Geologica Acta, Vol.1, Nº1, 2003, 73-84
Available online at www.geologica-acta.com

geologica acta

Cambrian sponge spicules and Chancelloriid sclerites from the Argentine Precordillera: A review

M.S. BERESI

IANIGLA, CRICYT
Avda. Ruíz Leal s/n, Parque Gral. San Martín (5500) Mendoza, Argentina.
E-mail: mberesi@lab.cricyt.edu.ar

ABSTRACT

Spicules of sponges and sclerites of chancelloriids have been collected from in situ Cambrian sections of the La Laja Formation (San Juan Precordillera). They have also been collected from carbonate olistoliths, which were emplaced from the Cambrian units in the Early Ordovician Los Sombreros Formation (San Juan Precordillera) and Empozada Formation (Mendoza Precordillera). The Cambrian La Laja Formation sequences were deposited in a shallow carbonate platform in the eastern part of the Precordillera. The Cambrian carbonate rocks, which make up the olistoliths in the Los Sombreros and Empozada Formations, record deposition in the slope environments which developed in the western Precordillera. Cambrian Porifera and sponge-like chancelloriid assemblages are known mainly from fragments of skeletal nets, dissociated spicules and sclerites, which enable us to define two assemblages. The first assemblage of spicules was defined from the upper Lower to Middle Cambrian sequences of the La Laja Formation. This assemblage consists of a variety of stauractines and sclerites of *Chancelloria* WALCOTT. The family Protospongiidae is represented by triradiate prodianes, pentactines and hexactines, all belonging to *Kiwetinokia* WALCOTT. The second assemblage, which consists of isolated hexactines, pentactines, monaxons and skeletal nets, was defined in the Cambrian derived olistholiths of the Los Sombreros and Empozada Formations. Early hexactinellid Protospongiidae with body preservation (*Diagoniella* ? and *Kiwetinokia*) also occur. Demosponges have a very limited record in the Cambrian of the Precordillera. Anthaspidellid sponges had been reported from the La Laja Formation and now from the San Martín olistolith (Empozada Formation). The occurrences of these two assemblages of spicules and sclerites in both the Cambrian platform and slope facies of the Precordillera contribute additional data for a better understanding of the relationships between the eastern and the western facies assemblages, which developed in the Precordillera during the Cambrian. Therefore, they are useful for paleoenvironmental and paleogeographical interpretations of the Cambrian depositional framework.

KEYWORDS | **Sponge spicules. Chancelloriids. Cambrian. Precordillera. San Juan. Mendoza. Argentina.**

INTRODUCTION

Sponges are the most primitively organized among multicellular animals. In most sponges, specialized cells secrete a mineral skeleton, generally in the form of spicules. Sponges have been a highly successful group throughout the Phanerozoic, colonizing most marine and some fresh water environments. Siliceous sponges, archaeocyatha and stromatoporids, were primary reef builders even in the Early Cambrian (Wood, 1991).

The knowledge of the fossil record of siliceous sponges is based on complete, relatively rigid skeletons or on isolated spicules, which are studied in thin sections or recovered as insoluble residues from sedimentary rocks. However, most of the evidence of fossil sponges consists

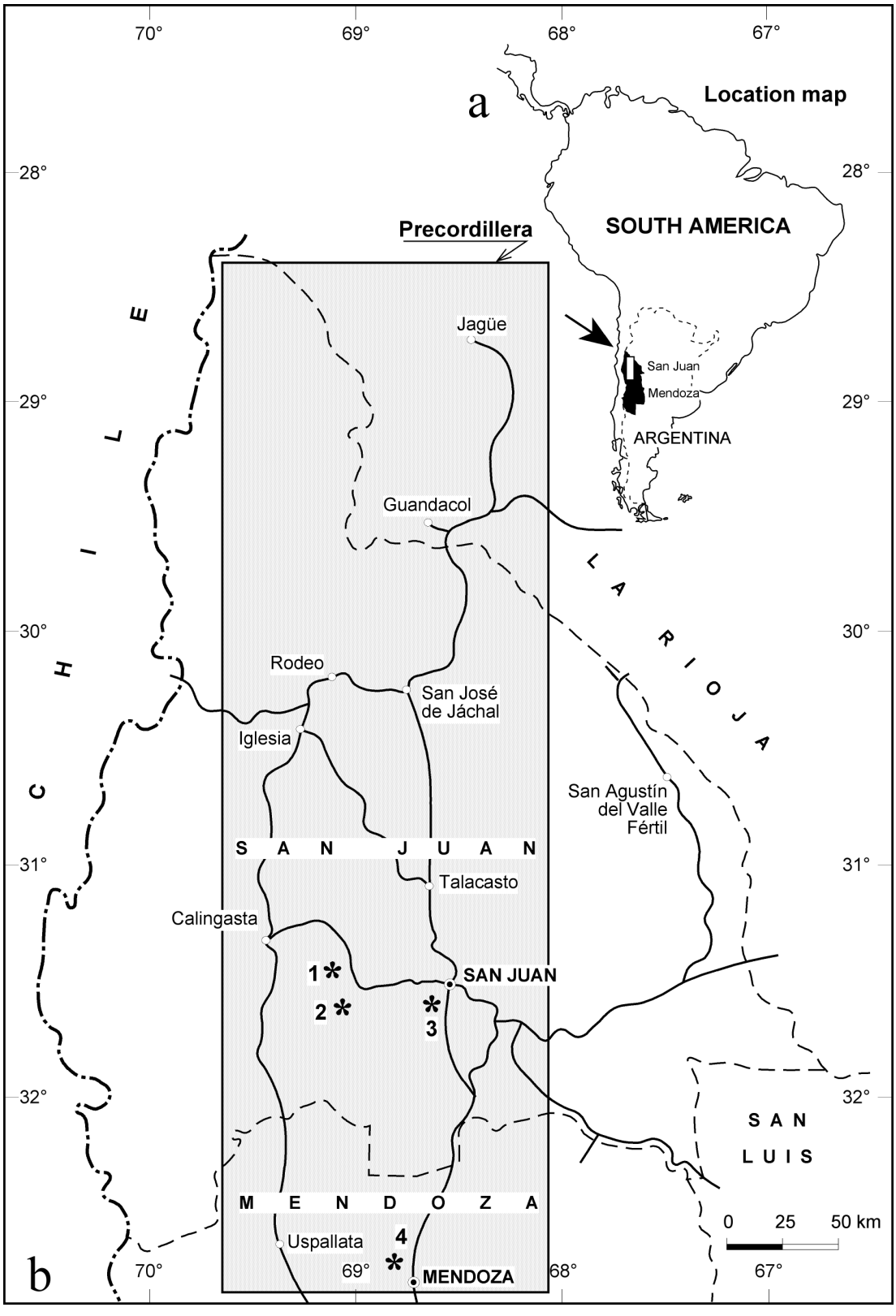

FIGURE 1 **Outcrop zones and fossil localities with Cambrian sponge spicules and chancelloriid sclerites in the Argentine Precordillera. a. Location of the provinces of San Juan and Mendoza within Argentina. b. Fossil sponge localities within the Precordillera region: Precordillera Occidental of San Juan: Outcrop zones 1 (Los Ratones Gulch) and 2 (Tres Saltos Gulch), both in the Tontal Range. Precordillera Oriental of San Juan: Outcrop zone 3, Las Lajas Gulch in the Chica de Zonda. Precordillera of Mendoza, outcrop zone 4 including Empozada Gulch, Agua de La Cruz Gulch and San Isidro Gulch, San Isidro region.**

TABLE 1 **Distribution of the sponge spicules and *Chancelloria* in the two fossil spicule assemblages of the Precordillera.**

Spicule assemblages in autochthonous sequences	**Spicule assemblages in allochthonous units**			
San Juan Precordillera		**Mendoza Precordillera**		
La Laja Formation	**Los Sombreros Formation**	**Empozada Formation**		
	Diagoniella ? *Kiwetinokia* sp. *Protospongia* sp. root tuft	hexactines stauractines	**La Cruz Olisto-lith**	**Late Cam-brian**
Stauractines of protospongiid-like structure Stauractines of diagoniellid-like structure *Kiwetinokia* sp. *Chancelloria eros* Anthaspidellidae hexactines monactines ? prodiaenes pentactines	*Protospongia* sp. hexactines stauractines prodianes pentactines	hexactines stauractines prodiaenes pentactines *Kiwetinokia uthaensis ?* *Chancelloria eros*	**San Martín Olisto-lith** **San Isidro Olisto-lith**	**Middle Cam-brian**
				Early Cam-brian

of isolated spicules. Most Cambrian siliceous sponges were composed of relatively simple spicules such as monaxons, stauractines, hexactines or pentactines.

The fossil record of Porifera in the Cambrian sequences of the Precordillera (western Argentina) consists mainly of disassociated spicules in carbonate rocks, whereas complete skeletons are very scarce. The aim of this paper is a taxonomic review of the sponge-spicule assemblages and sclerites of chancelloriids from the Middle and Upper Cambrian sequences in the Precordillera of San Juan and Mendoza Provinces. These data should be useful for the palaeoenvironmental and palaeogeographic interpretation of the Cambrian record in the study area.

PREVIOUS WORKS

Since the first report of *Chancelloria* and *Protospongia* from a Middle Cambrian olistolith of the Empozada Formation by Rusconi (1955), only a few publications have dealt with spicule assemblages collected from the Cambrian rocks of Argentina and in particular from Cambrian successions of the Precordillera.

The presence of *Protospongia* was cited by Pernas (1964) and then by Devizia (1973), from the San Isidro area in the Precordillera of Mendoza. Bordonaro and Martos (1985) described sclerites of *Chancelloria* WALCOTT, from autochthonous succesions of the La Laja Formation, Precordillera of San Juan. Also, Heredia et al. (1987) described hexactinellid spicules from the Upper Cambrian of the La Cruz olistolith (Empozada Formation) in the Precordillera of Mendoza. Farthermore, Beresi and Rigby (1994) described assemblages tentatively identified as *Kiwetinokia utahensis* WALCOTT, 1920, from latest Early Cambrian, and also spicules and chancelloriid sclerites from upper Lower and Middle Cambrian localities of the Precordillera of San Juan and Mendoza. Beresi and Heredia (1995) also described stauractines, hexactines and pentactines from the San Martín olistolith (Empozada Formation) in the Precordillera of Mendoza. Finally, Mehl and Lehnert (1997) described silicified

sponge spicule assemblages, which were recognised in the residues resulting from the search for conodonts in the Cambrian olistoliths of the Los Sombreros Formation.

GEOLOGICAL SETTING

The Cambrian rocks containing spicules are located in the Precordillera of San Juan and Mendoza provinces, western Argentina (Fig. 1 and Table 1). The depositional record of the Cambrian system in the eastern Precordillera consists of carbonate platform successions. These eastern successions graded laterally westward into facies assemblages which record the development of a continental slope (Bordonaro, 1985 and 1993, in this issue; Baldis and Bordonaro, 1982). Thus, major carbonate deposition on a carbonate platform-slope system took place in the Precordillera, during the Cambrian. Thick siliciclastic-dominated sequences (Los Sombreros y Empozada Formations), characterized the sedimentation in the slope environments during the Ordovician. Cambrian carbonate olistoliths are widespread in these Ordovician slope sequences (Figs. 1-3).

Cambrian Carbonate platform sequences

The La Laja Formation (Borrello, 1962) includes characteristic sections of the carbonate platform facies assemblages. This unit crops out at the south-western side of the Chica de Zonda Range in the Precordillera Oriental, (Fig. 1, Locality 3). The type section of the La Laja Formation is 700 m thick, and has been subdivided into three members (Fig. 2a) by Bordonaro (1980), who dated them as Middle Cambrian by means of trilobite assemblages.

Sponge spicules were collected from the early Middle Cambrian (*Plagiura–Poliella* Zone) limestones and argillaceous limestones of the Soldano Member (Fig. 2a). This member is characterized by thinly bedded, dark limy mudstones and yellowish grey fossiliferous packstones. The spicules are associated with inarticulate brachiopods, trilobites (*Kootenia*) and hyoliths such as *Hyolithes* sp., and *Saltarella* sp. (Bordonaro and Martos, l985). The La Laja sequence is characterized by the stacking up of thick limestone-sandstone cycles similar to those recorded in the Great Basin (south-western United States; Baldis and Bordonaro, 1982).

Cambrian continental slope facies (allochthonous units)

The Ordovician Los Sombreros Formation (Cuerda et al., 1983) characterizes the continental slope sedimentation which developed from the late Arenig to the Caradoc (Banchig and Bordonaro, 1994). This unit is up to 258 m thick and consists of carbonate and siliciclastic facies, including interbedded limy mudstones and shales, sandstones and conglomerates (Banchig et al., 1990). These slope deposits crop out mainly in the Tontal Range (Fig. 1, localities 1 and 2) in the Precordillera Occidental, to the west of San Juan city. The siliciclastic and carbonate sequence of the Los Sombreros Formation records several olistostromic events. The ancient Cambrian shelf margin collapsed during the Ordovician and the resulting calcareous blocks were gravitationally emplaced in association with muddy gravity flows. As a consequence, this Ordovician succession includes carbonate olistoliths derived from the Cambrian shallow, outer carbonate platforms and talus-slope sequences. The trilobite faunas indicate a Middle Cambrian (*Bathyuriscus-Elrathina* Zone) to Late Cambrian age (*Glyptagnostus reticulatus*; Bordonaro and Banchig, 1996) for these olistoliths.

The carbonate olistoliths have yielded a variety of Cambrian fossils, including sponge spicules. The spicules described in this paper were collected from the limy mudstones of one of the Cambrian olistoliths included in Los Sombreros Formation (Los Ratones Gulch locality; Fig. 1, locality l).

Sponge body fossils, with a preserved simple spicular morphology, were collected from olistoliths of the Los Sombreros Formation, which also yielded *Pseudagnostus* (Upper Cambrian s.l.). The external morphology and the choanosomal skeleton are moderately preserved. Isolated stauractines, anchoring and diagonally arranged spicules also occur in this locality.

The Empozada Formation (Harrington and Leanza, 1957) characterizes a Middle and Upper Ordovician mixed carbonate and siliciclastic slope sequence of the Precordillera in the Mendoza Province (Fig. 1, Locality 4). The Lower Member of the Empozada Formation is a Middle and Upper Ordovician olistostromic sequence, which crops out discontinuously in the southern end of the Precordillera. This Member consists of a 110 m thick succession of conglomerates, carbonate olistoliths, sandstones, matrix-supported conglomerates and black shales. The Ordovician paleontological record is mostly composed by graptolites, which characterize the *Paraglossograptus tentaculatus* Zone (Llanvirn), *Nemagraptus gracilis* Zone (Upper Llandeilo-Early Caradoc), *Climacograptus bicornis* Zone (Caradoc) and the *Dicellograptus complanatus* and *D. ornatus* Zones (Ashgill s.l.).

Cambrian spicule assemblages have also been reported from the La Cruz, San Isidro and San Martín olistoliths, which are embedded in the Lower Member of the Empozada Formation (San Isidro area, Precordillera of Mendoza; Fig. 1, locality 4 and Fig. 3). Sclerites of *Chancelloria* and other dissociated spicules occur in the Middle Cambrian (*Glossopleura* Zone) bioclastic wackestones found in the San Isidro olistoliths and in the dark mud-

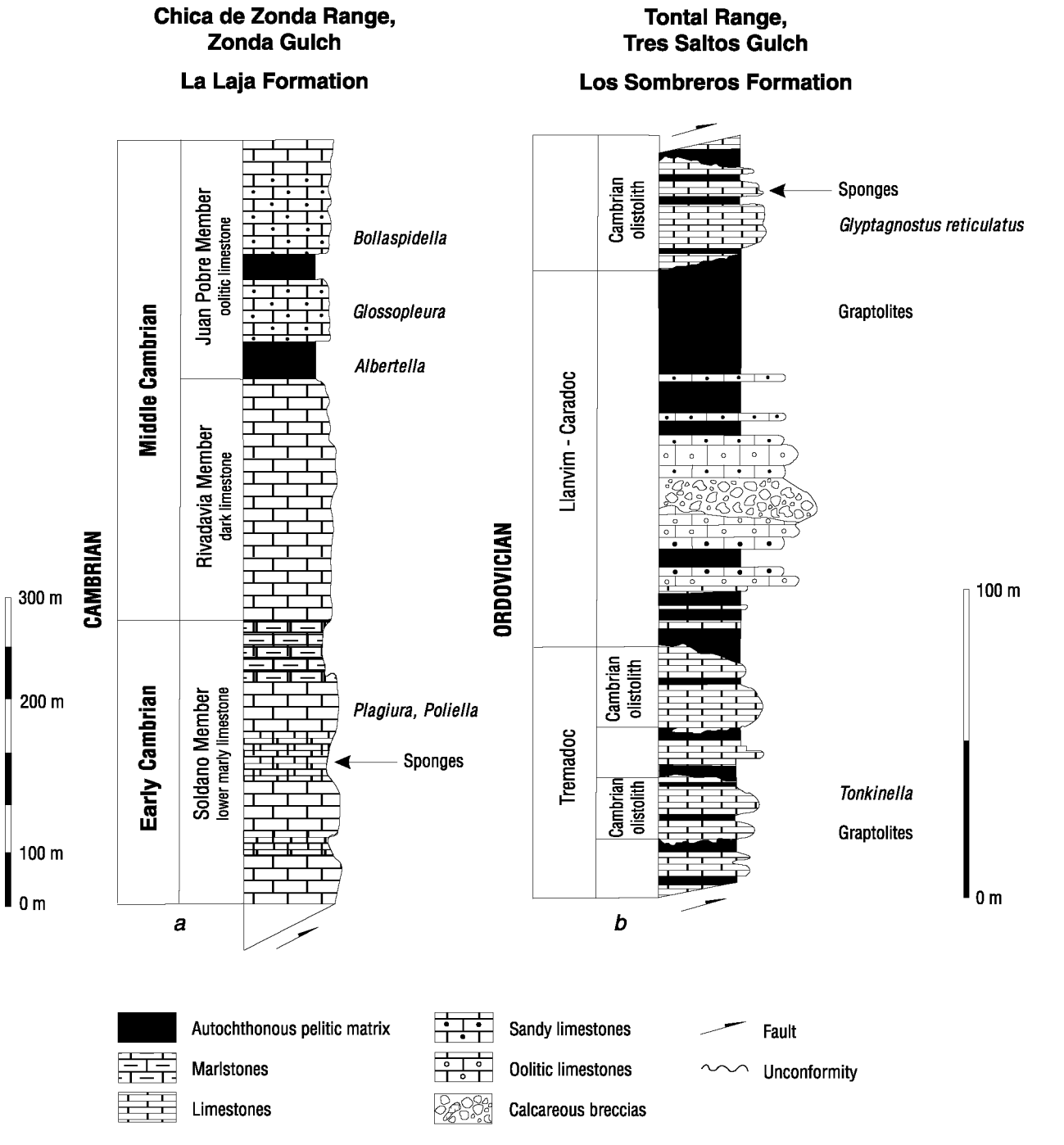

FIGURE 2 **Generalized stratigraphic sections of Cambrian sequences and Ordovician formations which include Cambrian derived carbonate olistoliths. These allochthonous units have yielded sponge spicules and *Chancelloria* sclerites. a. La Laja Formation, in the Chica de Zonda Range (Fig. 1, Locality 3). Sponge spicules and Chancelloriid sclerites occur mainly in the Soldano Member (from Beresi and Rigby, 1994). b. Los Sombreros Formation (Fig. 1, localities 1 and 2) in the Tontal Range. Sponge spicules occur in lower Middle and Upper Cambrian olistoliths emplaced in the successions of this Ordovician Formation (from Beresi and Banchig, 1997).**

stones which yielded late Middle Cambrian agnostids in the San Martín olistoliths. Finally, isolated Late Cambrian (*Proconodontus tenuiserratus* Zone) hexactines, pentactines and monaxons occur at the La Cruz olistolith.

LOCATION OF THE SAMPLES

Some of the sponge spicules were collected from the Middle Cambrian sequences that are exposed in the San

Juan Precordillera (Fig. 1 localities 1 to 3 and Fig. 2) and at one locality in the Mendoza Precordillera (Fig. 1 locality 4 and Fig. 3). The chancelloriid sclerites were collected from Lower Cambrian-Middle Cambrian rocks in the San Juan Precordillera (Fig. 1, locality 3 and Fig. 2a) and in the Mendoza Precordillera (Fig. 1, locality 4 and Fig. 3).

Late Cambrian fossils were collected from the Cambrian olistoliths included in the Los Sombreros Formation (Tres Saltos Gulch, Fig. 1 locality 2 and Fig. 2b) and in the Empozada Formation (La Cruz olistolith San Isidro area, Fig. 1 locality 4 and Fig. 3).

The samples of this fossil collection are deposited in the Unidad de Geología y Paleontología of the IANIGLA, CRICYT (Centro Regional de Investigaciones Cientificas y Técnicas), Mendoza, Argentina. All the fossil material is identified as CRICYT Z (Zonda Gulch collection), TS (Tres Saltos collection), SI (San Isidro coleection) and SM (San Martín collection).

SYSTEMATIC PALAEONTOLOGY

Phyllum: Porifera GRANT, 1836
Class: Demospongea SOLLAS, 1875
Family: Demospongiae SOLLAS, 1875

Genus and species indeterminate
Figures 4.1-4.3

A single rock sample (CRICYT Z-l), approximately 5 x 6 cm, includes nine small separate fragments. Because of the very fragmental nature and the moderately poor preservation of the fragments, it was impossible to identify these skeletal fragments beyond including them, with moderate certainty, into the family Anthaspidellidae (Beresi and Rigby, 1994). These are the only currently noted Cambrian anthaspidellids. Thus, these fragments of skeleton from the Middle Cambrian rocks of the Precordillera, in the province of San Juan, document a fourth occurrence, and the only one known thus far from South America.

Class: Hexactinellida SCHMIDT, 1870
Family: Protospongidae HINDE, 1887

GENUS ***Protospongia*** SALTER, 1864

***Protospongia* sp.**
Figure 5.5

Protospongia was first mentioned by Rusconi (1955) in the San Isidro area. Fragmentary fossils with regularly arranged quadrules of stauractines were assigned to *Protospongia* aff. *fenestrata* WALCOTT by Pernas (1964), from the Agua de la Cruz Gulch, San Isidro area. These fragments were referred to *Kiwetinokia* by Poulsen (1958). Devizia (1973) mentioned *Protospongia* from samples of the San Isidro olistolith, Mendoza Precordillera.

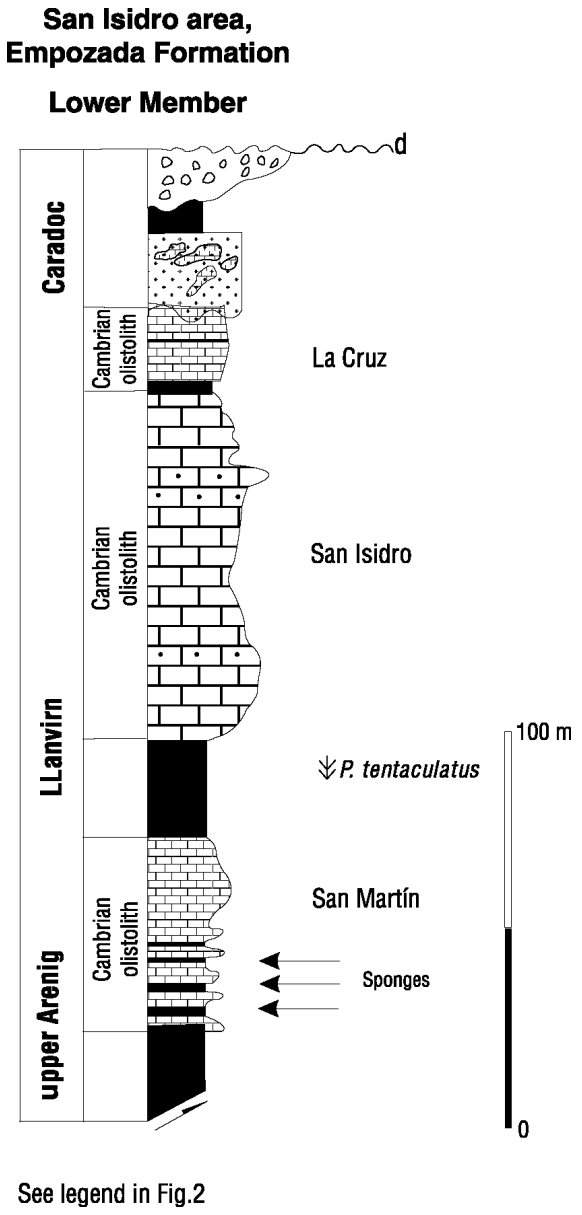

FIGURE 3 | **Stratigraphic section of the Ordovician Empozada Formation, in the San Isidro Gulch (Fig. 1, Locality 4); Sponge spicules occur in the San Martín olistoliths, which derived from Middle Cambrian successions and were emplaced in the Lower Member of the Empozada Formation (from Beresi and Heredia, 1995).**

Protosponge-like stauractines occur in several specimens from the Late Cambrian olistoliths included in the

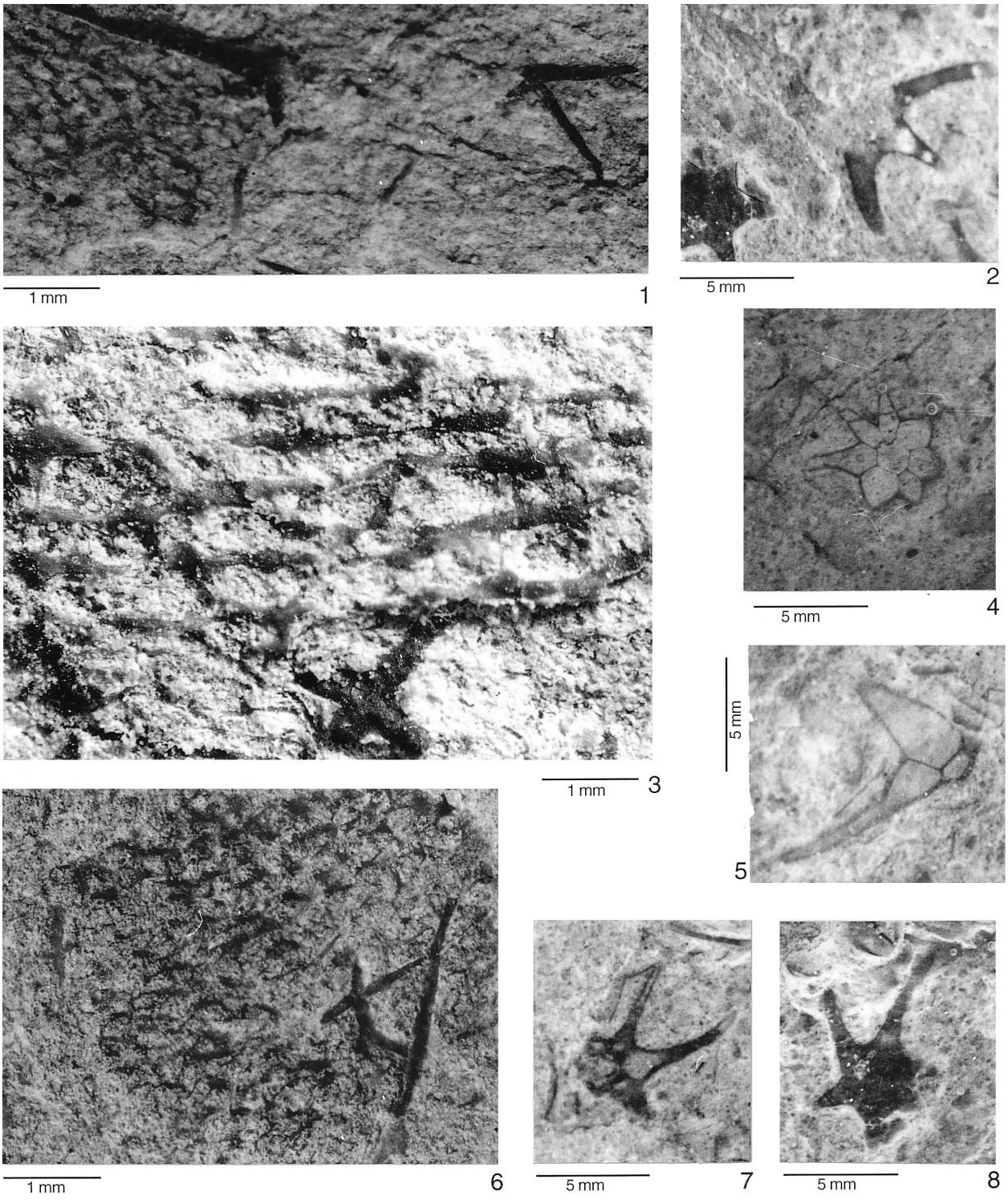

FIGURE 4 **Plate I: Anthaspidellid, genus and species indeterminate, hexactinellid sponge spicules and sclerites of the problematic *Chancelloria* from San Juan and Mendoza provinces. Anthaspidellid sponges. 1: small fragment. 3: long coarse trabs and dendroclones replaced in calcite, three-dimensional preservation; detail of articulation of dendroclones. 6: anthaspidellid fragment preserved somewhat diagonally. All from autochthonous assemblages of the Soldano Member, La Laja Formation, in the Zonda Gulch, Chica de Zonda Range, (Z-2). Regular hexactine fragments occur as associated spicules in 1, 3 and 6. *Chancelloria* sclerites. 2, 7 and 8: photomicrography of *Chancelloria* sclerites from San Isidro olistolith, Empozada Formation; ascending rays are commonly curved. 4 and 5: photomicrography of *Chancelloria eros* WALCOTT, 1920, sclerites, Middle Cambrian La Laja Formation, in the Zonda Gulch, Locality 3, Zonda Range (Z-3). Some sclerites preserve their prismatic central disk.**

Los Sombreros Formation, from the Tres Saltos Gulch, San Juan Precordillera. The largest specimen of one sponge (TS 1-a) from this locality occurs on a single bedding surface, which appears to be nearly complete. One border of the body is well preserved. Two small associated specimens (TS 2, TS 3) assigned to *Protospongia* sp. also occur from this locality (Beresi and Banchig, 1997).

Specimens with distinctly oriented stauractines, arranged in regular vertical-horizontal pattern have been described from the Middle Cambrian of the San Martín olistoliths of the Empozada Formation (Beresi and Heredia, 1995).

GENUS ***Diagoniella*** RAUFF, 1894

Diagoniella ? sp.
Figures 5.1 and 5.8

Isolated stauractines with rays not at mutual 90º angles, as in *Diagoniella*, are moderately common in the La Laja Formation and in Cambrian olistoliths of the Los Sombreros Formation, San Juan Province and in the San Isidro olistoliths of the Empozada Formation, Mendoza Province (Beresi and Rigby, 1994).

Two fragments with diagonally arranged, small scale, stauractine-based skeletal net occur in Cambrian olistoliths of the Los Sombreros Formation, Tres Saltos Gulch, at the Tontal Range (TS 4-a, TS 5). The diagonally arranged spicules may resemble stauractines, but proximal and distal rays are evident as central swellings at ray junctions of the hexactines. These fragments were assigned to the genus *Diagoniella* with some doubts (Beresi and Banchig, 1997).

GENUS ***Kiwetinokia*** WALCOTT, 1920

Kiwetinokia utahensis ? WALCOTT, 1920
Figures 5.4 and 5.7

Walcott (1920) proposed the genus *Kiwetinokia* to include an array of dissociated spicules, including triradiate prodiaenes, stauractines, hexactines, and more or less large monactine spicules. He noted that a small part of articulated skeletal net suggested that the intact and consistently oriented stauractines, as in *Protospongia*, may have been part of the original skeletal mesh. These spicules are associated with the variety of Y-shaped prodiaenes that seem to be a distinctive part of the assemblage.

Numerous slabs showing a mass of intermingled stauractine, triactine, and monactine spicules, of the Class Hexactinellida, were described from the Precordillera of San Juan and Mendoza. A variety of these disassociated spicules occur on shale fragments from the San Martin and San Isidro Middle Cambrian olistholiths, Empozada Formation in the San Isidro and Agua de la Cruz Gulchs, both from the San Isidro area in the Precordillera, Mendoza Province. In the San Juan Province, they also occur in the La Laja Formation, Sierra Chica de Zonda, Precordillera Oriental (Z-2), and also in the Cambrian olistoliths included in the Los Sombreros Formation, in the northern part of the Tontal Range, Precordillera Occidental.

As the material from San Juan has the same array of spicules, except for the twisted rods, Beresi and Rigby (1994) have included the Cambrian material from San Juan in the genus *Kiwetinokia*, and with some question in the species *K. utahensis* WALCOTT, 1920. In general, dimensions of spicules in the material from San Juan fall within the ranges of spicules described as distinctive of *Kiwetinokia utahensis* WALCOTT, 1920.

Beresi and Banchig (1997) described a large specimen from an Upper Cambrian olistolith, (Los Sombreros Formation in the Tres Saltos Gulch), with a variety of disassociated spicules, referring to it as the genus *Kiwetinokia* sp. from an Upper Cambrian olistolith, Los Sombreros Formation in the Tres Saltos Gulch.

Stauractines
Figures 4.9 and 4.11

Stauractine are moderately common spicules in the allochthonous assemblages in the San Martín (Beresi and Heredia, 1995) and the La Cruz (Heredia et al., 1987) olistoliths of the Empozada Formation and in the Los Sombreros Formation (Mehl and Lenhert, 1997). These spicules have four rays usually at mutual right angles, without proximal-distal rays; rays are smooth, subcylindrical in the proximal part, but taper distally to sharp pointed tips. They are present in several sponge orders.

Hexactines
Figure 4.10

Hexactinellid spicules occur in samples from the Los Sombreros Formation (Locality 1) and from Locality 3 in the La Laja Formation, from San Juan Province (Beresi and Rigby, 1994). Hexactines also occur in samples from the La Cruz Upper Cambrian olistolith and the San Martín Upper Middle Cambrian olistolith in the Empozada Formation, San Isidro area (Heredia et al., 1987; Beresi and Heredia, 1995). Most spicules have remnants of six rays preserved.

Pentactines

Pentactines are somewhat less common, occurring in nearly all hand samples from autochthonous assemblages of the La Laja Formation, San Juan Province (Beresi and Rigby, 1994) and from allochthonous assemblages of the

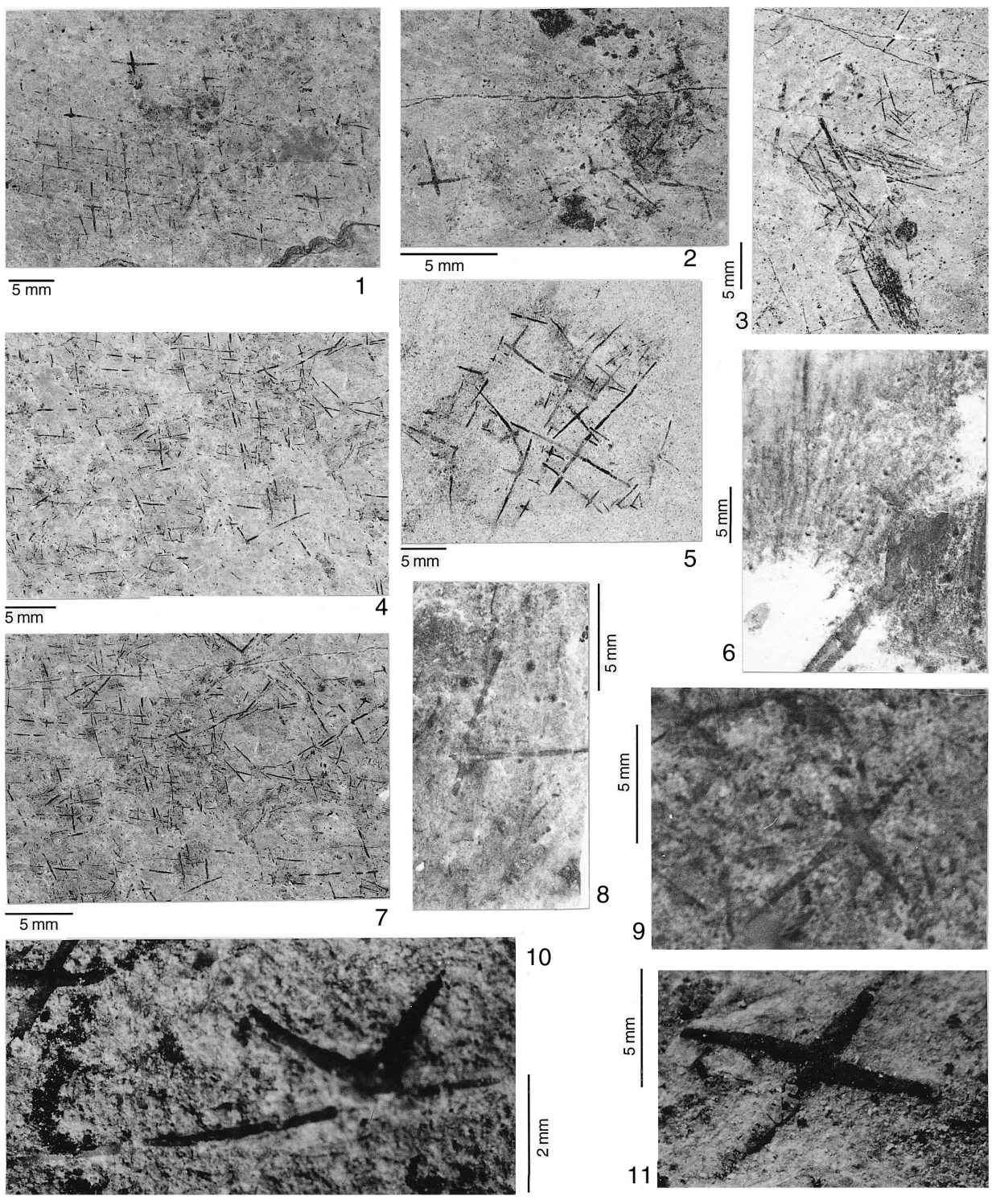

FIGURE 5 | ***Diagoniella?*** **sp. (TS 4-a) Tres Saltos Gulch, Los Sombreros Formation. 2: Associated stauractine and hexactine spicules occurring on a single surface (TS 5); root tufts, Tres Saltos Gulch, Los Sombreros Formation, Precordillera Occidental of San Juan. 3: Root tuft (TS 2-b). Large monaxons or monactine-like spicules in bundle with small stauracts or hexacts (TS 2-b), 6: root tuft spicules associated with hexactines between tracts (TS 3-c), 4 and 7: *Kiwetinokia utahensis?* WALCOTT, 1920, spicules occur as an irregular strew in spiculitic shaly limestone, La Laja Formation, Chica de Zonda Range (Z 2), 5: *Protospongia* sp. showing reticulated quadrules of the stauractine-based skeleton and long rayed hexactines forming marginal spines along the left margin (TS 1-a) Tres Saltos Gulch, Los Sombreros Formation. 6: Root tuft spicules associated with hexactines between tracts (TS 3-c), Tres Saltos Gulch, Los Sombreros Formation, Precordillera Occidental of San Juan, 8: *Diagoniella ?* sp. hexactine (TS 3-a), 9 and 11: stauractines from the San Martín Olistolith, Empozada Formation, San Isidro area (SM 2), 10: hexactine with four rays preserved from San Isidro olistolith, Empozada Formation (SI 3).**

San Martín olistolith, Mendoza Province (Beresi and Heredia, 1995).

Monactine-like spicules

Numerous long ray fragments are the coarsest spicules in the fossil assemblage from La Laja Formation. These spicules may be oxeas, or perhaps only long bits of prodiaenes or pentactines, with no certain evidence of tapering to proximal points in either direction. The coarsest rays range from 9 to 12 mm long, and are 0.18 mm in diameter at generally slightly expanded mid-lengths (Beresi and Rigby, 1994).

Root tuft
Figures 5.3 and 5.6

The only Cambrian root tufts were found in samples from the Upper Cambrian, Los Sombreros Formation, in the Tres Saltos Gulch (TS 2-b, TS 3-c), San Juan Precordillera (Beresi and Banchig, 1997).

Two bundled spicules are the most prominent skeletal features of this assemblage. The root spicules are broken at both ends, thus it cannot be determined whether the spicules are diactines or monoactines. In addition to the long spicules, smaller triaxons, hexactines, stauractines, and anchoring spicules are associated with the variety of Y-shaped prodiaenes. These spicules are scattered over and outside the tuft, and it is not certain that they really belong to the sponge.

The figured specimen (TS 3-c; Figure 5.6) is a root tuft with coarse and fine radiating coronal spicules that extend out some distance from the margin of the central disk.

Chancelloriid Sclerites

Phylum uncertain: Chancelloriids
Family: Chancelloriidae WALCOTT, 1920

GENUS ***Chancelloria*** WALCOTT, 1920

Chancelloria eros WALCOTT, 1920
Figures 4.2, 4.4-4.5 and 4.7-4.8

Walcott (1920) was the first to describe chancelloriid skeletons and sclerites or skeletal elements from the Middle Cambrian Burgess Shale of British Columbia, Canada. He originally included *Chancelloria* within the Porifera. Rigby and Nitecki (1975) and Rigby (1978) included the Chancelloriidae within the heteractinid calcareous sponges. Bengtson and Missarzhevsky (1981) pointed out that the sclerites were secreted as mineralized sheaths over organic precursors, in a structure not known in sponges. Consequently, they concluded that the sclerites were not spicules like those in living sponges but belonging to the Coeloscleritophora, a major group of enigmatic metazoans. Rigby (1986) in his redescription of the Burgess Shale sponges, also concluded that the chancelloriids were not likely of sponge origin. Bengtson (1990) described the family Chancelloriidae as coeloscleritophorans, with armour consisting of spiny sclerites.

Numerous isolated sclerites were collected from the San Isidro area (Rusconi, 1955) and from the La Laja Formation, Precordillera of San Juan (Bordonaro and Martos, 1985; Beresi and Rigby, 1994). They generally consist of a well-defined central disk and six radiating tangential or marginal/lateral rays, generally in a plane; but some have only rays; some sclerites are dissociated so individual rays or central disks may be isolated. Central disks range from circular to distinctly hexagonal prismatic; the upper surfaces of these disks appears to have been bulbous, but this surface has been removed on most sclerites by erosion. One vertical ray margined by two gently curved ascending rays is the most commonly preserved rays within sclerites. The preservation is largely incomplete because sclerites appear embedded in matrix and opposite rays are largely removed by erosion.

PALEOECOLOGICAL IMPLICATIONS

In terms of ecology, the early hexactinellids in the Cambrian seem to have inhabited a variety of low-energy, relatively deep-water settings with soft bottoms. Quiet conditions may have been necessary because of their delicate construction. Cambrian siliceous sponges became fairly widespread in quiet waters, in offshore marine environments in China, Australia, Siberia and North and South America.

The Precordillera spicule fauna bears some similarities to other assemblages from Laurentia. Nevertheless, spicules from the Calcareous Heteractinida are poorly represented, presumably because the Precordillera fauna lived in a deeper water setting.

The spicules of the Precordillera are disorganized but concentrated in thin layers and without mixing with other bioclasts, indicating that, although derived from many disintegrated sponge skeletons, they underwent minimal transport. Petrographical observation of the limestone facies indicates that only some of the spicules retain their primary silica mineralogy. Most of them occur as calcite cement-filled moulds because the tendency of opaline silica to dissolve in seawater and during early burial diagenesis. Calcification of the spicules can be related to a local rise of the pH in the decayed sponge.

In the two fossil assemblages from the Precordillera, the genera *Protospongia, Kiwetinokia, Diagoniella* and *Chancelloria*, are moderately common and occur on bedding planes of the lime-wackestones. The samples do not show monospecific sponge assemblages.

Major spicules resemble stauractines, but closer scrutiny shows proximal and distal rays as small central swellings in the ray junctions of the hexactines. Nodes represent rudimentary or atrophied proximal-distal rays, but well developed paratangential rays give rise to stauractine-like appearance of spicules, according to Mehl et al. (1993). These spicules were transported and buried in carbonate periplatform deposits by slow currents.

The sponge associations studied can be interpreted as remains of a single community that grew on low-energy, stable marly to silty sea floor and under normal marine salinity. The presence of anchoring spicules suggests that some of the sponges were attached to the substrate with these specialized spicules and root tufts. Thus, they probably lived in moderately quiet though occasionally turbulent environments. They had stalks to keep them well above the sediment. Other sponges had not root tufts.

CONCLUDING REMARKS

Two of the three early Palaeozoic classes of sponges occur in the Cambrian faunas from western Argentina.

Fossil spicules are widespread in the upper Lower, Middle and Upper Cambrian sequences of the Precordillera, a fact that evidences the abundance of siliceous sponges. The record of siliceous fossil sponges known from the Precordillera, is mainly based on disarticulated spicules and scattered, poorly preserved, body fossils of early hexactinellids.

Two major spicule assemblages which correspond to carbonate platform and slope environments have been distinguished The sponge remains occur in depositional facies which record platform, peri-platform and slope environments.

Most spicules in the assemblages studied are stauractines of protospongiid-like or diagoniellid-like structure. They document the abundance of early hexactinellid sponges in the platform margins of the Precordillera. These spicules were transported and buried in carbonate peri-platform deposits by slow currents. The sponge associations can be interpreted as remains of low diversity communities that grew under low-energy conditions, stable marly to silty sea floor and normal marine salinity.

Hexactinellida with developed thin walls composed by irregularly oriented spicules (*Kiwetinokia*) or with primitive rectangular skeletal pattern (*Protospongia* and *Diagoniella*) are the most common in the assemblages recorded in the Cambrian olistoliths emplaced in the Ordovician slope sequences.

Sclerites of chancelloriids are found in both carbonate platform and slope assemblages. The preservation of most specimens suggests that they were gently transported and buried not far from their living places, probably in a continental shelf margin (peri-platform environment).

ACKNOWLEDGMENTS

I gratefully acknowledge Dr. J.K Rigby, Dr. García Bellido and Dr. Lluís Cabrera for their critical comments, which have improved this paper.

REFERENCES

Banchig, A.L., Bordonaro, O.L., 1994. Reinterpretación de la Formación Los Sombreros: secuencia olistostrómica de talud, Precordillera Argentina. Actas V Reunión de Sedimentología, La Plata, 2, 283-288.

Banchig, A.L., Keller, M., Milana, J., 1990. Brechas calcáreas de la Formación Los Sombreros, Quebrada Ojos de Agua, sierra del Tontal. Actas XI Congreso Geológico Argentino, San Juan, 2, 149-152.

Baldis, B.A., Bordonaro, O.L., 1982. Comparación entre el Cámbrico de la Great Basin Norteamericana y la Precordillera de San Juan, Argentina. Su implicancia Continental. Anales V Congreso Latinoamericano de Geología, Colombia, 1, 97-108.

Bengston, S., 1990. Chancelloriids. In: Bengston, S., Conway Morris, S., Cooper, B.J., Jell, P.A., Runnegar, B.N. (eds.). Early Cambrian fossils from South Australia. Association of Australasian Palaeontologists, Mem. 9, 45-69.

Bengston, S., Missarzhevski, V.V., 1981. Coeloscleritophora -a major group of enigmatic Cambrian Metazoans. U.S. Geological Survey, Open-file report 81-743, 19-21.

Beresi, M.S., Banchig, A.L., 1997. First hexactinellid spicules of the Late Cambrian Olistolith, of the Los Sombreros Formation, Tontal Range, San Juan Precordillera, Argentina. Revista Española de Paleontología, 12(2), 141-150.

Beresi, M.S., Heredia, S.E., 1995. Asociación de espículas de poríferos cámbricos de la Formación Empozada, Precordillera de Mendoza. Ameghiniana, 32(4), 401-405.

Beresi, M.S., Rigby, J.K., 1994. Sponges and Chancelloriids from the Cambrian of Western Argentina. Journal of Paleontology, 68(2), 208-217.

Bordonaro, O.L., 1980. El Cámbrico en la Quebrada de Zonda,

Provincia de San Juan. Revista Asociación Geológica Argentina, 35, 26-40.

Bordonaro, O.L., 1985. El Cámbrico de San Isidro, Mendoza, en facies de borde externo y talud de la plataforma calcárea de Precordillera. Primeras Jornadas de Geología de Precordillera, San Juan, 1,6-7.

Bordonaro, O.L., Banchig, A.L., 1996. Estratigrafía de los olistolitos cámbricos de la Precordillera Argentina. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V, 471-479.

Bordonaro, O.L., Martos, L., 1985. El género Chancelloria en el Cámbrico de San Juan. Reunión de Comunicaciones Paleontológicas, Asociación Paleontológica Argentina, San Juan, 6-7.

Borrello, A.V., 1962. Caliza La Laja (Cámbrico medio de San Juan). Notas Comité Investigación Científica, Buenos Aires, La Plata, 2, 3-8.

Cuerda, A.J., Cingolani, C., Varela, R., 1983. La graptofauna de la Formación Los Sombreros, Ordovícico inferior de la vertiente oriental de la sierra del Tontal. Ameghiniana, 20(3-4), 234-260.

Devizia, C., 1973. Estudio geológico del sector de San Isidro, Departamento Las Heras Mendoza .Tesis doctoral inédita. Museo de La Plata 319, 88 pp.

Harrington, H., Leanza, A.F., 1957. Ordovician trilobites of Argentina. University of Kansas, Department of Geology Special Publication, 1, 1-259.

Hinde, G.J., 1887-1888. A monograph of the British Fossil sponges. Palaeontographical Society of London, 1-92 (1887), 93-188 (1988).

Heredia, S.E., Bordonaro, O.L., Matteoda, E., 1987. Espículas de Poríferos de la Formación La Cruz, Cámbrico superior, Departamento de Las Heras, provincia de Mendoza. Ameghiniana 24(1-2), 17-20.

Mehl, D., Lehnert, O., 1997. Cambro-Ordovician sponge spicule assemblages in the Ordovician of the Argentine Precordillera and paleoenvironmental ties. Neues Jhrbuch für Geologie und Paläontologie, Abhandlungen, 204, 221-246.

Mehl, D., Rigby, J.K., Holmes, S., 1993. Hexactinellid sponges from the Silurian-Devonian Roberts Mountains Formation in Nevada and hypotheses of hexactines-stauractine origin. Brigham Young University, Geology Studies, 39, 101-124.

Pernas, R.D., 1964. El género Protospongia en el Cámbrico de Mendoza. Miscelánea 1, Consejo Investigaciones Científicas, La Plata, 3-4.

Poulsen, V., 1958. Contribution to the Middle Cambrian palaeontology and stratigraphy of Argentina. Matematisk, Fysiske Meddelsser DanskeVidenskabernes Selskab, Copenhaguen, 31 (8).

Rigby, J.K., 1978. Porifera of Middle Cambrian Wheeler Shale from the Wheeler Amphitheatre, House Range, in western Utah. Journal of Paleontology, 52, 1325-1345.

Rigby, J.K., 1986. Sponges of the Burgess shale (Middle Cambrian), British Columbia. Palaeontographica Canada, 2, 105 pp.

Rigby, J.K., Nitecki, M.H., 1975. An unusually well preserved heteractinid sponges from the Pennsylvanian of Illinois and a possible classification and evolutionary scheme for the Heteractinida. Journal of Paleontology, 49, 329-339.

Rusconi, C., 1955. Fósiles Cámbricos y Ordovícicos al oeste de San Isidro, Mendoza. Revista del Museo de Historia Natural de Mendoza, 8(1-4), 3-64.

Schmidt, O., 1870. Grundzuge einer Spongien-fauna des altantischen Gebeites. Leipzig, 88 pp.

Sollas, W.J., 1887. Sponges. In Encyclopaedia Britannica, 9th edition, London, 451 pp.

Walcott, C.D., 1920. Middle Cambrian Spongiae. Smithsonian Miscellaneous Collections, 67, 261-364.

Wood, R.A., 1991. Problematic reef-building sponges. In: Simonetta, A.M., Conway Morris, S. (eds.). The early evolution of Metazoan and the significance of problematic taxa. Cambridge, England, Cambridge University Press, 113-124.

Manuscript received October 2001;
revision accepted June 2002.