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Article

Middle Cambrian protospongiid sponges and chancelloriids from the Precordillera of Mendoza Province, western Argentina

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With 8 figures

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Abstract: A Middle Cambrian faunule from different sections of the San Isidro region, Precordillera of Mendoza Province, western Argentina, include previously recorded and new material. Specimens in the collections are simple reticulosan hexactinelliid determined as *Diagoniella* cf. *cyathiformis, Diagoniella* sp., (?) *Diagoniella* sp., indeterminate protospongioid spicule assemblages and several root tuft types. In addition a possible scleritome of *Chancelloria cruceana* Rusconi, 1954 is re-described and illustrated, and sclerites assigned to ~~*Allonia*~~ and *Archiasterella* are here described for the first time.

Key words: Middle Cambrian, protospongioid sponges, chancelloriids, San Isidro region, Mendoza Province, Precordillera Argentina.

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1. Introduction

The Porifera (sponges) are sessile filter-feeding organisms with an extremely effective and complex network of water-conducting channels and a defined bauplan. They are the oldest living metazoans. Their fossil record extends back to the Late Neoproterozoic although most of these reports are ambiguous and have been questioned (Pisera 2006). The beginning of sponge diversification during the Cambrian is relatively well known thanks to their very good preservation, from the Chengjiang fauna in China and the Burgess Shale in Canada, where even sponges with unfused spicules occur.

Spiculate sponges assigned to *Protospongia*, *Diagoniella* and *Kiwetinokia* and the first Cambrian anthaspidellid skeletal fragments, as well as sclerites of *Chancelloria* have been described and figured from the Middle-Upper Cambrian carbonate platform and slope facies of the Argentine Precordillera (Beresi & Rigby 1994; Beresi & Banchig 1997). A synthesis of Cambrian sponge occurrences in the Argentine Precordillera was given by Beresi (2003). *Protospongia asperoense* (Rusconi, 1952) and *Chancelloria cruceana* (Rusconi, 1954) were the first Cambrian species described from the San Isidro region, in the Precordillera of Mendoza Province. Disarticulated protospongiid spicules and chancelloriid sclerites were subsequently reported from this area by Pernas (1964), Devizia (1973), Bordonaro & Martos (1985), Heredia et al. (1987), and Beresi & Heredia (1995). Siliceous sponge spicules from diverse Cambrian and Ordovician sections of the Precordillera were described by Mehl & Lehnert (1997).

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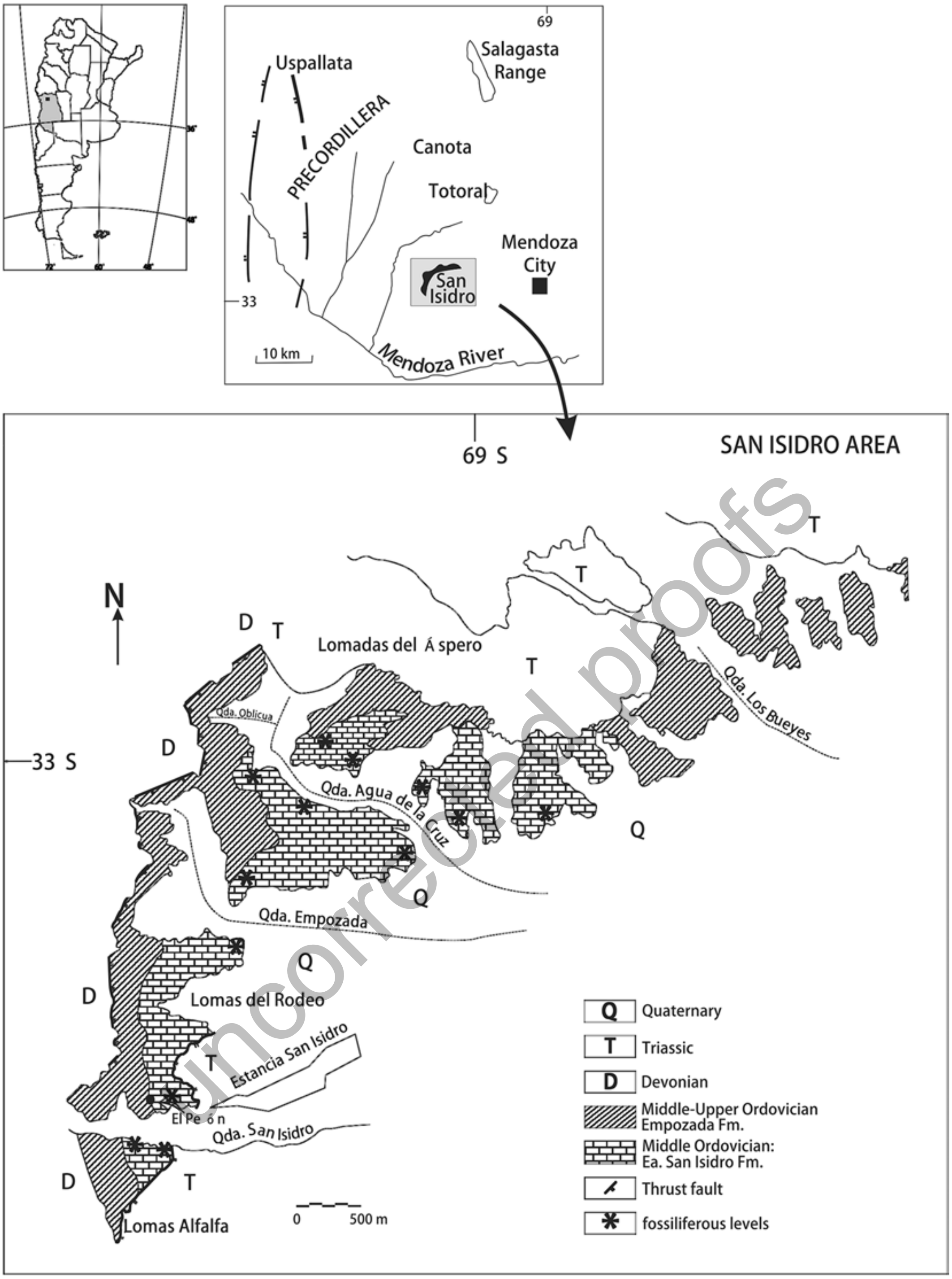

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Fig. 1. Location map of the San Isidro area, Precordillera of Mendoza Province, western Argentina, showing the fossiliferous levels (modified from Tortello & Bordonaro 1997).

In the collection samples studied here, there are a few preserved semi-articulated fragile protospongiid sponges. These sponges represent the simple reticulosan grade which have unilaminar skeletal net of hexactine derivatives spicules (stauractines, pentactines) in a regular ordered quadrupling. The majority of the

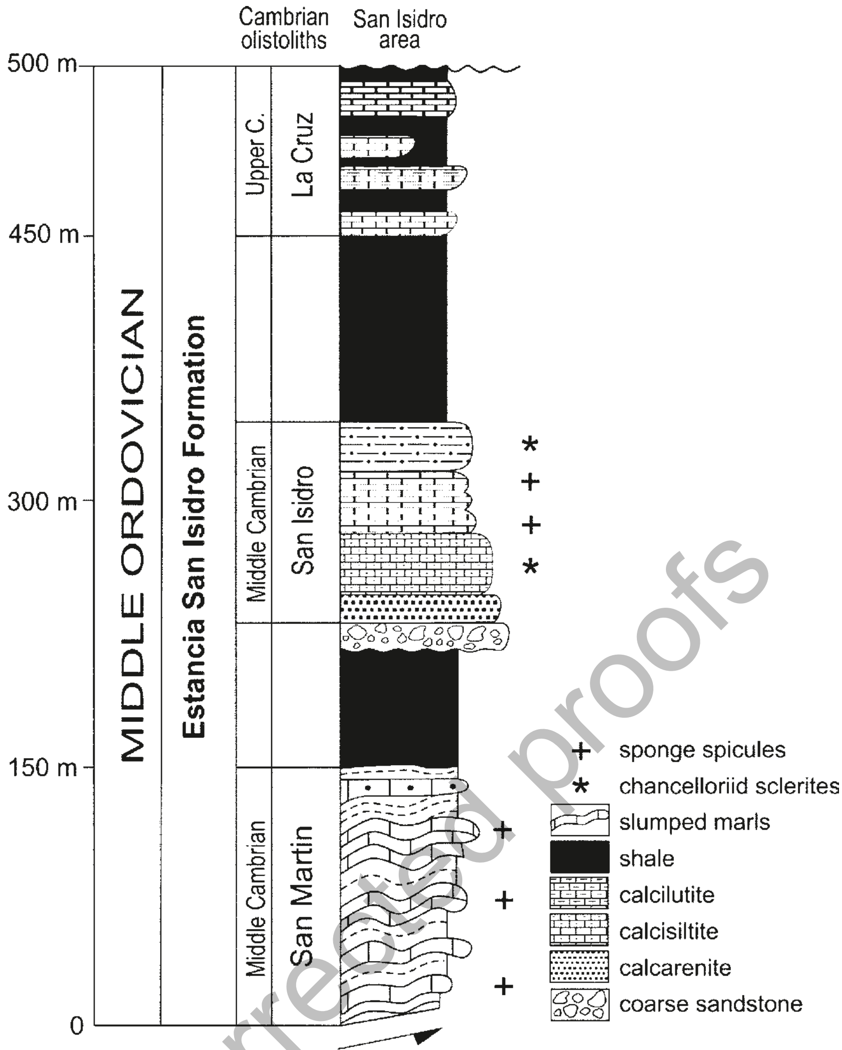

Fig 2. Schematic stratigraphic column of the Estancia San Isidro Formation (Middle Ordovician), San Isidro area, Mendoza Precordillera and sponge spicules and chancelloriid sclerites distribution.

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samples yield a mass of disarticulated spicules that make the interpretation of the relationships of these early fossils difficult.

Sclerites of chancelloriids are in the collections. Chancelloriids were sessile, benthic, radially symmetrical organisms. They range from the earliest Cambrian to the early Late Cambrian, flourishing in shallow marine environments, often as components of archaeocyathan mounds (Janussen et al. 2002). Walcott (1920) originally described chancelloriids as poriferans. However, others have suggested possible affinities with the extinct Coeloscleritophora (Bengtson & Missarzhevsky 1981) and rejected the presumed poriferan affinity (Bengtson & Hou 2001). This view was accepted also by some workers on sponges, e.g., Rigby (1986), Mehl (1996). For detailed taxonomic discussion see Bengtson et al. (1990). On the contrary, Sperling et al. (2007: 355) considered that these "Problematica" are organized around a poriferan body plan, namely a "benthic, sessile micro-suspension feeding organism" and they cannot be removed from the poriferan grade based simply on spicule characteristics." The principal coeloscleritophorans include chancelloriids, halkieriids, sachitids, and siphogonuchitids.

The aim of this paper is to [illegible]ument the Middle Cambrian protospongiid sponge, detached spicule assemblages, sclerites of chancelloriids, and a possible scleritome of *Chancelloria cruceana* discovered during a review of invertebrate collections stored in the "Museo de Ciencias Naturales y Antropológicas Juan Cornelio Moyano" (Mendoza), as part of the first author's project searching for new fossil material from this interesting and promising Precordilleran area.

2. Geological setting

The classic locality of San Isidro area is located at 29°55' N, 118°05' E, in the eastern side of the Precordillera of Mendoza Province, western Argentina (Fig. 1), as part of a vast carbonate platform. In this region, the Darriwilian talus olistostromic Estancia San Isidro Formation (Heredia & Beresi 2006) contains diverse Cambrian-Ordovician allochthonous blocks (olistoliths) (Fig. 2). The "San Isidro olistoliths" record trilobites of lower Middle Cambrian age (*Glossopleura* and *Oryctocephalus* zones sensu Bordonaro et al. (1993), together with *Hyolithes* sp., phosphatic brachiopods, *Girvanella,* echinoderm ossicles (?), sponge spicules and chancelloriid sclerites from the shallow carbonate platform. The "San Martín olistoliths" (upper Middle Cambrian) are composed of dark fine-grained mudstones and marls, which yielded late Middle Cambrian agnostids (Bordonaro et al. 1993) and assemblages of protospongioid spicules which point to a deep-water setting (peri-platform environment). Sponges and chancelloriids from the carbonate samples of the San Isidro and San Martín olistoliths (Middle Cambrian) are described in this paper, while those fossiliferous samples from the Upper Cambrian La Cruz olistoliths are not included in this study.

3. Material and methods

Professor C. Rusconi collected many of the Cambrian and Ordovician invertebrate specimens in the collection of the Museo de Ciencias Naturales y Antropológicas J. C. Moyano, Mendoza City, on numerous field trips during the period 1930-1945. The majority of these samples were recovered from the San Isidro region and nearby areas. He erected a large number of new taxa, published in diverse papers from 1933 to 1958 (e.g., Rusconi 1950, 1952, 1953, 1954, 1955).

The palaeontological collection stored at the Museum includes 654 type specimens (Cerdeño 2005) of fossil invertebrates, vertebrates and plants. Of these specimens, 323 are invertebrates from the Cambrian, Ordovician, Triassic, Jurassic and Tertiary. They are mainly trilobites, brachiopods, bryozoans, cephalopods, ostracods, gastropods, echinoderms, corals, and bivalves; only two specimens (MCNAM-PI 13289 and PI 13295) are sponges and one is identified as a chancelloriid (MCNAM-PI. 15671). However, the first author recently began a detailed revision of a part of the Cambrian specimens not included in the type material.

From a total of 150 revised samples there are 60 samples of marlstones, calcipelites and calcarenites bearing spicules and chancelloriid sclerites together with trilobites, *Hyolithes*, and phosphatic brachiopods, the sponges represent~~ing~~ 40 % of the studied samples. ~~Of these, 28 % represent protospongiids and unidentified hexactinellids, 7 % root tufts and 5 % chancelloriids. Of these,~~ 40 samples bearing the best preserved spicules assemblages and chancelloriid sclerites are described in this paper.

Sponge spicules and chancelloriids were examined by binocular microscope (Olympus SZ61); photographs were taken with this microscope.

Chancelloriid terminology used here follows Sdzuy (1969), Beresi & Rigby (1994) and Randell et al. (2005), with a few modifications. A basic chancelloriid sclerite possesses a central ray perpendicular to the body wall, and lateral rays lying parallel to the body surface surround the central ray. Rays enter the central disc proximally and project distally. Individual sclerites are described by number of lateral rays + number of central rays (e.g., a 5+1: sclerite has five lateral rays and one central ray. Lateral rays are classified by their orientation relative to the main body axis. Since the lateral ray oriented towards the apex is termed the vertical ray, those perpendicular to it are called the horizontal rays.

Repository: All sponges and chancelloriids treated here are deposited in the Invertebrate collection of the Juan Cornelio Moyano Museum, at Mendoza, Argentina, under the catalogue numbers MCNAM- PI 13281 to 23059.

5. Systematic Palaeontology

Class Hexactinellida Schmidt, 1870
Subclass Amphidiscophora Schulze, 1887
Order Reticulosa Reid, 1958
Superfamily Protospongioidea Finks, 1960
Family Protospongiidae Hinde, 1887
Genus *Diagoniella* Rauff, 1894

Type species: *Diagoniella coronata* (Dawson & Hinde, 1889) from Cambro-Silurian strata in Little Métis, Quebec, Canada.

Remarks: The current definition of Protospongiidae (Finks & Rigby 2004) includes only vasiform to spheroidal thin-walled forms with a regular to subregular, quadruled skeleton of stauractines and/or pentactines and minimal ray overlap (Rigby 1978, 1986; Rigby & Murphy 1983); such a definition is followed here. As currently defined, the group is certainly paraphyletic and includes many groups that could reasonably be described as separate monophyletic genera. *Diagoniella* is characterized by its diagonally oriented stauracts. In the genus *Protospongia* stauracts are more or less parallel to the principal axis of the sponge body. The goblet-shaped *Gabelia* consists mostly of regularly oriented hexacts rather than stauracts (Rigby & Murphy 1983).

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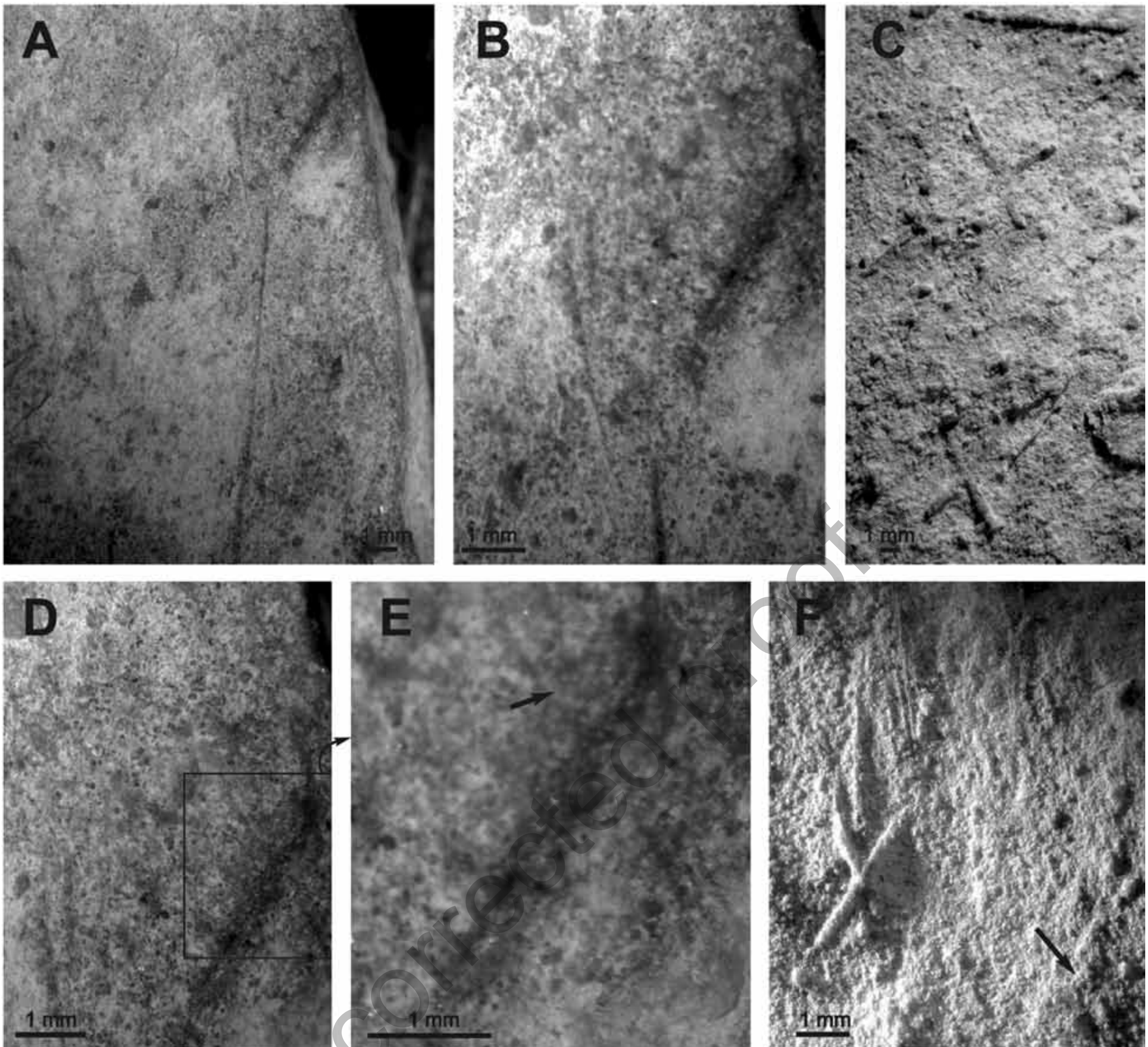

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Fig. 3. *Diagoniella cyathiformis* Dawson & Hinde, 1889 from the Middle Cambrian of San Isidro, Mendoza, MCNAM-PI 13300. **A** – Overall view. **B** – Cup- or inverted cone-shape of the body sponge. C – Stauractines and partial network outside the sponge on the same slab. **D** – View of the skeletal structure of the sponge body. **E** – Detail view of D with diagonally-arranged spicules on the right margin of the cup. **F** – Partial network of the sponge margin still preserved (arrow) and large stauractines.

Diagoniella cyathiformis (Dawson & Hinde, 1889)
Fig. 3A-F

1889 *Diagoniella cyathiformis*. – Dawson & Hinde, p. 23.
1978 *Diagoniella cyathiformis*. – Rigby, p. 1336, pl. 1, figs. 2-3 ; pl. 2, fig. 1.
1983 *Diagoniella cyathiformis*. – Rigby, p. 255, fig. 6F-H.

Material: One specimen, MCNAM-PI 13300, J.C. Moyano Museum, Mendoza, Argentina, collected by C. Rusconi.

Description: The small, unique, high conical-shaped sponge is a thin-walled protosponge having stauracts arranged diagonally to the principal axis of the sponge with at least two orders of stauractines and one extended basal ray. The flattened sponge is 5.8 mm tall, expanding upward from a basal flattened width of approximately of 1.4 mm to a maximum width at the summit of 4.3 mm (Fig. 3A). Although a dense film has obscured parts of the sponge, a delicate articulated skeletal mesh is preserved in the upper right margin (Fig. 3E). Diagonally arranged stauractines form regular rhombic quadrules formed by horizontal and vertical rays of spicules apparently quincunxially arranged and ranging from 0.5-0.7 mm across mm in maximum dimensions, with some regularity down to 0.15-0.20 mm across. Large stauracts appear regularly spaced 1.5-3 mm apart and smaller 0.2mm apart.

Stauracts have ray diameters of 0.05-0.02 mm and 0.70-0.40 to 0.15 mm long. Other tiny x-spicules (0.10 mm long) suggest that a moderately uniform dermal layer may have been developed. A single long monaxon spicule attaches at the pointed base of the body (Fig. 3A). This elongated anchoring spicule is 14.65 mm long and 0.19 mm across.

Locality and age: Middle Cambrian San Isidro olistoliths (*Glossopleura* Zone) of the Estancia San Isidro Formation, San Isidro region, Precordillera of Mendoza.

Remarks: The tiny conical sponge documented here has apparently two or perhaps three preserved orders of spicules that can be distinguished in its body wall and only one greatly elongated proximal ray, which acts as anchoring spicule. Dimensions and the body-shape of the sponge are somewhat similar to those of *D. hindei* WALCOTT, 1920, although the observed spicule sizes would correspond to the 3th and 4th spicule-order of this species. *Heminectere minima* (BOTTING, 2004) from the Silurian of British Columbia, even though of similar size is a fusiform protospongiid rather than a conical sponge. Basal part of the Precordilleran specimen is decidedly conical with a pointed base very similar to *Diagoniella cyathiformis*, while in *D. hindei* it is subcylindrical, almost tubular. So, as immature forms of *D. cyathiformis* tend to be distinctly triangular and/or flattened rather than subcylindrical to ovoid as *D. hindei,* we interpreted the figured specimen as closely similar to the species *D. cyathiformis* from the Middle Cambrian Wheeler Shale and Marjum Limestone (RIGBY 1978, 1983). At present, we consider the single specimen as a juvenile form of *D. cyathiformis*.

The simplest hexactinellid tufts appear to have been simple modified hexactines as seen in various small protospongiid species (e.g., *Protospongia mononema* DAWSON & HINDE, 1889) and to modern amphidiscophoran (e.g., *Monorhaphis*) with only one greatly elongated proximal ray forming an anchor, and five distal rays. The apparent monactine nature of the root spicule may indicate a distinct root-tuft character for *Diagoniella* species.

Diagoniella sp.
Fig. 4A-D

Material: MCNAM-PI 15672; two specimens with articulated mesh (a and b) and a fragment of articulated mesh (c) occur on the same calcareous slab.

Description: Two associated small conical-cylindrical to obconical sponges (a and b) with diagonally-oriented spicules and a fragment of skeletal structure (c) occur on the same bedding plane of a calcareous slab (Fig. 4A-D). The obconical sponge a (Fig. 4B) is 10.5 mm tall, with maximum width 2.8 mm and with diagonally-oriented arrays of ranked spicules. The largest of these small spicules appears to have coarsest rays approximately 0.70-0.60 mm long, which border rectangular openings of this general width and height. These small rectangular openings are subdivided into four smaller openings by very small microspicules (0.10 mm long). The sponge b (Fig. 4C) is apparently 26 mm tall, with a maximun width of approximately 10 mm and shows a skeletal net with diagonally-oriented spicules. Coarsest stauractins have 0.05-0.03 mm across and 1.0-0.8 mm long and smallest ones 0.020 mm across and 0.20 mm long. The fragment of skeletal net c (Fig. 4D) shows well defined rhomboidal quadrules of 1.5-1.8 mm across. Three orders of spicules are evident in parts of this fragment; largest spicules of 1.5-1.7 mm long show overlapping of rays, intermediate spicules are 0.35 mm long and smallest one 0.10-15 mm long.

Remarks: Dimensions and the body-shape of specimen (a) are similar to those of *Diagoniella hindei* WALCOTT, 1920. It differs markedly from other species such as *D. cyathiformis* RIGBY, 1978, which is widely conical and has larger spicules, *D. coronata* DAWSON & HINDE, 1889 which is a subspherical sponge and *D. robisoni* RIGBY, 1978 which is a moderately large sack-shaped to globular sponge. Specimen (b) is similarly-sized to *D. cyathiformis*; meanwhile the skeletal net fragment (specimen c) shows the largest preserved quadrules somewhat similar to those of first-order quadrules of *D. robisoni* (RIGBY 1978).

(?) *Diagoniella* sp.
Fig. 4E-J

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Fig. 4. *Diagoniella* sp. **A** – Impression of two small conical-cylindrical sponges (a-b) and parts of the diagonal skeletal arrangements (c), MCNAM-PI 15672. **B** – Small conical sponge (a), **C** – Flattened larger cylindrical sponge (b). **D** – Skeleton fragment showing diagonally arranged stauracts in the centre of the slab (c). **E-G** – (?) *Diagoniella* sp., MCNAM-PI 15546. E: Sponge. F: Detailed view of fragment with aligned rays. G: Structure with small circular openings that are diagonally placed and some spicules. **H** – Trilobite spine impressed over the sponge surface with stauractines and a pentactine (arrow), MCNAM-PI 15682. **I** – Two small *Diagoniella* sp., one shows small circular openings (arrow), MCNAM-PI 13287. **J** – Stauractines, one with a curved ray, over two young conical (?) *Diagoniella* sp. (left side), MCNAM-PI13302. **K** – Hexactines and skeletal net fragments with diagonally-oriented spicules (arrow), MCNAM-PI13282. **L** – Black areas with partial network (arrow) and a long hexactine, MCNAM-PI13287.

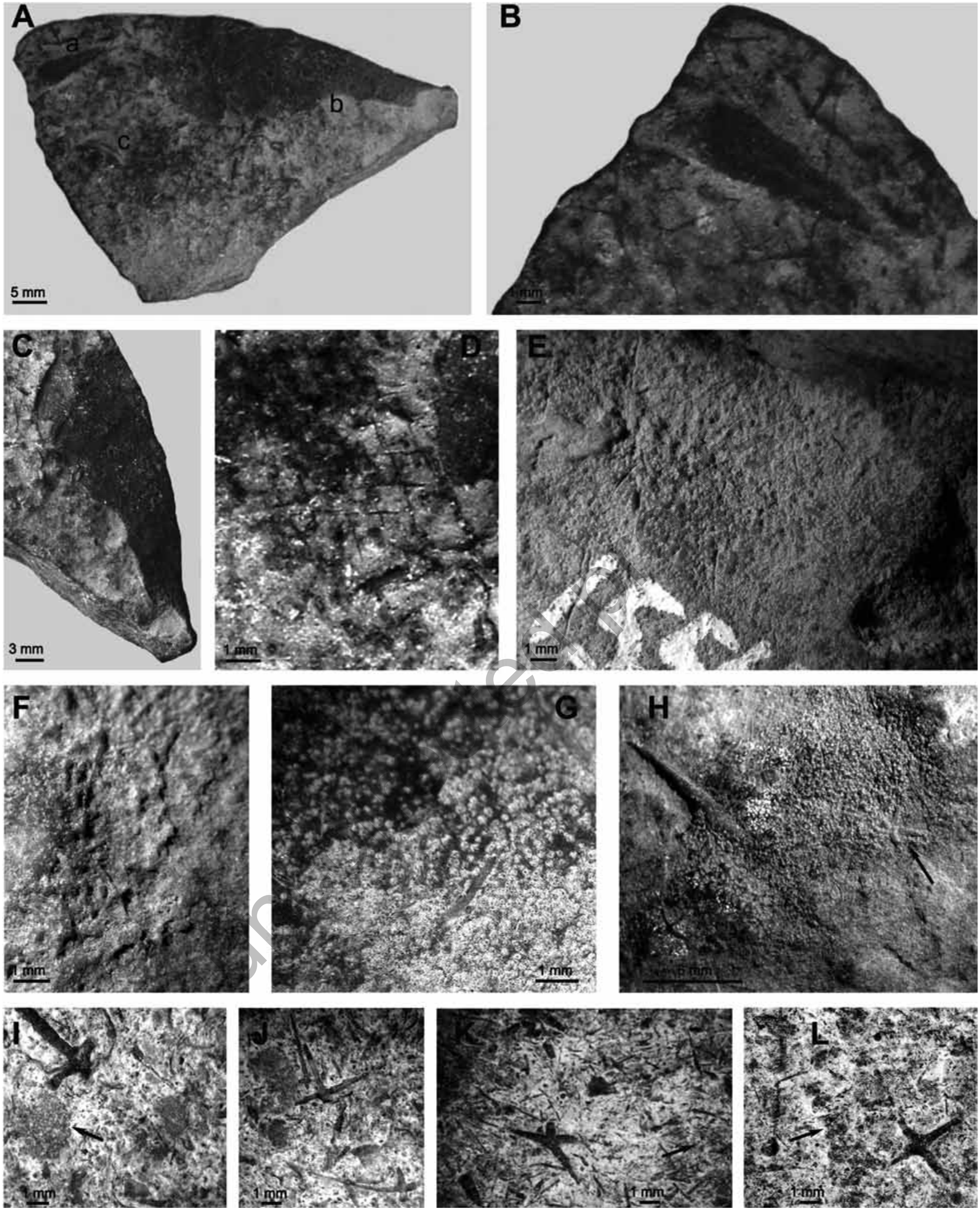

Fig. 4.

Material: MCNAM PI 13282, 13287, 13302, 15546, 15682. All specimens figured.

Description: The steeply obconical forms (samples 15546, Fig. 4E-F and 15682, Fig. 4H) show hints of diagonal spicule rays and small skeletal pores that are diagonally placed and closely spaced. Circular openings irregularly and closely spaced are 0.10-0.20 mm in diameter (sample 15546, Fig. 4G). Two small sponge fragments show subconical outlines (sample 13287, Fig. 4I and 13302, Fig. 4J) and diagonally oriented small stauractines. Numerous samples of the collection have preserved fragments of delicate, single mesh, with stauracts in regular diagonal array.

Remarks: The obconical forms are interpreted as questionable (?) *Diagoniella*. The sponges of samples 15546 and 15682, do appear somewhat similar to the skeletal structure of the steeply obconical specimen interpreted as *Diagoniella hindei* (Fig. 4A) described above. The ovoid forms with areas where partial networks are still preserved could be small immature sponges such as *Diagoniella*.

Indeterminate protospongiids
Fig. 5A-L

Material: Sponge spicules were recovered in many samples. Articulated arrays: MCNAM-PI 13285, 13291, 13297, 13300, 13302, 23058, 23059; disarticulated spicules only: MCNAM-PI 13281, 13287, 13292, 15470, 15480, 15486, 15682, 16272, 19949. Figured specimens, 13291, 13292, 13297, 13302, 15486, 19949.

Localities and age: Middle Cambrian San Isidro olistoliths (Empozada Creek and Cerro Martillo) and San Martin olistoliths (Agua de la Cruz Creek), Precordillera of Mendoza.

Description: Assemblages of just simple stauractines and some few hexactine-pentactines of diverse sizes with gradationally smaller spicules and fragments of skeletal nets occur on bedding planes in numerous calcisiltites and calcilutites. Spicules have been mineralogically replaced during diagenesis by white calcite (Fig. 5I). Stauractines are both x and +-shaped spicules (Fig. 5A-L) and some stauracts show gently curved horizontal rays 1.50 -3.65 mm up to 16 mm long and basal diameters of 0.3 -0.8mm. Few stauracts have rays of nearly equal length of from 2.5-3.0 mm and 0.25-0.40 mm in basal ray diameter (samples 15470, 15480). Longest stauracts have rays of 6-8 up to 10 mm and basal diameter of 0.40-0.70 mm (samples 13281, 13285, and 13287); thin and delicate stauracts have predominantly long rays of 1.2-2.5 mm and tiny spicules have rays of approximately 0.l0-0.25 mm long.

In samples 23058 and 23059, stauracts in the articulated arrays are stacked three-dimensionally and not flattened, with outer coarser elements gradationally overlying finer elements. Some fragments show stauracts forming small regular orthogonal quadrules (Fig. 5B-F) and a dark film covers part of the skeletal net below the larger isolated stauracts (Fig. 5K).

In some slabs spicule rays slightly overlap making evident their lyssacine character (Fig. 5D) but in other ones spicule rays appear as a fusion of the tips of several rays (e.g. sample 13297, Fig. 5E).

In sample 13302 (Fig. 5G-H), stauracts or/and hexactines have marked elongate vertical (?) rays of 2-6 mm long and maximum basal ray diameters 0.25-05 mm. These rays overlap each other, thus forming apparently a long curving row, not well preserved.

Remarks: A wide range of disarticulated remains are present but unidentifiable at genus level. The fragments represent a simple structural grade of reticulosan. This type of morphology may be regarded as similar to that of the most primitive hexactinellids (e.g., Mehl 1991, 1996; Finks 2003). Botting (2003), on the other hand, considers that the *Protospongia* spicule arrangement could have derived from a more tractose arrangement by peramorphic growth to large sizes.

Spicules with gently curved rays, such as occur in *Protospongia*, could be specialized large anchor-like dermal stauractines, or hypodermal hexactine-based spicules. Staurcts and /or hexacts with a marked elongated vertical (?) ray arrangement has a vague similarity to *Gabelia intermedia* Rigby & Maher, 1995, from undifferentiated Devonian and Silurian rocks of the Snake Mountains locality, Nevada, and to *Heminectere minima* Botting, 2004, from the Caradoc of central Wales.

The occurrence of fragments of thin-walled skeleton of simple stauracts with some indication of rectangular y/o diagonal reticulation and several size order-stauracts (Rigby 1978, 1986; Rigby & Murphy 1983) could point to a systematic affiliation with the Protospongiidae.

Indeterminate protospongioids
Fig. 6A-H

Material: MCNAM-PI 13287, 13290, 13291, 13294, 13000, 13302, 15482, 15674, 15682, 23059. Figured specimens, MCNAM-PI 13287, 13290, 13291, 15682.

Localities and age: Middle Cambrian San Isidro olistoliths (San Isidro Creek) and San Martin olistoliths (Agua de la Cruz Creek), Precordillera of Mendoza.

Description: Mass of disarticulated and irregularly distributed spicules. Spicules hexactines, triactines (Y-shaped spicules; Fig. 6A-D) and simple stauracts occur on the calcareous slabs. Hexactines (Fig. 6E-H) are 5 to 12 mm long, with basal ray diameter of 0.4-0.9 mm. Central nodes 0.6-0.8 mm across corresponding to proximal and distal rays normal to tangential rays and conclusively prove that such spicules are not stauractines but hexactines. Length of triactine spicule rays at least 5.5 mm, with basal diameter of 0.20 mm.

Remarks: It is interesting to note that there are hexactine-based spicules associated with simple stauractines and some few triactines. The preservation of some spicules allows a

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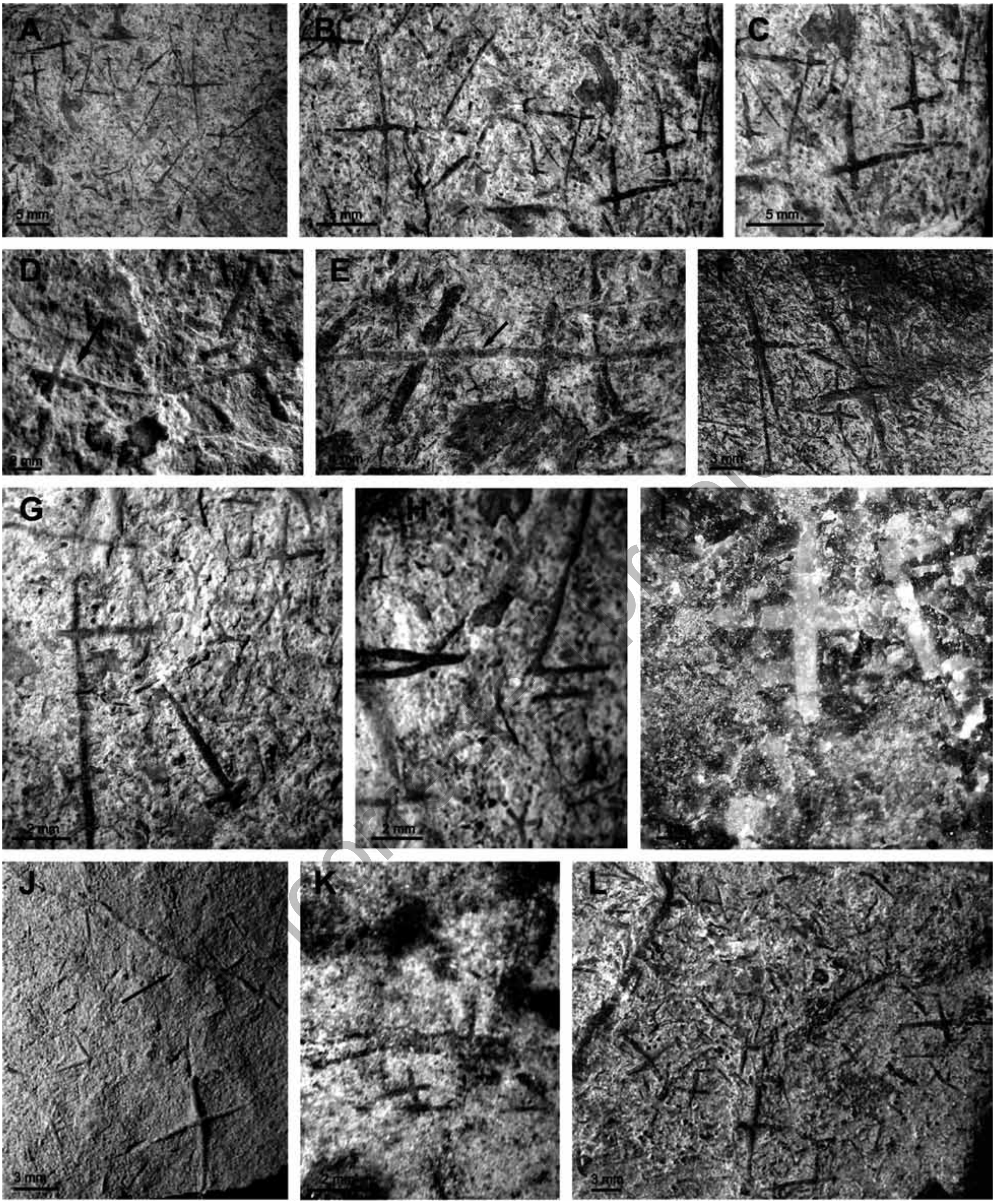

Fig. 5. Indeterminate protospongiids. **A**-**C** – Large spicules with orthogonal quadrules, MCNAM-PI 13291. **D** – Overlapping rays of first-order spicules (arrow), MCNAM-PI 13297. **E** – Spicule rays appear as a fusion of the tips of adjacent rays (arrow), MCNAM-PI 13297. **F** – Moderately preserved skeletal mesh and quadrules, MCNAM-PI 23058. **G**-**H** – Stauractines or hexactines with marked elongate vertical (?) rays. H: Stauractines with curved horizontal rays and marked elongate ray, MCNAM-PI 13302. **I** – Stauractine with sub-equal ray length, MCNAM-PI 19949. **J** – Detailed view of a large stauractine over remains of skeletal net (arrow). **K** – Ovoid form with preserved skeletal net of a probable immature protospongiid sponge, MCNAM-PI 15486. **L** – All spicules appear irregularly transported, MCNAM-PI 13292.

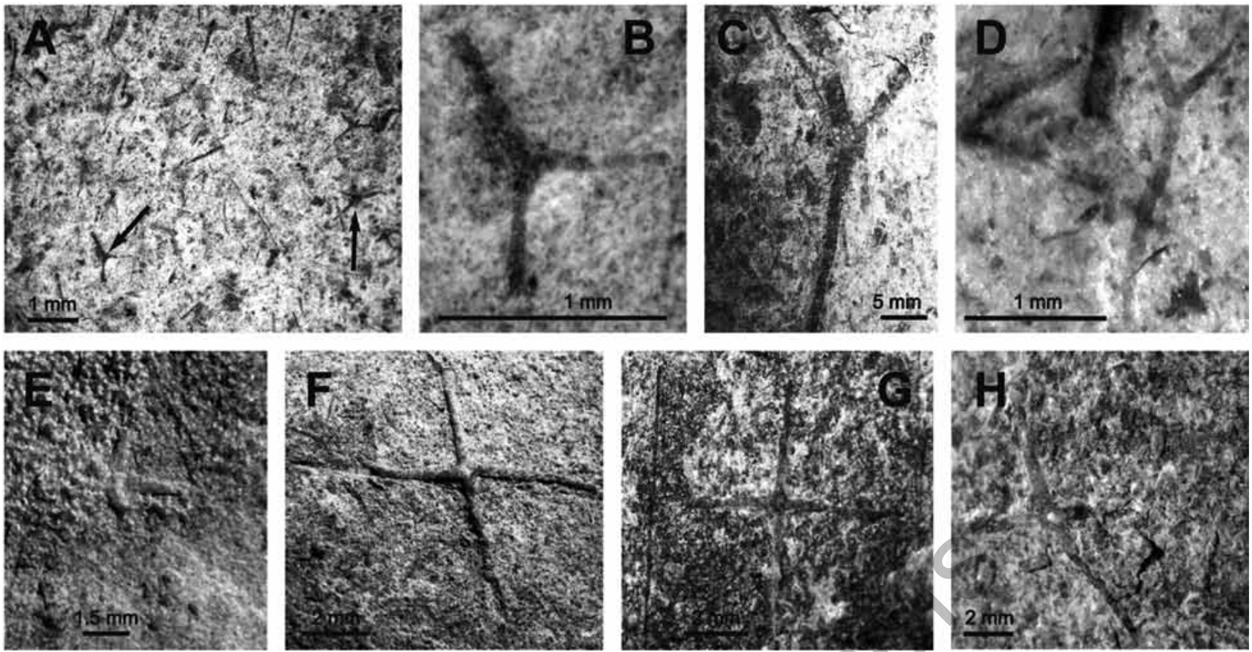

Fig. 6. Indeterminate protospongioids. **A-C** – Triactines (Y-shaped spicules), MCNAM-PI 13291. A: Overall view. B-C: Detail of Y-shaped spicules. **D** – Y-shaped spicule, MCNAM-PI 13287. **E-G** –Hexactine-based spicule. E: Sample MCNAM-PI 15682. F: Detail of central node of a hexactine, MCNAM-PI 13287. G: Large hexactine and monactine, MCNAM-PI 13291. **H** – Hexactine-based spicule, MCNAM-PI 13290.

clear recognition and measurement of central nodes corresponding to proximal and distal rays normal to tangential rays and conclusively proves that such spicules are not stauractins but hexactins. These hexactine-based spicules are taxonomically very widespread in different protospongioid taxa. Thus many protospongioid sponges must be represented. For example in the Family Protospongidae (Finks et al. 2004) many genera such as S*aetaspongia* Mehl & Reitner in Steiner et al., 1993) from the Lower Cambrian of China; *Testiispongia* Rigby, 1983a from the Middle Cambrian of Utah (USA); *Asthenospongia* Rigby et al., 1981 from the Arenig of Idaho; *Gabelia* Rigby & Murphy, 1983 from Devonian of Nevada; *Palaeosaccus* Hinde, 1893; *Hunanospongia* Qian & Ding in Ding & Qian, 1988 and *Quadrolaminiella* Chen et al., 1990 between others. Owing to the disarticulated preservation of these hexactines in the samples of the collection, identification at a genus-level is impossible.

Sponge root tufts
Fig. 7A-H

Root tuft structures are difficult to assign to known taxa because of the lack of distinctive features, and preservation in association with the sponge bodies. However, according to Botting (2004), Early Palaeozoic development of root tufts may be of interest in broad scale phylogenetic and ecological studies, and they should be described where possible. The presence of root tuft appears be a character in primitive hexactinellids.

Several anchoring structures have been recovered from the San Isidro area and can be grouped as: type A, multiple dense tufts; type B, parallel root spicule cluster; type C, divergent splays of monaxons with a common base, type D, single dense long tufts and type E, one long ray.

Root tufts similar to types B and C were recovered from the Upper Cambrian of the Tontal Range, in the Western Precordillera of San Juan Province (Beresi & Banchig 1997). Type C and D are similar to the groups 1 and 2 by Botting (2004) from the Caradoc sponge fauna in central Wales.

Type A: multiple dense tufts
Fig. 7A-B

Four root tuft spicule clusters appear to be inserted in the preserved base of a small sponge that is 5.8 mm across, in which only the spheroidal outline of the base is regularly preserved and recrystallized as white calcite (sample 13301). Each bundled tuft is composed of dense closely packed monaxon spicules (oxea?). The central bundle has fine spicules that are up to 15 mm long and approximately 0.02-0.04 mm across. The long spicule bundles are associated with other fine intertuft stauractines (0.3 mm long). The

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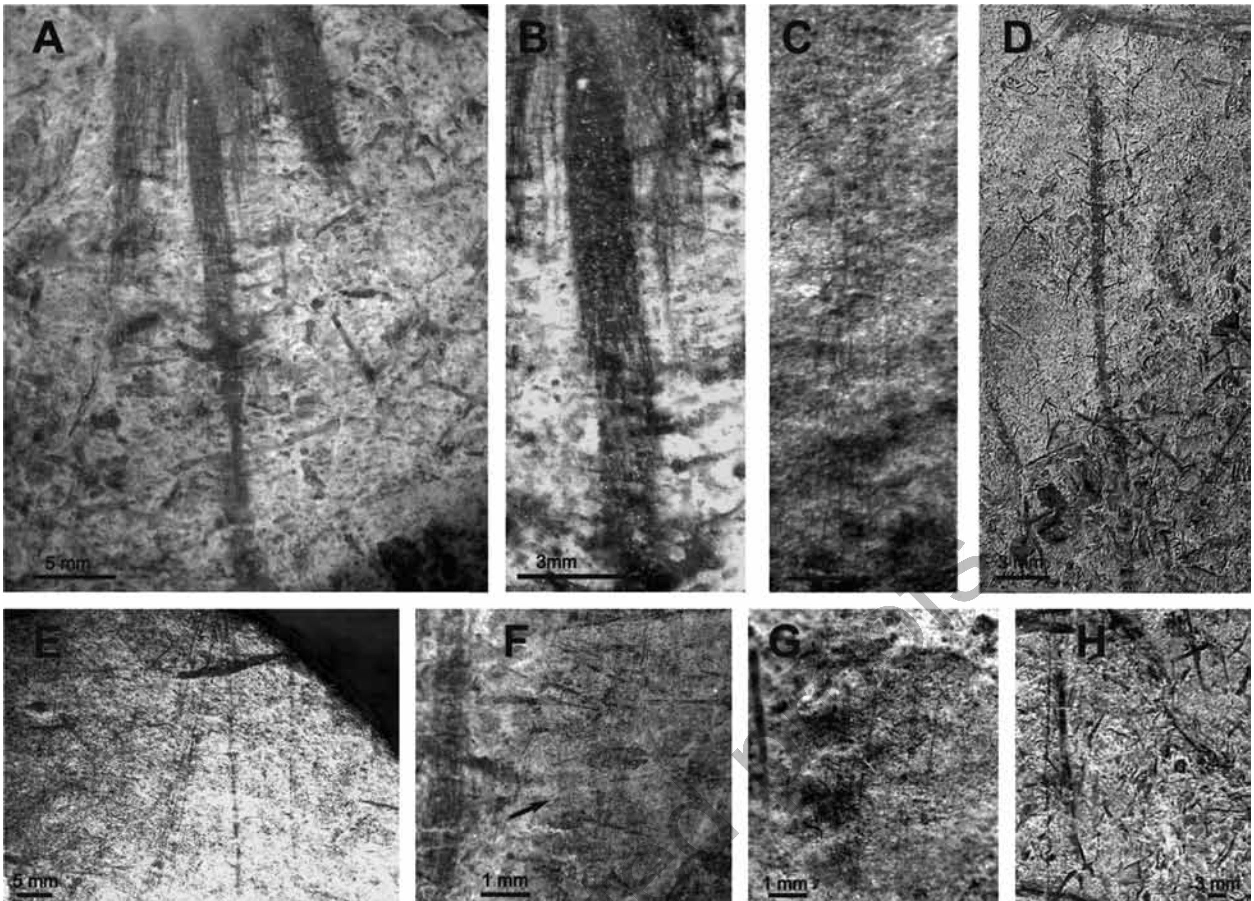

Fig. 7. Root tufts. **A**-**B** – Type A, multiple dense tufts, MCNAM-PI 13301. A: Divergent splays of three monaxon clusters with a common base. B: Detailed view of a cluster. **C** – Type B, parallel fine root spicules, MCNAM-PI 15486. **D**, **F**-**H** – Dense single tuft. D: Sample MCNAM-PI 13292. F: Single root tuft and probable small protospongiid sponge (arrow)**,** MCNAM-PI13290. G: Dense single tuft and parallel fine spicules, MCNAM-PI 13290. H: Type D, Single root tuft, large monaxon and stauractines, MCNAM-PI 13282. **E** – Type C, divergent fine root tufts, MCNAM-PI 13287. **E**, **G**-**H** – Type E, one single elongate ray, MCNAM-PI 13287, 13290, 13282.

bundles are approximately 1.5 to 2.0 mm across and they apparently expand downward from the base of the sponge body (?).

Type B: parallel fine spicule tuft
Fig. 7C-G

In samples 13292, 15486, attachment structures are composed of 6 to 10 parallel thin root spicules (monaxons?) which are predominantly 7.0- 16 mm long and 0.6-0.8 mm across, lacking preserved pointed ray tips. Scattered transported spicules (sample 13287) include large ones that are probably root spicules. They are associated with fine inter-tuft and large stauractines and individual root tufts which could be isolated prostalia?

Type C: divergent splay of monaxons with a common base
Fig. 7E

Several long spicules appear grouped in two bundles of tufts (samples 13287, 13290). Spicules packed side by side parallel with long spicules of 10 mm to 15 mm long with ray tips broken on most spicules of clusters and rays 0.07 up to 0.10 mm across at their maximum diameters. The tufts expand from 4 long spicules in the proximal area (at insertion to sponge body?) to 8 long fine oxeas/diacts (?) in distal regions (away from body) from where they spread approximately 3-5 mm apart. Long spicules are associated with fine inter-tuft stauractines. These spicules lie on the calcareous slab with fragment of trilobites and disarticulated small stauractines.

Type D: dense single tuft
Fig. 7D, F-H

A single cluster of root tufts, at first sight appear as more or less dense tuft attachment structures with fine monaxons of 45 mm up to 70 mm long (sample 13282).

Type E: one ray greatly elongate
Fig. 7E, G-H

The hexactinellid root tuft structure is one enlarged monaxon (samples 13287, 13290, 13282).

Remarks: Diverse morphologies of the root tufts with fragments of primitive hexactinellids are represented in the samples of San Isidro collection. The type A: multiple dense tufts, above, may be similar to sponges with hollow spheroidal or sac-shaped forms with groupings of long thin diacts in tufts of the Family Teganiidae. According to Botting (2004) the simplest hexactinellid tufts appear to have been modified hexactines as seen in various small protospongiid species with one ray greatly elongated (e.g., *Diagoniella cyathiformis*, this paper, *Protospongia tetranema,* and *P. mononema* Dawson & Hinde, 1889). It is possible that this represents the ancestral state of root tufts, although other early hexactinellids exist in which no root structures are known.

Class Coeloscleritophora Bengtson & Missarzhevsky, 1981
Order Chancelloriida Walcott, 1920
Family Chancelloriidae Walcott, 1920

Emended diagnosis (after Janussen et al. 2002): Sessile epitheliozoans with armour consisting of spiny sclerites mineralized on organic precursors within or beneath outer epidermis. Sclerites hollow, usually composite, consisting of individual spines united at base.

Genus C*hancelloria* Walcott, 1920

Type species: *Chancelloria eros* Walcott, 1920.

Emended diagnosis (after Janussen et al. 2002): Slender cylindrical to conical Chancelloridae, sometimes with irregularly thickened root at base. Sclerites composite, radially symmetrical with four to more than eight lateral rays, partly of different sizes, arranged in a more or less horizontal plane, from which they may distally curve away; central ray protrudes vertically, but may occasionally be missing.

Chancelloria cruceana Rusconi, 1954
Fig. 8A-E

1954 *Chancelloria cruceana*. – Rusconi, p. 1, fig. 1a-b.
1955 *Chancelloria cruceana*. – Rusconi, pl. 1, fig. 1.

Emended diagnosis: Chancelloriids with star-shaped sclerites of ray composition dominantly 6+1, arranged in a horizontal plane and with one central ray protruding vertically; the basally-pointed rays are shorter than the other tangential rays. Rays are large, slender (fully formed rays 8-10 mm long; basal width of rays up to 07-0.8 mm).

Holotype: MCNAM PI 15671 by Rusconi (1954). Other material**:** MCNAM PI 13295.

Type locality: San Isidro olistoliths (Agua de La Cruz Creek, 100 m northwest Cerro Martillo), San Isidro area, Precordillera of Mendoza.

Description: Clusters of composite sclerites, somewhat oriented and grouped occur on the bedding plane of the thin yellow calcisiltite fragment 12.5 x 11 cm, and appear to belong to a possible scleritome (Fig. 8A-B). A fairly constant orientation of the larger sclerites and the smaller sclerites may be part of the original chancelloriid scleritome. Almost 40 sclerites were counted with a 6+1 distribution being dominant. Individual sclerites are star-shaped and composed of six radiating, tangential rays, of different sizes, in one plane and one central ray protruding vertically which is broken off, ranging from 0.8-1.1 mm across. Spacing between the central discs of sclerites range 2, 3 to 4.5 mm. Two rays are curved. Another important feature is the nature of the short, basally-pointing rays. They seem to be tapering, particularly clearly in Fig. 8E, which suggest that they are not broken. Apparently the basally-pointed rays are shorter than the others and do not appear broken off. This could be a characteristic feature of these sclerites. Numerous central rounded discs and large curved and straight rays appear isolated and some of the 6 rays have been largely removed by erosion. There are a few smaller sclerites associated with the large ones on the slab. Rays have a maximum preserved length of 10 mm with 0.4 up to 0.8 mm diameters at their bases, in the point where they articulate. Lateral rays are typically 6-7 mm long, but some reach up to 10 mm in maximum length. Basally-pointed lateral rays curve through approximately 25º- 30º up to 35º at the middle part of the rays, and then curve to approximately 15º-20º at terminal parts of the rays.

Sclerites have largely resisted compaction and their walls and internal cavities appear be replaced by secondary crystalline calcite. The preservation does not reveal details of the sclerite surfaces, and it is not possible to observe the undersurface showing pores (foramina). The original drawing of this specimen by Rusconi (1954) shows the characteristic collapsed furrow on some rays, indicating their originally thin-walled construction, but this feature is not observed in the sample described here.

Remarks: The lectotype of *C. eros* Walcott, 1920, designated by Goryansky (1973, USNM 66524) clearly shows the 7+1 sclerite composition typical of the species. Counting of 124 sclerites on two well preserved specimens of *C. eros* from the Wheeler Shale (Janussen et al. 2002) was distributed as: 6+1= 5; 7+1= 43; 8+1= 3: uncertain= 73. A fairly

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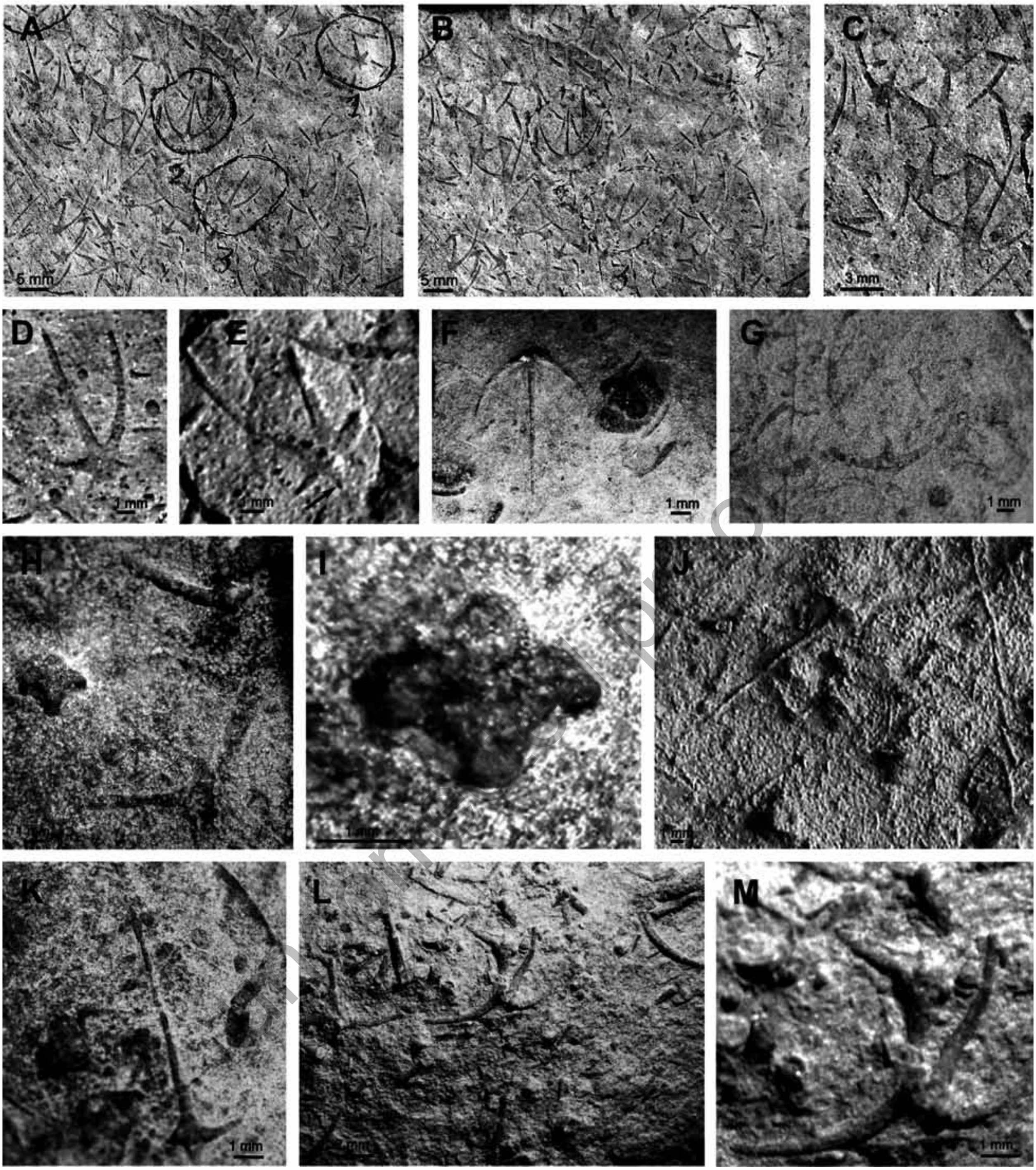

Fig. 8. Chancelloriids. **A-C** – Overall view of scleritome of *Chancelloria cruceana,* Rusconi, 1954, holotype MCNAM-PI 15671. **D-E** – Detailed view of sclerites. D: Sclerite with 6+1 rays. E: Sclerite with (?) basally-pointed ray's shorter. **F** – *Chancelloria* sp. and trilobite cephalon of Ptychopariida, MCNAM-PI 15674. **G-K** – *Archiasterella* sp., MCNAM-PI 15673. G: Sclerites with two lateral rays and disarticulated rays. H: Central part of sclerites. I: Detailed view. J: Sclerite with one large ray preserved. K: Sclerite with four rays and trilobite fragment. **L-M** – Fragment showing transported sclerites with apparently four arcuate rays, MCNAM-PI 16272.l. M: Detailed view of large sclerite with curved rays.

constant orientation of the larger sclerites and the smaller sclerites may be part of the scleritome, as in *C. eros*. Sclerites of the San Isidro on the "scleritome" are 6+1 and, with a length of individual rays up to 10 mm long and 0.5-0.6 mm diameter, are among the largest sclerites of chancelloriid known and are longer and thinner than those in *Chancelloria eros* Walcott, 1920. The general appearance of these sclerites with possibly a shorter basally-pointed ray between the two larger curved rays as described by Rusconi (1954).

Chancelloria sp.
Fig. 8F

Material: One sclerite and isolated rays from the San Isidro olistoliths. MCNAM-PI 15674.

Localities and age: Middle Cambrian San Isidro olistoliths (San Isidro and Empozada creeks), Precordillera of Mendoza.

Description: Only one large, incomplete chancelloriid sclerite with three preserved rays: a straight ray and two lateral curved rays occur associated with a cranidium of a ptychopariid trilobite. The vertical or basal ray is 10 mm long and 0.5 mm in diameter at the base, and lateral rays are 5 and 6 mm long and 0.4 mm diameter at the basal articulation. The lateral rays form an angle of approximately 45º from the basal or vertical ray.

Remarks: The arrangement and number of rays (3+0) in this specimen looks like an *Allonnia* Doré & Reid, 1965, which has a very regular scleritome, almost exclusively with three rays 3+0 sclerites, although Qian & Bengtson (1989) also included in this genus sclerites with four (4+0) and two (2+0) rays. However, the arrangement, orientation and lengths of the three preserved rays most closely resemble those of *Chancelloria cruceana* of sample 15671 more than *Allonnia*.

Genus *Archiasterella* Sdzuy, 1969

Type species: *Archiasterella pentactina* Sdzuy, 1969.

Archiasterella sp.
Fig. 8 G-K

Material: A few sclerites and numerous probably related single rays (MCNAM-PI 15673 and 16272).

Localities and age: Middle Cambrian San Isidro olistoliths (San Isidro and Empozada creeks), Precordillera of Mendoza.

Description: Four sclerites with four radiating rays in a plane (4+0) and without a central perpendicular ray (Fig. 8H-K) occur with fragments of trilobites (sample 15673). Maximum preserved length of the vertical ray is 6.5-4.5 mm with a diameter of 0.25-0.10 mm. Lateral ascending rays are 7-6 mm long and 0.07 mm across, forming an angle of approximately 45º with the vertical ray.

Numerous sclerites with apparently four arcuate rays (Fig. 8L-M) appear not to have a central disc in the limestone slab (16272) that is approximately 1 cm across. The curved ray is 3.2 mm long, from the node of the ray base, where the ray is 0.7 mm in diameter, to the tip which is 0.10 mm in diameter. A few moderately complete sclerites and fragments also occur on the reverse side of the limestone slab. The complete curved ray is 4.0 mm long, and irregularly S-shaped, with a sharp curve at the base, where it is 0.6 mm in diameter, beyond which it then arches and thins gradually to its pointed tip. The opposite curved ray is incomplete, but 4.0 mm long, has a less curved base but arches to the broken tip. The more or less straight ray narrows from a flaring base, which merges with the other flared ray bases, to the broken outer end. The lacy base opposite the straight one is incomplete and flares around the hollow central node.

Remarks: Because of the poor preservation, particularly the specimen MCNAM-PI 16272, the determination of this material is difficult. Nevertheless, the ray configuration (4+0) arrangement and orientation of the four rays point to a systematic affiliation with archiasterellid (Szduy 1969; Bengtson et al. 1990). The original sclerites' surface pattern is not visible. These sclerites might represent species of *Archiasterella*.

6. Conclusions

The fauna that inhabited the Middle Cambrian platform of the Precordillera shows the cosmopolitan occurrence of the main widespread genera such as *Protospongia*, *Diagoniella*, *Chancelloria*, and *Archiasterella*.

The simplest structural grade of reticulosan is represented in the sponge fauna, involving a single thin wall of hexactine-based spicules, possibly pentactines in regular, quadruled architecture.

Well preserved skeletal net fragments are found in thin dark mudstones associated with a deep carbonate platform (San Martin olistoliths). This may be interpreted as a consequence of having suffered a short transportation from the original site in a subtidal external platform. Other assemblages with masses of disarticulated spicules of different sizes and degree of fragmentation were reworked and deposited in comparatively shallower platform environment (calcarenites of the San Isidro olistoliths). Hexactine-based spicules, and triactines (Y-shaped spicules) assemblages could belong to others taxa, e.g. *Saetaspongia* and *Tricticispongia diagonata* Mehl & Reitner, 1993 from the Lower Cambrian, Yunnan, China which have skeletons with triactine, tetractine and hexactine spicules.

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The presence of diverse anchoring structure morphologies is significant because it indicates that these root structures are much more diverse than had previously been recognized for the Middle Cambrian. The presence of root tuft appears to be a character in primitive hexactinellids.

The scleritome of *Chancelloria cruceana* and isolated sclerites attributed to *Archiasterella* and *Chancelloria* sp., are among the distinctive fauna from the Middle Cambrian of San Isidro locality.

As the Argentine Precordillera was situated in a near-equatorial position during the Middle Cambrian times, this condition favours the flourish of these organisms as in other Cambrian warm platforms of the world. Protospongioid sponges and chancelloriids from the San Isidro area may provide useful information for palaeobiogeographic global correlations.

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