/17I-1; x 17

F: *Nochoroicyathus* sp. 2. Longitudinal section; specimen 98CE1/17I-3; x 7

G: *Urcyathus?* sp. Transverse section; specimen 98CE1/18a2–1; x 9

H: *Rotundocyathus* sp. Longitudinal section; specimen 98CE1/18a3–1; x 6.5

I: *Leptosocyathus?* sp. Fragment in transverse section; specimen 98CE1/18a3–2; x 9


A
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C
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Plate 2

A: *Erismacoscinus* sp. Transverse section; specimen 98CE1/11A-1–5; x 10

B, C: *Neoloculicyathus magnus* DEBRENNE, 1978

B: Fragment in transverse section; specimen 98CE1/11A-1–1; x 6

C: Transverse section encrusted by *Girvanella*; specimen 98CE1/11A-1–2; x 8

D, H: *Okulitchicyathus andalusicus* (SIMON, 1939)

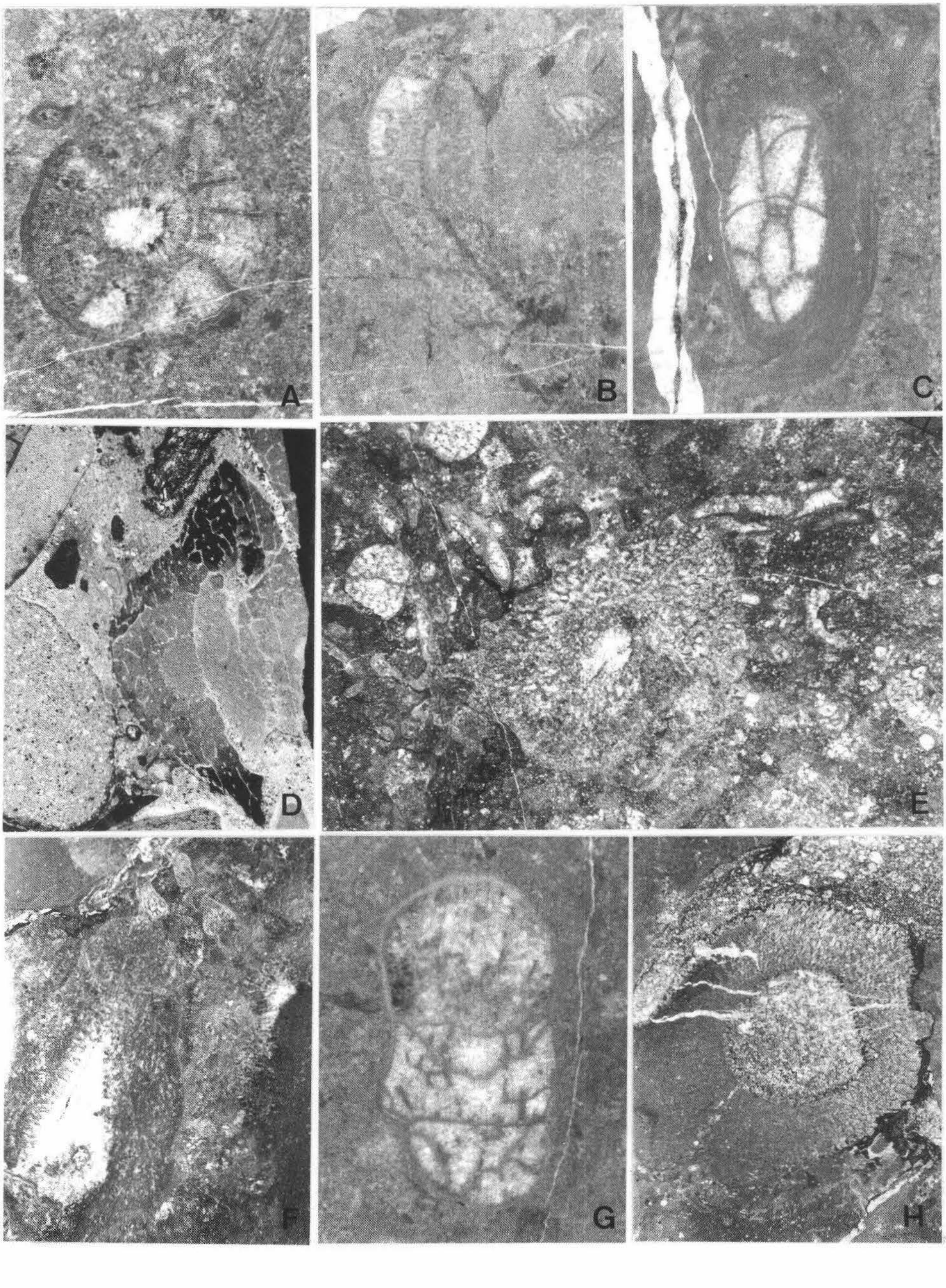
D: Oblique transverse section; specimen 98CE1/18a4–3; x 8,5

H: Transverse section 98CE1/19B-1; x 4

E: *Protopharetra gemmata* (DEBRENNE, 1964). Transverse section with stolons; specimen 98CE1/2D-1; x 6

F: *Protopharetra* sp. Longitudinal section; specimen 98CE1/8b2–1; x 3

G: Archaeocyathina gen. et sp. indet. Longitudinal section; specimen 98CE1/11A-1–3; x 12


A
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