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Upper Ordovician cryptostomatid bryozoans and microfossils from the Don Braulio Formation, Eastern Precordillera, Argentina

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Abstract: *UPPER ORDOVICIAN CRYPTOSTOMATID BRYOZOANS AND MICROFOSSILS FROM THE DON BRAULIO FORMATION, EASTERN PRECORDILLERA, ARGENTINA:* In the classical section of the Don Braulio Creek at the Villicum Range, Eastern Precordillera of San Juan Province, crops out the siliciclastic Don Braulio Formation of Hirnantian age. Fragments of bryozoan colonies, few poorly preserved sponge spicules and a crinoidal plate, were recovered from these shelf sediments. The bryozoan colonies remains are characterized by its erect growth habit, its small diameter, and for showing clear longitudinal striations. These fragments have a poor preservation, but they have been compared with the genus *Nematopora* belonging to the Arthrostylidae family (Rhobdomesina suborder, Cryptostomata order), that had numerous representatives during the Ordovician. Very scarce and highly fragmented sponge spicules are classified as hexactins. These microfossils have been recovered in the post-glacial deposits from the Don Braulio section at the Villicum range.

Resumen: *BRYOZOOS CRYPTOSTOMATIDOS Y MICROFÓSILES DE LA FORMACIÓN DON BRAULIO, ORDOVÍCICO SUPERIOR, PRECORDILLERA ORIENTAL, ARGENTINA:* En la clásica sección de la Quebrada de Don Braulio, en la Precordillera Oriental de la Provincia de San Juan, aflora la Formación Don Braulio de edad hirnantiana. Fragmentos de colonias de Bryozoos,algunas espículas de esponjas mal conservadas y una placa de crinoideos, fueron recuperados de los sedimentos silicoclásticos de esta formación. Los restos de las colonias de briozoos se caracterizan por su hábito de crecimiento erecto, su diámetro pequeño y por la presencia de estriaciones longitudinales. Estos fragmentos tienen una pobre preservación, sin embrago los mismos han sido comparados con el género *Nematopora* perteneciente a la familia Arthrostylidae (suborden Rhobdomesina, orden Cryptostomata), que tuvo numerosos representantes durante el Ordovícico. Escasas y fragmentadas espículas de esponja hexactinéllidas y otros tipos de microfósiles también han sido recuperados de los depósitos post-glaciales de la Formación Don Braulio.

Key words: Cryptostomatid. Bryozoans. Hirnantian. Microfossils. Precordillera Argentina

Palabras clave: Cryptostomatidos. Bryozoos. Hirnantiano. Microfósiles. Precordillera Argentina.

Introduction

The Don Braulio Formation was early defined by Baldis *et al.* (1982), a thin siliclastic unit (46 m of maximum thickness at the type section of the Don Braulio Creek, western flank of the Villicum range, Eastern Argentine Precordillera, located nearly 20 km to the north of San Juan city in San Juan Province, Argentina, which outcrops continuously for almost 3 km in the area. The study area is located at the Don Braulio Creek.

In the type section, the Don Braulio Formation unconformably overlays deposits of the La Cantera Formation (upper Darriwilian-Sandbian) (Heredia *et al.*, 2014), due to its erosive nature, and underlies the olistostromic deposit of the Rinconada Formation (Devonian) (figure 1). In other sections, the Don Braulio Formation overlies, throughout an unconformity the La Pola Formation (Sandbian), which overlies the La Cantera Formation.

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Four members were defined for the Don Braulio Formation (Peralta, 1993): the lower mud-supported Diamictite Member; Fossiliferous Mudstone and Sandstone Member; the Ocher Mudstone Member and the Ferriferous Upper Member (figure 1). The lower Member is interpreted as glacial-marine diamictite deposits (Peralta and Carter, 1990; Buggisch and Astini, 1993).

The Fossiliferous Mudstone and Sandstone Member (10-12 m thick), consists mainly of greenish grey siltstone and fine-medium grained sandstone with carbonate cement which include ochre calcareous fossiliferous lenses, bearing trilobites, brachiopods, crinoids and bivalves. This member is considered as a transgressive-regressive marine sequence (Buggisch and Astini, 1993).

The Hirnantian age of the Don Braulio Formation was formerly provided by *Dalmanitina sudamericana* and *Eohomalonothus villicunensis* described by Baldis and Blanco (1975) besides the brachiopods assemblage described by Levy and Nullo (1974) from the fossiliferous Mudstone and Sandstone Member. The brachiopod fauna was reviewed by Benedetto (1986), who referred it, to the "Hirnantia Fauna". Peralta and Baldis (1990) recorded *Normalograptus persculptus* near the top of the Fossiliferous Mudstone and Sandstone Member.

Cryptostomatid bryozoan fragments, few hexactinellid siliceous spicules and others microfossils were obtained from the acid residue of the ochre calcareous fossiliferous sample, this small collection of this original fauna are illustrated and described here.

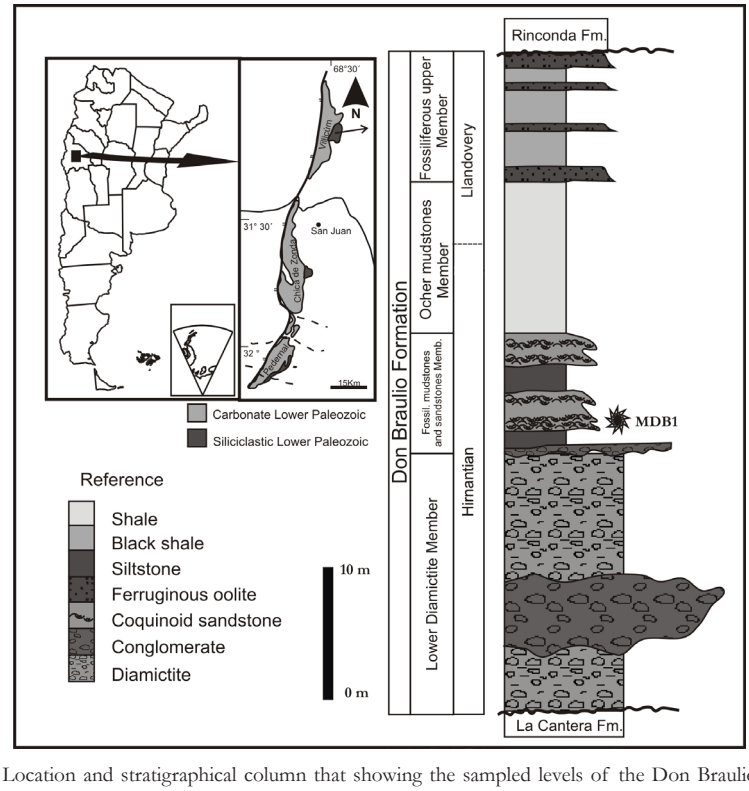

Figure 1- Location and stratigraphical column that showing the sampled levels of the Don Braulio Formation, at Villicum Range, Eastern Precordillera of San Juan, Argentina./ **Figure 1-** Mapa de ubicación y perfil estratigráfico mostrando los niveles muestreados de la Formación Don Braulio, Sierra de Villicúm, Precordillera Oriental de San Juan, Argentina.

Paleoclimatic condition: Gondwana Hirnantian glaciation event.

During the latest Ordovician strong evidences of the gradual cooling in the climate was supported for the Hirnantian mass extinction. The Gondwana latest Ordovician mass extinction is a clear example of the Hirnantian extinction and it is related to a gradual decline in global temperature, since most part of the continental platform of this paleocontinent was located between 40º and 60º S during the latest Ordovician and Lower Silurian times (Jiménez-Sánchez and Villas, 2010).

The gradual cooling and the oceans regression as well as the siliciclastic sediments unfilled the basin, were an effect of this ice-event that greatly reducing the habitat of life of bryozoans, what probably caused ones of the greatest extinctions events during the Paleozoic (Taylor and Ernst, 2004).

According to Muir *et al.* (2013), during the Hirnantian one Hexactinelliid family, the Brachiospongiidae, which appeared in Sandbian (lowest Upper Ordovician), continued into the Hirnantian and reached the Ludlovian (Upper Silurian). However most of the sponge families, nine in total, disappeared during the Hirnantian. The greater abundance of sponge skeletons in the fossil record corresponds to periods of high sea level of the phaneroceans, whereas almost no sponge spicules have been found during the periods of low sea level as during the Late Ordovician (Pisera, 1999).

Material and Methods

The sample was collected from fine sandstone lenses with carbonate cement in the lower part of the fossiliferous Mudstone and Sandstone Member at the Don Braulio Creek (figure 1). The 2 kg of sample was dissolved in dilute formic acid (Stone, 1987); the insoluble fraction was observed and picked for microfossil separation (siliceous spicules, bryozoans and a crinoid plate).The morphology of bryozoans and spicules was examined using light and scanning electron microscopy (SEM).

Paleontology

Repository. The material described here is housed in the"Instituto de Geología E. Aparicio" (INGEO) at the Universidad Nacional de San Juan under the numbers INGEO-MP-2570 (1-5) for spicules and INGEO-MP-2571(1-4) for bryozoans.

PHYLUM Bryozoa Ehrenberg, 1831
CLASS Stenolaemata Borg, 1926
ORDER Cryptostomata Vine, 1884
SUBORDER Rhabdomesina Astrova and Morozova, 1956
FAMILY Arthrostylidae Ulrich, 1882

Nematopora cf. ULRICH, 1888
Figure 2, Table 1

Remarks: By the Middle Ordovician the five orders that compose the Stenolaemata class (the dominant class during the Paleozoic) were present, although they did not reach their maximum diversity until the Upper Ordovician.

The order Cryptostomata is one of the five orders that compose the Stenolaemata class. Following Blake (1983) its zoaria present an erect habit of life, which range from unbranched morphologies until reticulate forms, with all intermediate state, and its cross-sections are circular or flattened depending mainly of the suborder. The external surface of the colonies are characterized by having autozooecial apertures arranged in longitudinal or spiral rows, showing different outline (from circular to rectangular); these apertures can be present in all zoarial surface or only in one side of the zoarium, resulting colonies with an obverse side with apertures and a reverse side without them. Other feature of the external surface is its ornamentation that can be composed of striae or ridges longitudinally arranged styles distributed in the surface and peristomes in the autozooecial apertures.

According with Blake (1983) in the 1983 Treatise Edition, the Cryptostomata order is divided in two suborders: Ptilodictyina and Rhabdomesina. One of the main differences between them can be found in the way in which zooecia are organized in the colony . Following, Karklins (1983) Ptilodictyina suborder is characterized by having bifoliated zoarium with both side of the zoarium symmetric respect a central plane call mesotheca and the zooecia growth from this plane; in this case the zoaria have oval or subelliptic cross-sections. By contrast, according with Blake (1983) most part of the genera assigned to the suborder Rhabdomesina are characterized by having slender erect zoarium (branched or unbranched) with zooecia that are organized around a central axes; in this case the zoarial cross-section is circular. The suborder Rabdomesina has also representative with slender erect zoarium, but with colonies where zooecia are only opened in one side of them. More complicated classifications of the Cryptostomata order take into account, for instance, differences in the mesotheca or in the way in which autozooecia are organized around the central exes, as well as differences in the internal morphology of the zooecia given place to a large number of the suborders and movement of the genera between that suborders. One of this classification is those showing in the web page http://www.bryozoa.net/ (Phil Bock, last revision 12th of September 2013) that divided the cryptostomatid in five suborders: Ptilodictyina, Rhabdomesina, Timanodictyina, Goldfussitrypina, and Streblotrypina. Here the classification of 1983 Treatise Edition is followed.

Description: Zoaria with erect growth habit, with dichotomously divided branches that show an average diameter of 0.2105 mm, measured just before the bifurcation point; fragments of zoaria have an average longitude of 0.8742 mm, but with a wide range, being the longest the zoarium that has smaller diameter; zoarial surface is marked by well-defined longitudinal striations. Large zoarial apertures compared with zoarial diameter, oval in shape with an average large and small diameter of 0.1211 and 0.0796 mm, respectively, and with a large separation between consecutive apertures; they seem to be present only in one side of the zoarium and with no more than two autozooecial rows per side

Remarks: This material has been only studied in its external morphology and the systematic assignation cannot achieve the generic level until new material, with possibility of being internally studied, is found. But, taking into account the external features of these fragments, as the slender erect habit of growth, with dichotomously divided branches, the ornamentation

of these branches and the present of autozooecial apertures only in one side of the zoarium, this material can be included without doubts in the family Arthrostylidae following the classification of the Treatise 1983 Edition. The studied of the genera assigned to this families shows that this material is very closely related to *Nematopora*, sharing with it the large size of the autozooecial apertures, the large separation between them and its arrangement in the colony surface, as well as the ornamentation of the zoarium. So, these zoaria are here compared with this genus until the recollection of new data allows us the definitive inclusion of this material in *Nematopora*.

Carrera and Halpern (2011) figured some fragments of bryozoans coming from the same formation (Don Braulio Formation) that *Nematopora* cf. described here. They assigned some of these fragments to the genus *Helopora*, but left them in open nomenclature to the species level, while other fragments are classified as *Phillopori*nidae indet. *Nematopora* cf. is easily distinguished from this material attending to the number of autozooeial rows in the zoarium. Also, from the taxa assigned to the genus *Helopora* can be distinguished by the presence of acanthoslyles and mesozooecia in *Helopora* sp.

Ernst and Carrera (2008) described two cryptostomatid species from the latest Ordovician (upper Katian) of the Argentinean Precordillera. One of them, *Moyerellas pinata* (Ernst and Carrera, 2008), belongs to the suborder Rhabdomesina. The genus *Moyerella* is externally easily distinguished from the material here referred to the genus *Nematopora* because it has more autozooecial rows, and they are present in both sides of the zoarium.

Occurrence: Fossiliferous Mudstone and Sandstone Member, Don Braulio Formation, Upper Ordovician (Hirnantian).

Locality: Don Braulio section, Villicum Range, Precordillera of San Juan Province.

Material: Four specimens studied in its external morphology.

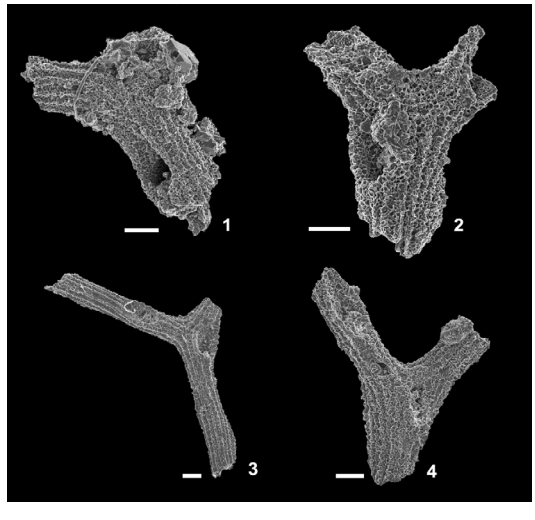

Figure 2- External morphology of the four studied specimens of *Nematopora* cf. dichotomously divided branches, large autozooecial apertures and longitudinal striations can be seen in all specimens. 1 – INGEO-MP-2571 (1); 2 – INGEO-MP-2571 (2); 3 – INGEO-MP-2571 (3); and 4 – INGEO-MP-2571 (4). Scale bar 100 μm. / **Figura 2-** *Morfología externa de los cuatro especímenes estudiados de* Nematopora cf. *Puede observarse en todos los especímenes la división dicotómica de las ramas, gran apertura autozooecial y estriación longitudinal. 1 – INGEO-MP-2571 (1); 2 – INGEO-MP-2571 (2); 3 – INGEO-MP-2571 (3); y 4 – INGEO-MP-2571 (4). Escala grafica 100 μm.*

Character	Or	X	DS	Nm	Nsp
Autozooecial large diameter (in mm)	0.0875-0.1562	0.1211	0.0296	5	4
Autozooecial small diameter (in mm)	0.0562-0.0963	0.0796	0.0151	5	4
Zoarial fragments longitude (in mm)	0.5591-1.3253	0.8742	0.3273	4	4
Zoarial diameter (in mm)	0.1445-0.2375	0.2105	0.0443	4	4

Table 1 –Measurements of *Nematopora* cf. / **Tabla 1-** *Mediciones de* Nematopora cf.

Hexactinellid spicules

Figure 3

Five broken very poorly preserved sponge spicules are the unique spicule type recovered in the acid residue of siliciclastic-carbonate lenses from the Don Braulio Formation. Isolates spicules range from small forms with ray diameters of 0.10–0.16 mm and preserved ray lengths of 0.60–0.95 mm. Two fragments could be isolated rays broken in half with circular cross section of the possible axial canal. The fragmented spicules could be hexactines or derivatives.

Remarks: In the Argentinean Precordillera, diverse spicule types belonged to the Demospongiae and Hexactinellida were collected from the Lower and Middle Ordovician carbonate platform to Middle Ordovician-lower Upper Ordovician siliciclastic platform (Mehl and Lehnert, 1997; Beresi and Esteban, 2003). While possible hexactinellid spicules from the Hirnantian glacimarine cool-deposits of the Precordillera were found and described here for the first time. Together with spicules a crinoid plate was found in the material.

Occurrence: Fossiliferous Mudstone and Sandstone Member, Don Braulio Formation, Upper Ordovician (Hirnantian).

Locality: Don Braulio section, Villicum Range, Precordillera of San Juan Province.

Material: Five specimens studied.

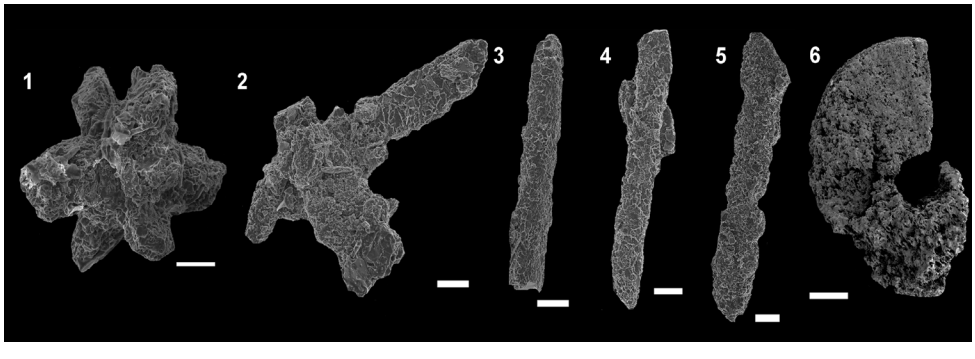

Figure 3- Scanning Electron Microscope microphotographs of poorly preserved hexactinellid spicules, sample MDB1 (Quebrada Don Braulio) elements 1-5: **1-** INGEO-MP-2570 (1); **2-** INGEO-MP-2570 (2); **3-** INGEO-MP-2570 (3); **4-** INGEO-MP-2570 (4); **5-** INGEO-MP-2570 (5); **6-** Fragment of crinoids plate, INGEO-MP-2572 (1).Scale bar 100 μm. / **Figura 3-** *Microfotografías SEM de espículas hexactinéllidas pobremente preservadas, muestra MDB1 (Quebrada Don Braulio) elementos 1-5:* **1-** *INGEO-MP-2570 (1);* **2-** *INGEO-MP-2570 (2);* **3-** *INGEO-MP-2570 (3);* **4-** *INGEO-MP-2570 (4);* **5-** *INGEO-MP-2570 (5);* **6-** *Fragmento de placa de crinoideo, INGEO-MP-2572 (1). Escala grafica 100 μm.*

Conclusions

The ochre calcareous fossiliferous lenses from the Hirnantian fossiliferous Mudstone and Sandstone Member of the Don Braulio Formation, at the Villicum Range, Eastern Precordillera of San Juan Province provided fragments of delicate branches belonging to cryptostomatid bryozoans, and few isolated hexactines showing all rays broken.

Hexactinellid sponges flourish mainly in quiet deep-water conditions and bryozoans mainly inhabited open marine environments of low turbulence at depths 20 and 50 m (Brood, 1975).

The fragmentary preservation of this reworked fauna points out toward pre-burial transport. These are features that strongly indicate transportation by currents prior to their final deposition in the upper carbonate sandstone lenses of the Don Braulio Formation with higher energy levels.

Taking into account that the Argentine Precordillera was situated at higher latitudes during the latest Ordovician, bryozoans and spicules from the Hirnantian marine deposits represent peri-Gondwanan, high palaeo-latitude Precordilleran fauna.

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