SPONGE SPICULE ASSEMBLAGES FROM THE MIDDLE ORDOVICIAN OF PONÓN TREHUÉ, SOUTHERN MENDOZA, ARGENTINA

Matilde S. BERESI[1] and Susana E. HEREDIA[2]

[1] IANIGLA, CRICYT; A. Ruiz Leal s/n; 5500 Mendoza, Argentina,
e-mail: mberesi@lab.cricyt.edu.ar, fax: 54-261-428-5940
[2] Museo Universidad Nacional del Comahue; Buenos Aires 1400; 8300 Neuquén, Argentina, e-mail: sheredia@uncoma.edu.ar

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ABSTRACT

Sponge spicule assemblages are described from residues of conodont samples from Ordovician strata in the Sierra Pintada, southern Mendoza Province, Argentina. Spicules have been recovered from the Arenigian allochthonous megaconglomerates and from autochthonous limestones and carbonates sandstones of the Ponón Trehué Formation. This formation is a clastic-carbonate sequence representing olistostromic and turbidite facies. Conodonts in this formation are Llandeillan in age. The spicules are calcified and moderately preserved. The material shows a low diversity. Poriferan taxa found in this formation include heteractinid spicules as well as hexactinellid hexactines and non-lithistid demospongiid triaene and oxeas with some doubt. Associations of exclusively heteractinid spicules are restricted to allochthonous blocks of the shallow carbonate platform of the San Juan Formation (Arenig). In the outer platform and slope, autochthonous calcarenites and dark limestones contain hexactine spicules. These spicules evidence the existence of sponges in the Ordovician of the Ponón Trehué area, as a part of the Precordillera terrane.

Keywords: Ordovician, sponge spicules, San Rafael, Mendoza, Argentina.

RESUMEN

Se describe una asociación de espículas de esponjas obtenidas de muestras de residuos para conodontos de sedimentitas ordovícicas aflorantes en la Sierra Pintada, al sur de la provincia de Mendoza, Argentina. Las espículas han sido recuperadas de bloques alóctonos de calizas de edad arenigiense y de calizas y areniscas calcáreas autóctonas de la Formación Ponón Trehué. Esta formación ha sido interpretada como una secuencia clástica-carbonática de talud que representa facies olistostrómica y turbidítica. De acuerdo con la asociación de conodontos la edad de esta formación corresponde al Llanvirniense superior (Llandeiliense). Los taxones incluyen Heteractinidae (Calcárea) Demospongidae (no lithístida) y Hexactinellidae. Las espículas están calcificadas y en general bien conservadas. La asociación medianamente diversificada incluye octactinas como formas predominantes, sexirradiadas, triactinas, hexactinas y oxeas con alguna duda. Las espículas calcáreas están restringidas a los bloques alóctonos provenientes de la plataforma somera inframareal de la Formación San Juan (Arenigiense). Las calizas y areniscas calcáreas autóctonas de la Formación Ponón Trehué, contienen espículas hexactinas. Las espículas descriptas evidencian la existencia de esponjas calcáreas desarrolladas en ambiente de plataforma somera y de esponjas hexactinéllidas de ambiente de plataforma externa y talud, que habitaron los mares del Ordovícico del área de Ponón Trehué, como parte del terrane de Precordillera.

Palabras clave: Ordovícico, espículas de poríferos, San Rafael, Mendoza, Argentina.

INTRODUCTION

Sponges are the most primitively organized of multicellular animals. In most sponges, specialized cells secrete a mineral skeleton, generally in the form of spicules. It is this skeleton, as a whole or as isolated spicules, which becomes fossilized and which provides the basis for the classification of fossil sponges. Isolated

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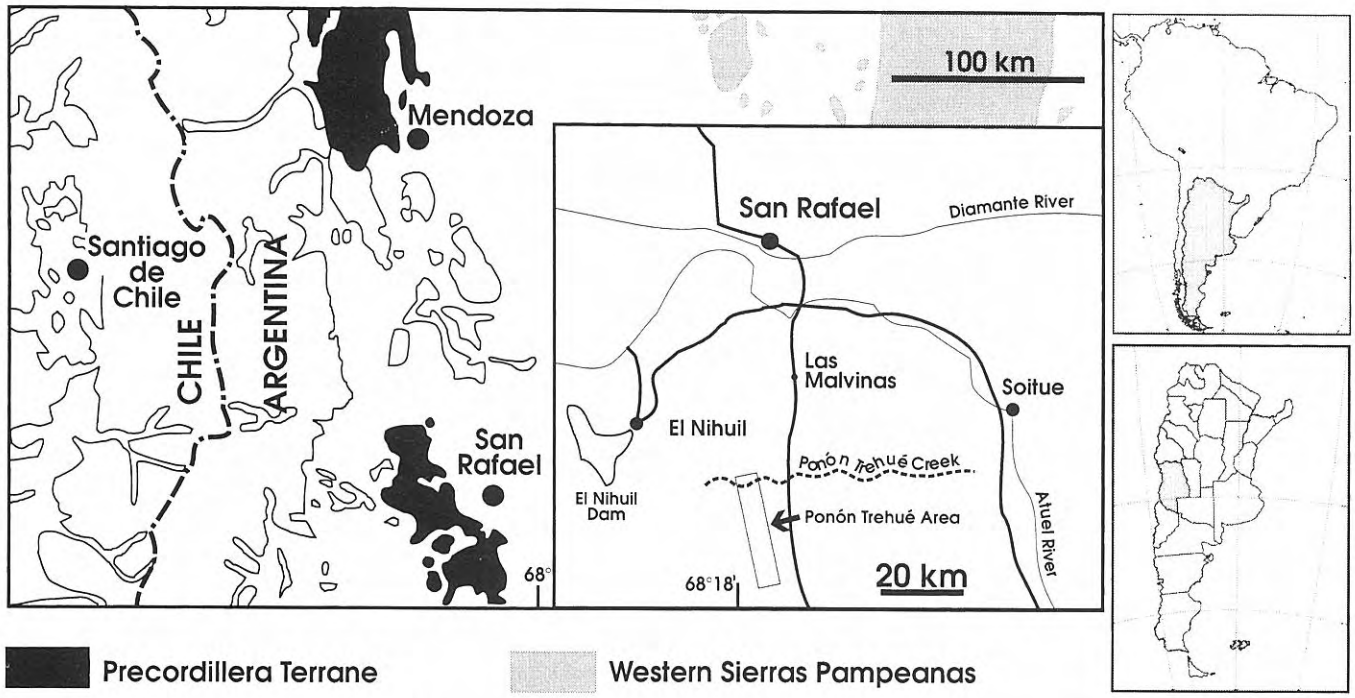


Figura 1. Location of the Ponón Trehué locality in the Sierra Pintada, southern Mendoza Province, Argentina.

sponge spicules were recovered from dilute (5%) acetic-acid residues of conodonts of clear gray limestones and black argillaceous limestones of the Ponón Trehué Formation, Sierra Pintada, southern Mendoza Province, Argentina. The studied spicule assemblages were collected from two stratigraphic levels. The oldest level corresponds to Arenigian allochthonous megaconglomerates of the *Oepikodus evae* Zone on Ponón Trehué Creek. The other level corresponds to the one from Llanvirnian autochthonous limestones and carbonate sandstones with conodont associations belonging to the *Pygodus serra* Zone (*Eoplacognathus foliaceous, reclinatus* and *robustus* subzones) and the *P. anserinus* Zone (Heredia, 1982; 1996; 1998) of the La Tortuga section to the south of Ponón Trehué Creek.

Preservation in the assemblages is, in general, very good; the calcareous skeletal elements consist of microgranular spar. The samples with *O. evae* are found in clear shallow-water bioclastic wackestones of megablocks. Bioclasts are brachiopods, ostracods and trilobites. The Llanvirnian samples are wackestone-packstone of very fine to fine grain with common crinoids, brachiopods, ostracods and bryozoans. The purpose of this study is to document, for the first time, the recovered spicule assemblage from the allochthonous and autochthonous carbonates, in the Middle Ordovician slope succession of the La Cantera and La Tortuga sections, Ponón Trehué Formation, southern Mendoza Province, western Argentina.

STRATIGRAPHY

The isolated Ordovician outcrops of Ponón Trehué, Sierra Pintada, south of San Rafael in the province of Mendoza (Argentina) represent the only record of clastic-carbonate successions in a cratonic setting in the Argentine Precordillera (Fig. 1). These platform carbonates from a terrane of the Precordillera (Cuyania terrane by Ramos, 1995) are unique in South America. The exotic origin of the Precordillera is now accepted, although the timing of accretion and the geotectonic models remain controversial. Recent research (Dalla Salda *et al.*, 1992; Astini *et al.*, 1995; Dalziel *et al.*, 1996) suggests an origin from the Ouchita embayment at the southern margin of Laurentia. The Precordillera terrane extends in outcrop from 29° S up to 33° S latitude; the outcrops appear again, at the surface, at 35° 00' S, 68° 20' W, around Sierra Pintada. In Sierra Pintada, outcrops of Lower Paleozoic rocks, whose lowest sedimentary facies are represented by the Ponón Trehué Formation (Llandeilo), suggest turbidite facies (Heredia, 1996).

The area of Sierra Pintada is characterized by outcrops that contain Grenvillian granitic basement (Bordonaro *et al.*, 1996), Ordovician and Carboniferous sediments, and Tertiary basalt rocks. The crystalline basement is composed of siliciclastic metasediments, gneisses and granitoids. The contact between the Precambrian and the Ordovician sequence is an erosional unconformity (Criado Roqué and Ibañez, 1979; Heredia, 1996). The Ordovician beds have been called the Ponón Trehué Formation (Criado Roqué and Ibañez, 1979), or Lindero Formation (Nuñez, 1979). Bordonaro *et al.* (1996) and Lehnert *et al.* (1998) attempted a reorganization defining two formal units: the Ponón Trehué Formation (Late Tremadoc through Late Arenig) and the Lindero Formation (Llanvirn-Llandeilo). The sequence of limestones that these authors recognize as the Ponón Trehué Formation has been interpreted as Lower

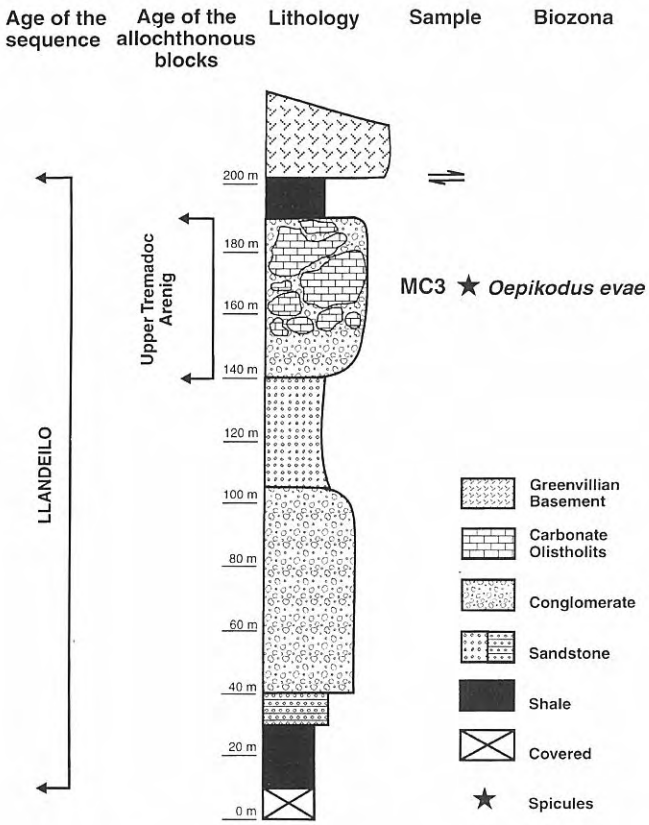


Figura 2. Stratigraphic column for the La Cantera section, Ponón Trehué Formation (Llandeilo) exposed on Ponón Trehué Creek. Position of the spicules in the allochthonous carbonate blocks are indicated by an asterisk.

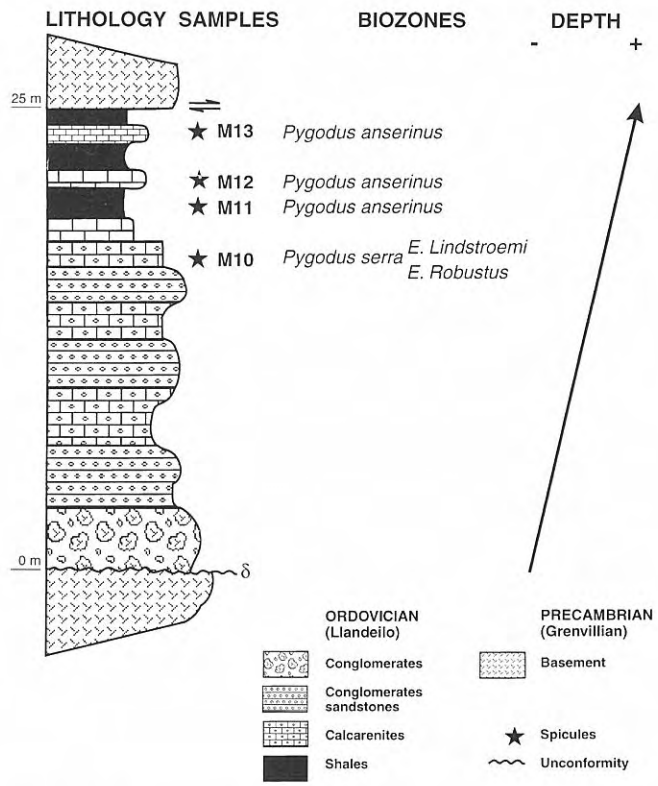


Figura 3. Stratigraphic column for the La Tortuga section, Ponón Trehué Formation (Llandeilo) exposed along the south of the Ponón Trehué Creek, where the fossil spicules were recovered. Positions of the spicules are indicated by an asterisk.

Ordovician olistoliths inside an olistostromic matrix (Heredia, 1996), deposited during the Llandeilo.

Although these Ordovician outcrops have recently been defined in two formal units (Bordonaro *et al.*, 1996; Lehnert *et al.*, 1998), in this contribution we use the old classical nomenclature of Ponón Trehué Formation (*sensu* Criado Roqué and Ibañez, 1979) that includes the outcrops to the north as well as to the south of Ponón Trehué Creek (Fig. 1). This clastic-carbonate sequence represents two different environments. The first environment is represented in the northern sector of the Ponón Trehué Creek and on the Ponón Trehué Creek (Fig. 1). Here, there is an olistostromic sequence composed of allochthonous megablocks of light-gray limestones originated in the Ordovician carbonate platform of the Precordillera. This olistostromic sequence has 80 m of maximum thickness (Fig. 2). These platform carbonates correspond to the San Juan Formation deposited during the uppermost Tremadoc to Lower Llanvirn. This formation widely extended in the Precordillera contains a rich and diverse benthic fauna. It represents an open shallow subtidal environment and location within the photic zone (Beresi, 1992). The second environment is found to the south of the Ponón Trehué Creek, where there is an outcrop of the La Tortuga section, (Fig. 3). This is composed of autochthonous sandstones, conglomerates, limestones and black shales, representing a turbidite sequence (Heredia, 1996; 1998). These turbidite deposits, containing *P. serra* and *P. anserinus* conodont associations, suggest the Lower Llandeilo as the time of deposition of the carbonate blocks derived from the platform toward the slope.

The Ponón Trehué Formation is discontinuously exposed in Sierra Pintada, Southern Mendoza Province. This area is structurally complex, and a continuous section, La Tortuga, was measured (Heredia, 1996) from the Upper Llanvirn to Llandeilo for the conodont-bearing strata. On top of metamorphic rocks (Criado Roqué and Ibáñez, 1979) of Grenvillian age and covering an erosion surface, an Ordovician normally-graded siliciclastic-carbonate succession has been deposited. With a total thickness of 25 m, this succession appears truncated by faults at the top (Fig. 3). Different strata are present in this section, including conglomerates, sandstones and green shales, megaconglomerates with gray limestone blocks and conglomerates, sandstones, calcareous sandstones, thin limestones and black shales. The last deposit association contains a fossil community that is composed of trilobites, brachiopods, crinoids, ostracods, conodonts and sponge spicules. The basal units of this sequence contain a mixture of conodonts that indicate a Late Tremadoc to Late Arenig age (Lehnert *et al.*, 1998).

Samples	Section	Conodont/Zone	Spicule type	Age
MC 3	P. Trehué Creek	*Oepikodus evae*	sexiradiates triactines	Arenig
MC 4	P. Trehué Creek	*O. evae*	monaxons triactines sexiradiates	Arenig
MT 9	La Tortuga	*Pygodus serra*	octactines	Lower Llanvirn
MT 10	La Tortuga	*P. anserinus*	octactines monaxons	Late Llanvirn
MT 11	La Tortuga	*P. anserinus*	triactines monaxons	Late Llanvirn
MT 12	La Tortuga	*P. anserinus*	octactines triactines hexactines	Late Llanvirn
MT 13	La Tortuga	*P. anserinus*	hexactines octactines	Late Llanvirn

Table 1. Details for each sample, including spicule type.

SPONGE SPICULE ASSEMBLAGES

A variety of sponge spicules were recovered from acetic-acid residues (Plates I, II and III). The assemblage of isolated spicules is mostly represented by octactine-based spicules, triactine-based spicules, monaxons forms and minor hexactines. Spicules are only moderately preserved and are not ornamented. The material shows a low diversity. The material in this publication is stored in the collections of IANIGLA of CRICYT (Centro Regional de Investigaciones Científicas y Técnicas), CONICET, Mendoza, Argentina (numbers IANIGLA-PI 901-923).

Two Ordovician spicule assemblages have been studied: (I) Arenigian Assemblage (*O. evae* Zone) which has sexiradiates, monaxons with canals, and triactines; and (II) Llandeilian Assemblage (*P. serra* and *P. anserinus* zones) which has octactines, hexactines, and triactines.

Spicule types from each sample of the fossiliferous localities and the conodont zones are shown in Tab. 1. Types of carbonates and the depositional paleoenvironment representing them, for the two-spicule assemblages shown in Tab. 2. Total percentage of the spicule types in the two assemblages are shown in Tab. 3.

SYSTEMATIC PALEONTOLOGY

PHYLUM PORIFERA Grant, 1872
CLASS CALCAREA Bowerbank, 1864
ORDER HETERACTINIDA De Laubenfels, 1955
Family **Eiffeliidae** Rigby, 1986

Diagnosis

Octactinellids with sexiradiate spicules and without a secondary basal skeleton. The six spicule rays all radiate in one plane from a flattened central plate. Normally, the six rays are approximately the same length. No central rays present.

Stratigraphic distribution: Early Cambrian to Early Carboniferous (Rigby, 1983).

Plate I. Spicules recovered from acid-etched residues of the Ponón Trehué Formation, Sierra Pintada, San Rafael, Mendoza. Scale bar 0.1 mm.

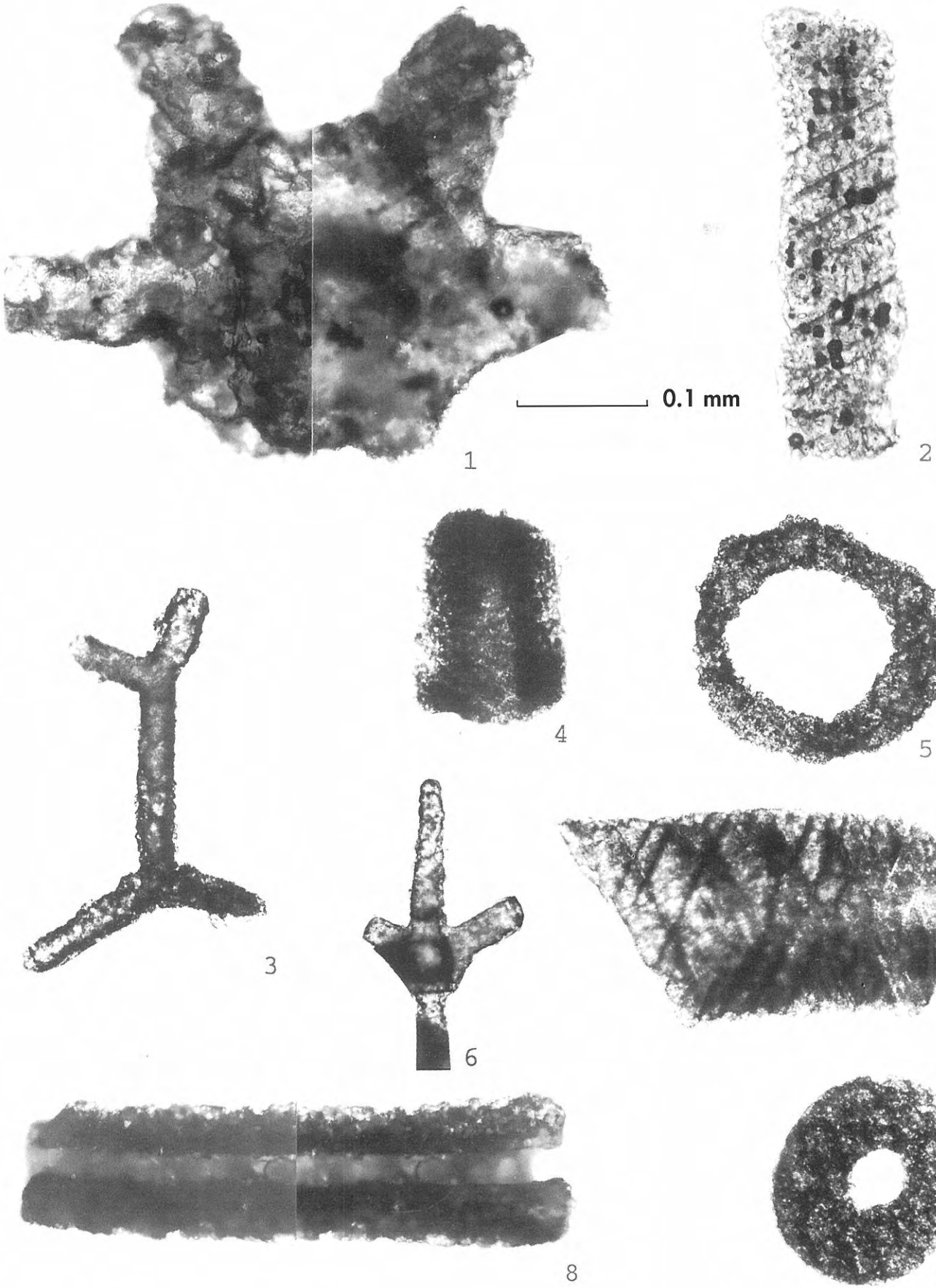
1 Sexiradiate spicule. The proximal-distal vertical ray shows as a prominent node.

2,4,5,7-9. Monaxon spicules. 5,9 Transversal sections of monaxon spicules with central canal. 4,8. Longitudinal sections show the axial circular canal. 2,7. These spicules appear to have been sheared diagonally by diagenetic processes.

3 Calcarean triactine.

6 Octactine spicule shows the distal ray and two of the tangential rays broken.

Plate I



Assemblages	Type of carbonate	Depositional Paleoenvironment
I Arenig	Clear, nodular, fossiliferous wackestone-packstone	Carbonate megablocks of olistostromic slope
II Late Llanvirn	Dark thin bedded bioclastic packstone	Turbidite slope sequences

Table 2. Paleoenvironments and types of carbonates of each assemblage.

Spicule types	Total Percentile in the two Assemblages
octactines	57
triactines	25
oxeas (?)	11
hexactines	7

Table 3. Percentile of different spicule types in the assemblages.

Sexiradiate spicules, incertae sedis
Plate I, fig. 1; Plate II, figs. 1-2

Description

The spicules are planar spicules with six tangential rays uniformly spaced radiating from a common center. The six rays of each spicule occur in a plane and are separated by approximately 60 degrees. Normally, the six rays are approximately the same length. Spicules are not ornamented and are without proximal and distal rays. These rays radiate uniformly as straight structures from the central disc, then they taper uniformly.

Rays are fragmented and their length varies from 1.6 to 1.8 mm, with basal ray diameters from 0.10 to 0.20 mm. The central discs are approximately 0.2 to 0.4 mm in diameter.

Remarks

The sexiradiate spicules (octactinellid type) of this assemblage, are very similar to those of the family Eiffeliidae, which ranges from the Early Cambrian to the Early Carboniferous (Rigby, 1983). According to Johns (1994), this family represents the first lineage of the three evolutionary trends of the Heteractinida. The Eiffelidae are known from the Ordovician San Juan Formation (Carrera, 1994 a, b).

Mehl and Lehnert (1997) described sexiradiate spicules as belonging to *Eiffelia* sp., found in some localities of the Arenigian autochthonous platform of the San Juan Formation, Precordillera. This assemblage is related to reef-mound horizons and biostromes with sponges, stromatoporids, receptaculitids and some autotrophic organisms. However, we believe that they were not derived from *Eiffelia* as pointed out by the mentioned authors. *Eiffelia* is exclusively a Middle Cambrian genus, only known from the Middle Cambrian Burgess Shale (Walcott, 1920: 329-331) and it is not possible to find it in an Ordovician autochthonous carbonate platform.

The occurrences of distinctive *Eiffelia*-like spicules in the San Juan Formation platform were most probably derived from some Ordovician genus of Eiffeliidae. Possibly, they could have been derived from *Chilcaia bimuralis* (Family Eiffeliidae, Carrera, 1994 a: 216) which are octactinellids with sexiradiate spicules without proximal or distal rays. Our sexiradiate spicules are very similar to the second-order spicules described for *Chilcaia bimuralis* in the Las Tunas section, which is time-equivalent to the *E. suecicus* conodont Zone. The occurrences of distinctive *Eiffelia*-like spicules indicate their provenance from the platform of the San Juan Formation.

Family **Astraeospongiidae** Miller, 1889

Diagnosis

Heteractinid sponges characterized by relatively large polyactine calcite spicules having six evenly spaced rays approximately in the same plane and two generally short rays normal to this plane, the latter reduced to a mere lump in some spicules.

Stratigraphic distribution: Early Cambrian to Early Carboniferous (Rigby, 1983).

Octactine spicules, incertae sedis
Plate I, fig. 6; Plate III, figs. 1,2,6,7

Description

The octactine spicules have a prominent central knob corresponding to the broken distal-proximal rays. These small nodes are 0.08 to 0.15 mm in diameter. Some octactines show prominent nodes because of the replacement. The spicules are robust and unsutured, initially

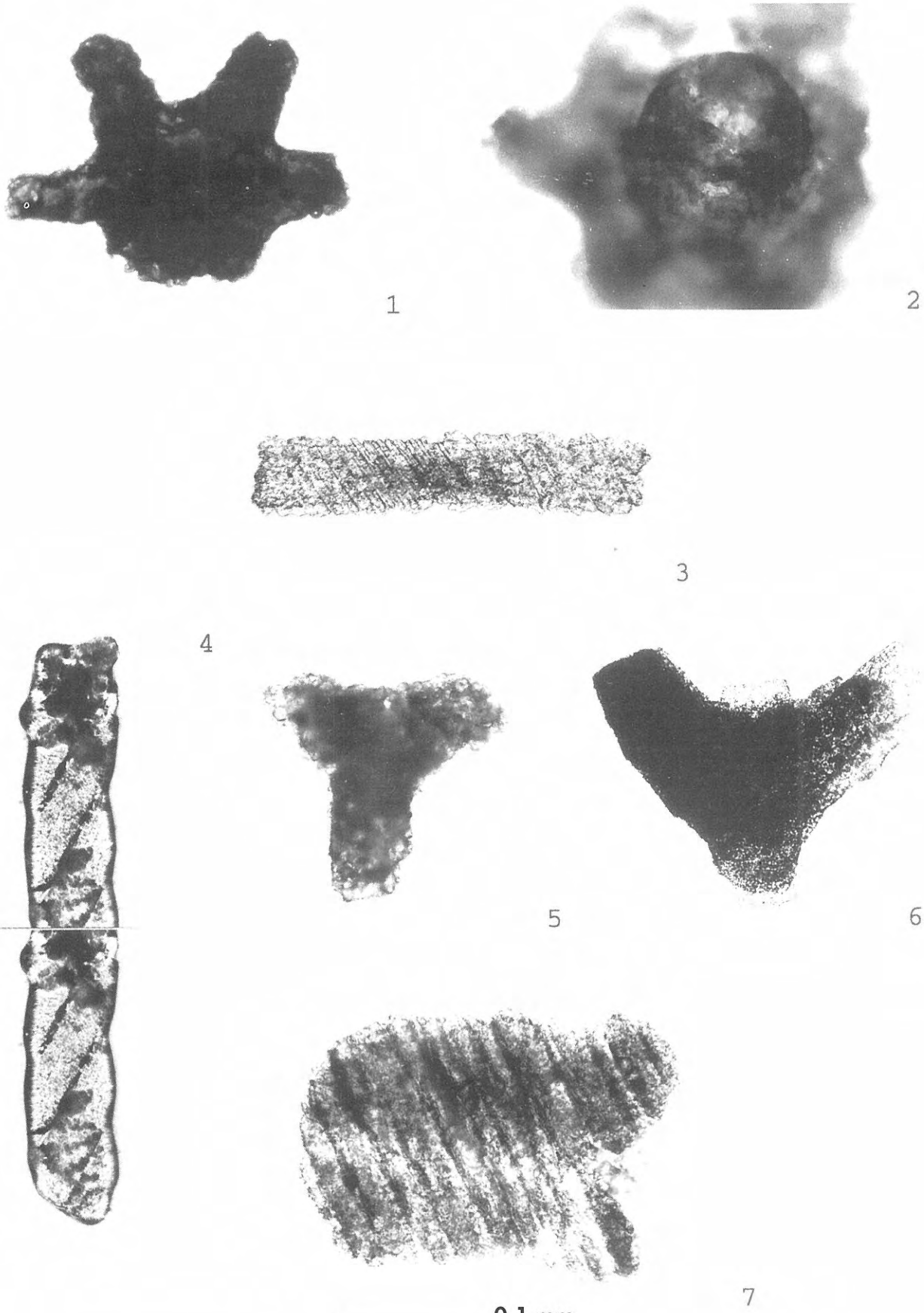
Plate II. Photomicrographs showing spicules from the Ponón Trehué Formation. Scale bar 0.1 mm.

1, 2 Sexiradiate spicules with vertical ray aborted and shorter horizontal tangential rays. 2. The proximal-distal ray showing as a low node, in the central part of the disc.

3,4,7 Monaxon spicules sheared diagonally by diagenetic processes.

5-6 Calcarean triactines. 5. Fragment of a simple triactine. 6. *Anatriaene*, particular triactine spicule with tangential rays curved.

Plate II



calcium carbonate, with individual tangential rays up to 1 mm long or longer and with basal ray diameters of 0.15 to 0.10 mm. Most of the spicules have horizontal ray lengths of 0.6 to 0.8 mm. These rays radiate uniformly from the central disc that is 0.3 to 0.4 mm in diameter. Spicules are not ornamented.

Remarks

These octactines spicules are common in the family Astraeospongiidae (Rigby and Nitecki, 1975: 338) with basically the same octactinellid based skeleton. Octactines were found by Mehl and Lehnert (*op. cit.*) within and in-between the upper reef mound horizons of the Los Potrerillos section (*A. variabilis* Zone), San Juan Precordillera. Spicules somewhat similar to the octactine-based spicules described here were described and illustrated by Rigby and Toomey (1978, Text-fig. 3) from organic buildups in the Lower Ordovician of southern Oklahoma. The association studied is also similar to the assemblage found in organic buildups present in the El Paso Group of the Franklin Mountains, West Texas (Toomey, 1970).

Triactine spicules, incertae sedis

Plate I, fig. 3; Plate II, figs. 5-6

Description

The basic spicule is a simple triactine in which three rays diverge from one another, generally not in the same plane but oriented approximately 120 degrees apart. Lateral rays diverge as cylindrical units to where the lower rays diverge, and then taper moderately uniformly. A particular spicule of the assemblage could be an *Anatriaene* where two tangential rays curve downward symmetrically with respect to a third straight perpendicular ray. Some intermediate-sized triactines show overgrowth at the outer surface.

Remarks

Some of these triactines may be fragments of the peculiar spicules called dodecaactines, which are the basis of the genus *Dodecaactinella* Reif, 1968; others are simple triactine spicules. There is only one spicule that definitely looks like triactine, but it could be an anchor-like ending of a triaene, in particularly an *Anatriaene*. This spicule has two tangential rays that are gently curved; however, it is possible that there is another curved ray that is broken. Some spicules are moderately common as anchoring spicules in a lot of the early lithistid sponges or they may occur as armoring superficial spicules in some of the thick-walled forms (Rigby, personal communication, 1998).

CLASS HEXACTINELLIDA Schmidt, 1870

Diagnosis

Porifera with siliceous triaxial spicules, originally hexactines, always with central canals. The three axes are perpendicular to each other.

Stratigraphic distribution: Late Proterozoic (Steiner *et al.*, 1993; Gehling and Rigby, 1996) to Recent.

Hexactinellida spicules, incertae sedis

Plate III, figs. 4, 5

Description

Spicules are normal hexactines in which the three axes meet at mutual right angles. The hexactines are the only hexactinellid spicules found in the assemblage of the Ponón Trehué Formation. Rays appear to be smooth and tapering, but details of the fine skeleton are lost because of replacement. These spicules are not common in the assemblage.

Remarks

Samples from the top of the Llandeilian assemblage of Sierra Pintada occur together with the conodont faunas of the *Pygodus anserinus* community (Heredia, 1996). Hexactinellid spicules occur in slope deposits of Empozada Formation (Llanvirn) from San Isidro area, Mendoza Precordillera (Beresi and Heredia, 1994) and of Las Aguaditas Formation (Llanvirn-Caradoc) from the northern part of the San Juan Precordillera (Mehl and Lehnert, 1997). These spicules also occur in the San Juan Formation in the Pachaco section (Gnoli and Serpagli, 1980) and the Tambolar section (Mehl and Lehnert, 1997), both in the San Juan Precordillera.

? Demospongian oxeas

Plate I, figs. 2, 4, 5, 7-9; Plate II, figs. 3, 4, 7; Plate III, fig. 3

Description

Some fragments appear like monaxial oxeas, with a single axis. They range from relatively small to medium forms. In all such spicules, the fine pointed ends are broken away. The spicules are straight, but complete ones were not observed. Thus, they may be monactine or diactine. In transverse section, the spicules are conspicuous as clear circular rings. The spicules are preserved as multicrystalline calcite. Scanning electron microscope (SEM) examination shows diagenetic pits that occur frequently. The particular characteristic of these spicules is the large axial canal that is circular in cross section. Other spicules of this assemblage

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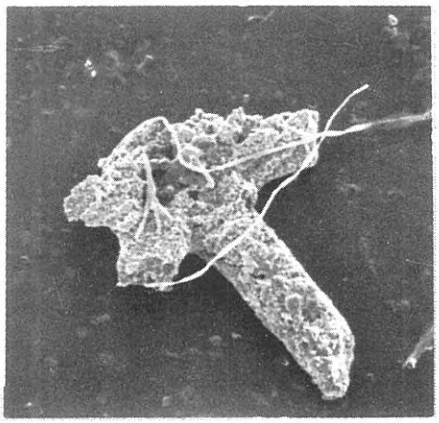
Plate III. Scanning electron microscope (SEM) photomicrographs with scale bars of 1,4,6,7: 1.0 mm; 2,3,5: 0.1mm.

1,2,6,7 Octactine spicules showing general characteristics. The proximal-distal vertical rays and some rays are broken. 1. Fragmentary spicule of octactinellid type.

3 Monaxon spicule shows the central circular canal.

4-5 Hexactine spicules.

Plate III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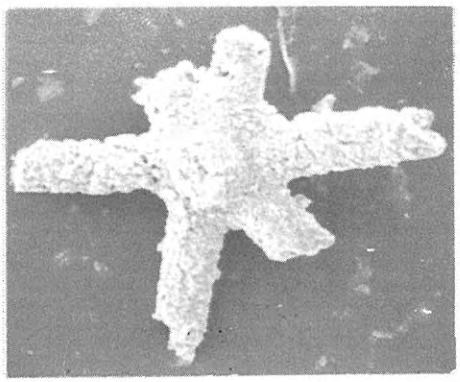
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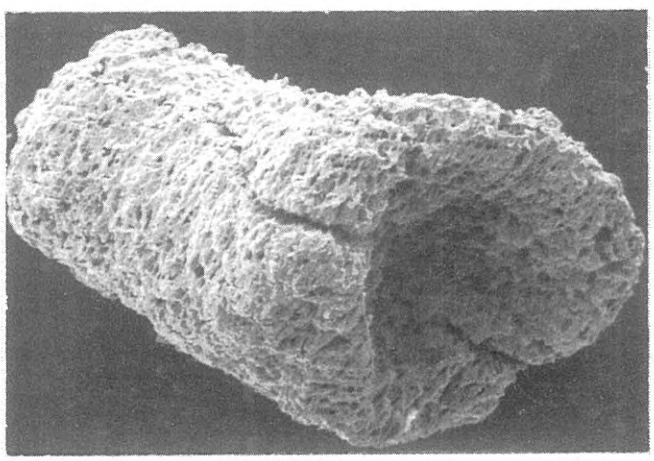
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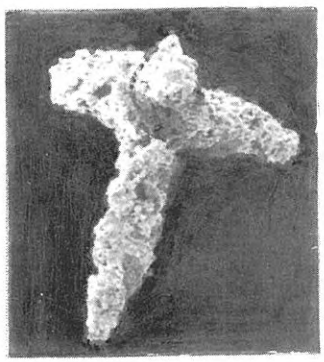
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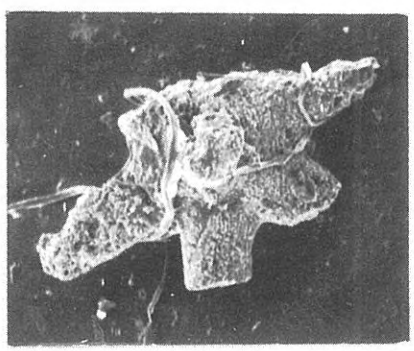
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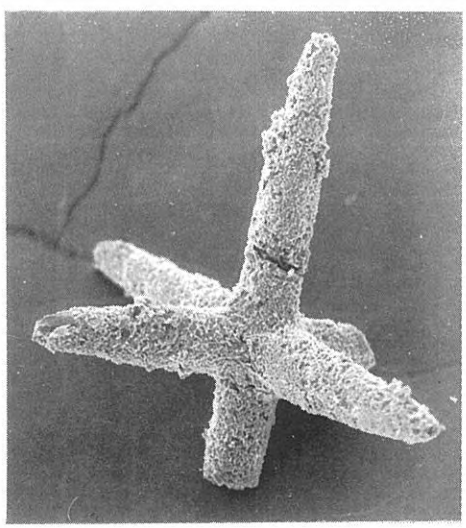
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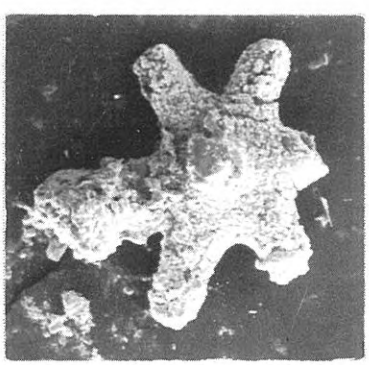
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appear to have been sheared diagonally by diagenetic processes (Rigby, personal communication, 1998). Some of these spicules could be parts of others spicules from the collection.

Remarks

Spicules in this assemblage that were determined to be oxeas (?) were not found in other localities of the Precordillera. As they are only fragments, their disassociated occurrence does not allow us to characterize them in terms of family or genus. If the spicules were initially calcareous, they would lack an axial or crepidal canal in the rays. Calcareous spicules generally have solid rays. Opaline siliceous spicules are generally deposited around an organic fiber, commonly evident in well-preserved spicules as an axial or crepidal canal along ray axes. Therefore, spicules in this assemblage were originally siliceous demosponge spicules. The axial canal observed is circular in cross section, as opposed to square as normally found in hexactinellid sponges

PALEOECOLOGY AND CORRELATION

Sponges have colonized most marine environments throughout the Phanerozoic. Reduced sedimentation rates are a precondition for the establishment of sponge communities. Generally, slow burial and/or rapid destruction leads to isolated spicules (West, 1995). Recrystallization, replacement, or both, will not only alter the original mineralogy, but also modify or destroy the original microstructures. Compression, distortion, or both will through compaction by overlying sediments alter the original morphology.

The Heteractinida are known only from the Paleozoic and have skeletons composed of large octactines or octactine-based spicules and three-rayed spicules. This group occurs in sediments that accumulated in shallow, vigorous, clean high-energy water. None are reef producers, although they may occur in marginal reef flank facies. All heteractinid sponges appear to have been marine forms and the relatively deeper or quieter marine environments seem to have been the habitats in which these particular sponges thrived.

Development of the nomenclature of this small group has been somewhat complex. The Heteractinida as a group, are common in marly or argillaceous rocks of moderately quiet water facies and never found in depositional environments of turbulent or highly agitated water (Rigby, 1983). In the composition of the Middle Ordovician spicule fauna of the Ponón Trehue Formation, the Heteractinida are indicated by the presence of sexiradiate and octactine spicules. In most spicules, only small nodes represent proximal rays. These are remnants of what must have been rays that were broken and removed by erosion prior to burial of the fragments (Rigby *et al.*, 1979).

The calcarean triactine spicule is a constituent feature of the Calcarea (Mehl and Reitner; 1995; Reitner and Mehl, 1995) and thus does not allow any further systematic attribution within this taxon (Mehl and Lehnert, 1997). Rigby and Toomey (1978) suggest that such triactine spicules were originally calcareous.

The skeletons of the oldest Hexactinellida are comprised of unfused spicules. The hexactine spicules are generally restricted to a deeper or an open marine environments in the record of the Cambrian-Ordovician strata of the Precordillera. Their occurrence could be controlled by depth or by one or more factors commonly correlated with depth, such as temperature, oxygen level, clear water or turbulence. The hexactinellids of the Ponón Trehué Formation occur together with conodont faunas of the *Pygodus-Periodon*-community, typified by a deeper slope environment around Laurentia.

CONCLUSIONS

The complete absence of desma types of the Lithistida in the assemblages is striking. This fact was pointed out by Mehl and Lehnert (1997). This is especially notable due to the fact that the entirely preserved sponge fossils that are found in the bedded limestones and bioherms of the Early Ordovician, San Juan Formation, are mainly desma-bearing demosponges of the Group Orchocladina (Beresi and Rigby, 1993). This could indicate that not all of the facies of this extensive carbonate platform of the Precordillera were destroyed, and that parts of the platform were redeposited as allochthonous blocks in the Ordovician slope sequences of the western Precordillera.

The Octactinellidae (Heteractinida) spicules of the Ponón Tréhué Formation are the most abundant type of spicules of the assemblages, although complete body sponges have not been found at present. The presence of Eiffeliidae spicules in allochthonous blocks confirms the existence of these sponges in the San Juan Formation and their provenance. They occurred in a shallow subtidal carbonate platform environment that developed far away from the slope where they were redeposited.

The record of Early Paleozoic hexactine spicule associations in the Precordillera shows a presence predominately in Cambrian carbonate blocks deposited in different Ordovician olistostromic successions (*e.g.*, Los Sombreros and Empozada Formations); however, these hexactine spicules are scarce in the San Juan Formation. They are also found in autochthonous sediments at the top of the La Tortuga section and are Llandeilian in age. These limestones yield hexactine spicules that represent outer platform and periplatform environments.

The spicule associations described in this paper represent the first notice of this most austral Ordovician section in the context of the Argentine Precordillera.

"Both fused and unfused skeletal elements may be of importance to the micropaleontologist, but it is principally with disassociated, disarticulated spicules that micropaleontologists can probably make great contributions most easily because it is that record which has been investigated least in fossil sponges" (Rigby, 1983).

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