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Hexactinellid Sponges from the Lower Tremadocian Volcancito Formation, Famatina Range, Northwestern Argentina

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ABSTRACT

Examples of reticulated skeletal net of hexactinellid *Protospongia* species, the first reported from the region, occur on bedding planes in black siliceous siltstone in the upper part of the Lower Tremadocian Volcancito Formation in the Famatina Range of northwestern Argentina. Only fragments of the nets are preserved, so specific identification is impossible. They are associated with a second species known only from a few isolated spicules in a probably coarser quadruled net fragment. Small problematic spindle-shaped isolated microspinose impressions also occur in one of the siliceous fragments, where dissociated hexactine spicules are also preserved. These lowermost Ordovician protosponges further document the relatively primitive hexactinellid assemblages which apparently thrived along the black-shale margins of Paleozoic continents.

INTRODUCTION

The sponge record in Lower Paleozoic rocks of Argentina is not well documented. Sponges are mostly represented by dissociated spicules in Cambrian and Ordovician rocks of the Precordillera region. Beresi (1985) described demosponges found in living positions within micritic units in the San Juan Formation (Arenig), at three different localities in San Juan Province. Heredia, et al., (1987) described coarse-rayed hexactinellid spicules from the Upper Cambrian La Cruz Formation of the San Isidro area, Mendoza Province. New records of Demospongea and Hexactinellida from the San Juan Formation were subsequently reported by Beresi (1990), who made a paleoecologic study using the new sponges and those of Beresi (1985). A more detailed description of Cambrian sponges from the Precordillera was provided by Beresi and Rigby (1994), who analyzed the anthaspidellid lithistid and hexactinellid spicule assemblages, which were assigned with question to *Kiwetinokia utahensis*? Walcott, 1920. Beresi and Heredia (1995) described spicule assemblages from the Cambrian San Martín olistoliths included in the Lower Member of the Empozada Formation (Llanvirn) from the San Isidro area. That assemblage contains a variety of dissociated spicules including stauractines, hexactines and pentactines of Hexactinellida. However, the skeletal structure and form of these sponges are unknown.

Aceñolaza and Toselli (1977) mentioned the presence of hexactinellid indet. spicules from the Loma del Kilometro Member of the Arenig-?Llanvirn Suri Formation (Mangano and Buatois, 1994), from the Famatina region, but no detailed systematic data were provided. The aim of this paper is to document for the first time the presence of sponges in the Lower Ordovician Volcancito Formation of the Famatina region of Argentina. The material studied consists of small collections of protosponges preserved in black siliceous graptolitic shales. These protosponges again document the occurrence of such relatively primitive hexactinellid sponges in Paleozoic black-shale facies at margins of the continents (Walcott, 1920; Rigby, 1966, 1978, 1983, 1986, 1995; Rigby and Harris, 1879; Beresi and Rigby, 1994; Rigby, et al., 1996). Specimens are deposited in the Invertebrate Fossil Collection of the University of Tucumán (PIL).

GEOLOGIC AND DEPOSITIONAL SETTING

Deposits of the Ordovician Famatina terrane comprise epiclastic (Tremadoc) and volcaniclastic (Arenig-Llanvirn) rocks widely exposed in La Rioja and Catamarca provinces

of northwestern Argentina (Fig. 1). These sediments accumulated in different marine basins related to the western Gondwana volcanic arc (Aceñolaza and Toselli, 1988; Mangano and Buatois, 1992, 1996; Mannheim, 1993).

The two formations are included into the Cachiyuyo Group (Aceñolaza and Toselli, 1981). The Volcancito Formation is the basal unit of the group, and has a maximum thickness of about 350 m. It is composed of low-grade metamorphic fossiliferous dark-blue to black shales and sandstones, with interbedded thin limestone beds. The formation is exposed at two localities on the eastern flank of the Famatina Range, at Puesto Volcancito and at Peña Negra. The protosponge material described herein came from black siliceous graptolitic shales of the upper part of the Lower Tremadoc Volcancito Formation at Peña Negra where two sedimentary facies have been recognized (Fig. 2).

Facies A: Thinly laminated, black siltstones.

These thick siltstones exhibit laterally continuous laminae, which range between 2 and 4 mm thick. Beds are tabular with sharp tops and bases. Dense graptolite concentrations and less common small protosponges occur on some bedding planes. The sponges are associated with graptolites such as *Rhabdinopora patula* (Bulman and Rushton, 1973) and *Rhabdinopora* sp. and other dendroids (Gutierrez-Marco; personal communication, 1995). These siltstones have high concentrations of organic matter and are considered typical "Black Shale" facies (Esteban, 1994; Aceñolaza, et al, in press). This facies represents sedimentation from suspension fall-out in very low-energy settings below storm wave base.

Facies B: Massive sandy siltstones.

These siltstones occur as tabular layers, 5 to 10 cm thick, and are commonly interbedded within Facies A. Beds are generally massive, but may grade upwards into thinly laminated intervals. They have sharp bases and display lateral thickness variations. Isolated graptolite colonies are locally present. Facies B is thought to represent deposition from highly concentrated turbidity currents.

In the Peña Negra locality, sedimentation was characterized by predominant suspension fall-out (Facies A), only exceptionally punctuated by episodic sedimentation (Facies B). The black shale facies indicates accumulation in a reducing medium, suggesting development of an anoxic event in the early part of the Ordovican (Esteban, 1994). Oxygen depletion in the studied sequences is suggested by the dark sediments and high concentrations of preserved organic matter. A lack of benthic activity allowed the preservation of the thin laminations of Facies A siltstones. Absence of infaunal and epifaunal organisms colonizing the sea floor suggests anoxic conditions both above and below the sediment-water interface. These general characteristics indicate that the analyzed stratigraphic interval of the Volcancito Formation was deposited in a restricted basin in oxygen-depleted bottom waters.

SYSTEMATIC PALEONTOLOGY

Class HEXACTINELLIDA Schmidt, 1870
Subclass AMPHIDISCOPHORA
F. E. Schulze, 1887
Order RETICULOSA Reid, 1958
Suborder PROTOSPONGIOIDEA
Hinde, 1887
Superfamily PROTOSPONGIOIDEA
Finks, 1960
Family PROTOSPONGIIDAE Hinde, 1887
Genus PROTOSPONGIA Salter, 1864
PROTOSPONGIA species A
Figures 3.1, 3.2, 3.4, 3.5, and 3.8

Description.—Moderately small, test-tube-like sponges with hemispherical base and cylindrical upper part. Oscular margin unknown in fragments available. Most complete fragment with complete diameter of 13–15 mm, in part above hemispherical base, and total fragment has height of 25 mm from base to fractured-torn upper margin. Skeleton thin-walled reticulation of quadrangularly-arranged hexactines with long tangential rays, but with short proximal and distal rays. Spicules arranged into quadrules in which first-order quadrules 2.5–2.7 mm high and 1.7–2.1 mm wide, in upper cylindrical part of sponge where structure most well organized. These quadrules with first-order hexactines at each of four corners, with vertical rays 2.0–2.22 mm long and 0.10–0.15 mm in basal diameter, whereas horizontal rays 1.3–1.5 mm long and with basal diameters like that of vertical rays. Proximal-distal rays preserved as nodes to only 0.1 mm long, maximum, and of same diameter as other rays in spicules.

Second-order quadrules 1.4–1.5 mm long and with basal diameters like that of vertical rays. Proximal-distal rays preserved as nodes to only 0.1 mm long, maximum, and of same diameter as other rays in spicules.

Second-order quadrules 1.4–1.5 mm high and 0.8–1.0 mm wide, formed by second-order spicules placed in centers of first-order quadrules. These spicules with vertical rays 1.5–1.6 mm long and horizontal rays 1.2–1.4 mm long, both with basal ray diameters of approximately 0.06–0.07 mm. Locally, third-order quadrules 0.8 mm high and 0.5 mm wide produced by spicules with rays 0.5–0.6 mm long and 0.05 mm in diameter. Smaller orders of spicules not clearly preserved but in reticulate thatch-like impression, fourth-order quadrules 0.4–0.5 mm high and 0.2–0.25 mm wide moderately well-defined locally.

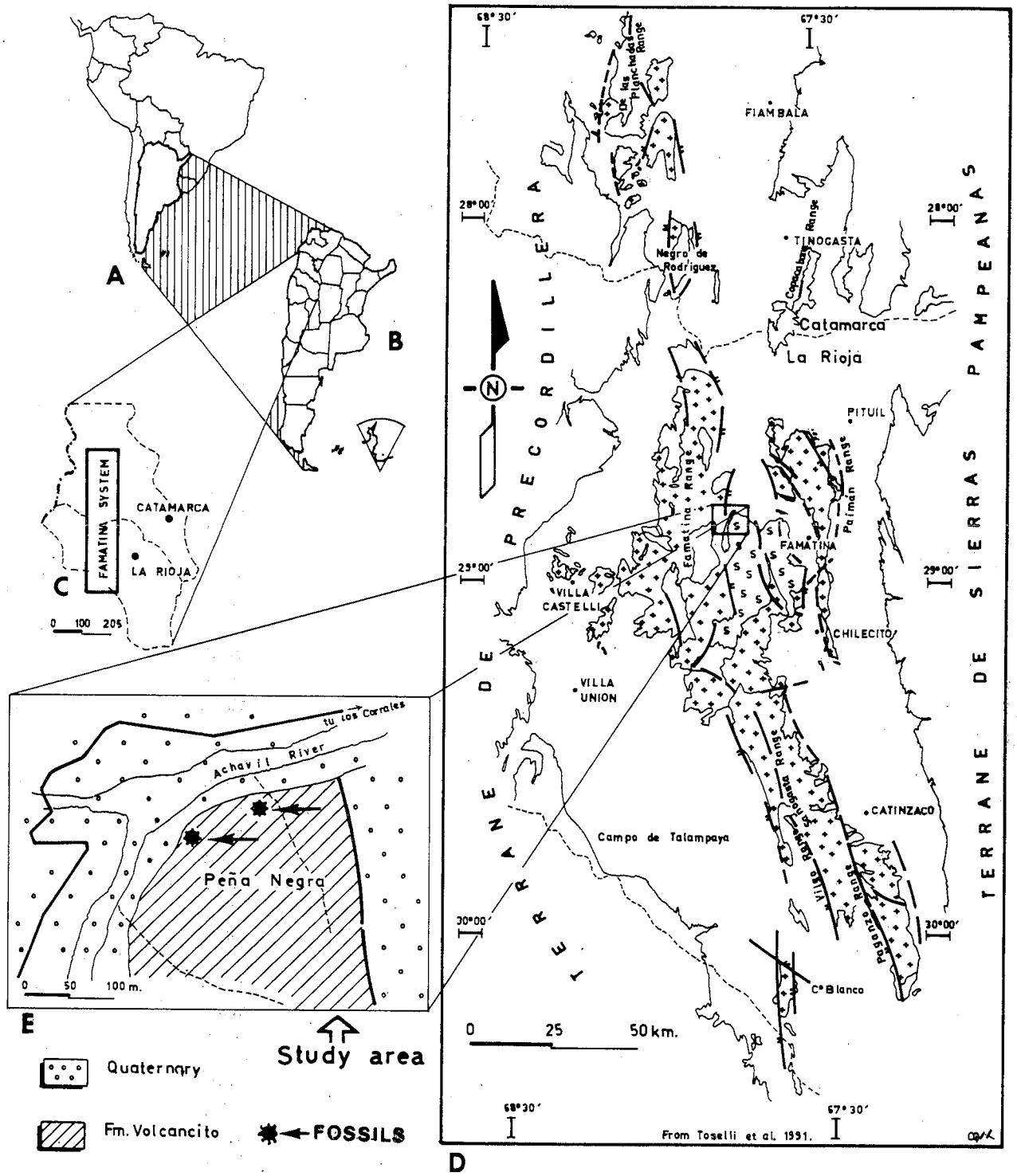


Figure 1. Index maps to the sponge locality in the Peña Negra section of the Famatina range in northwestern Argentina. (A) Location of Argentina within South America. (B) Location of the provinces of Catamarca and La Rioja within Argentina. (C) Map of Catamarca and La Rioja provinces showing the position of the Famatina System. (D) Geologic map of the Lower Paleozoic rocks of the Famatina System showing the position of map E. (E) Geologic sketch of the Volcancito Formation in the Peña Negra, in the Famatina System of La Rioja province.

Quadrules in lower hemispherical part appear like expanding latitude and longitude grid, but with moderate irregularity possibly produced by compression of specimen, but also possibly by irregular growth and spicule implacement in basal part of sponge.

Other less complete fragments of same species occur at three levels within black siltstone fragment. These generally with approximately same quadrule and spicule structure, but both larger fragments with complex appearance because of apparent flattening of both walls of thin skeleton

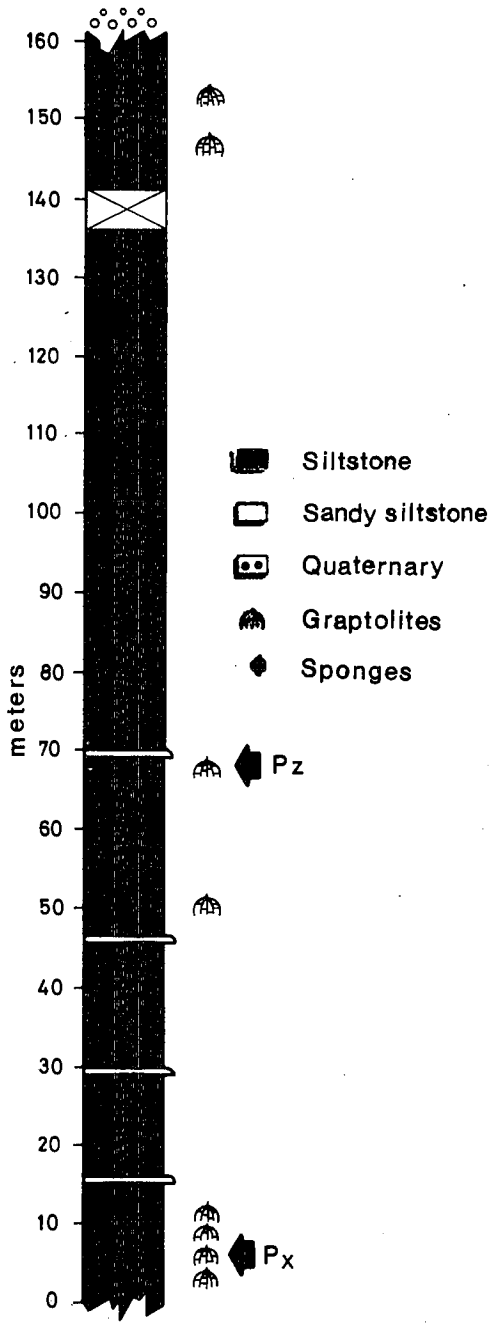
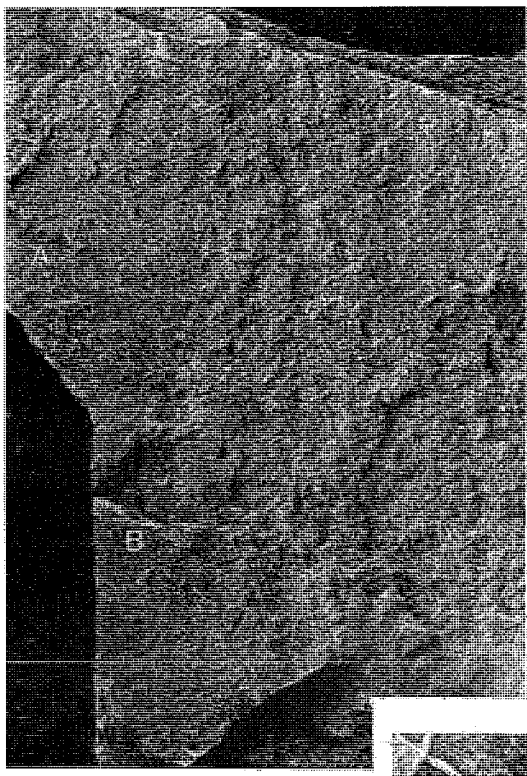


Figure 2. Stratigraphic section of the upper part of the Lower Tremadoc Volcancito Formation of Peña Negra, Profile 2, on the eastern flank of the Famatina Range, La Rioja Province, northwestern Argentina. Sponge occurrences are shown by the large arrows.

Figure 3. Protospongia *species and small spindle-shaped structures of uncertain origin from the Lower Tremadocian Volcancito Formation in the Famatina region of northwestern Argentina.* 1, 2, 4, 5, 8, Protospongia *species A, specimen PIL 14.192 (PX 132), from Profile 2, Peña Negra section.* 1, *Nearly complete sample with fragments of two sponges with protosponge-type skeletal net, one in the lower and one in the upper left, black siltstone impression was dusted with ammonium chloride to emphasize the minor relief of the relatively simple skeletal net. The impression in the upper left (A) was produced by a single wall, but the impression in the lower left (B) was made by two walls flattened across one another, x2;* 2, *latex cast of the impression in the upper left of figure* 1, *the hexactine spicules are in microrelief in the center and lower left and are arranged in characteristic quadruled protosponge skeletal structure; up to 4 orders of quadrules are locally preserved, but most of the impression shows only first- and second-order patterns, x2;* 4, *photomicrograph of skeletal structure in the upper part of the impression near the central part of figure* 2, *showing both positive and negative relief features on hexactines in the well-ordered skeletal net, in the limonite-stained original or showing casts of natural molds where the spicules have been weathered away, as in the upper left, x10.* 5, *Photomicrograph showing the more confused skeletal pattern in the double-walled preservation of sponge in the lower left in figure* 1. *First-order quadrules show moderately well in the upper left, but the irregular orientation of the second layer of the thin sponge wall shows well in the lower right. Detailed area is near the base of the specimen in figure* 1. *Proximal and distal rays of hexactines show in the coarse spicules on the right, x10;* 8, *photomicrograph of the natural surface of the black shale showing impressions of hexactines, largely first and second-order, producing characteristic protosponge quadrules, parallel lineations in the lower left suggest fourth-order quadrules but spicules are not clearly defined, detailed area is in the central part of the sponge shown in the upper left in figure* 1, *x10.* 3, Protospongia *species B, a latex mold of a small fragment showing the coarse first-order and locally second-order spicules and quadrules in the incomplete fragment of a reticulate net, specimen PIL 14.193, (PZ 134) from the Volcancito Formation, Profile 2 at Peña Negra section, x2.* 6, 7, *"Fossils" of unknown affinity, abundant spindle-shaped isolated bodies irregularly oriented with occasional associated hexactine spicules. The micronodose or almost spinose microsculpture of the spindle-shaped objects shows on several in the center and in the lower left, PIL 14.194 (PZ 135), from Profile 2, Peña Negra section;* 6, *x2;* 7, *x10.*



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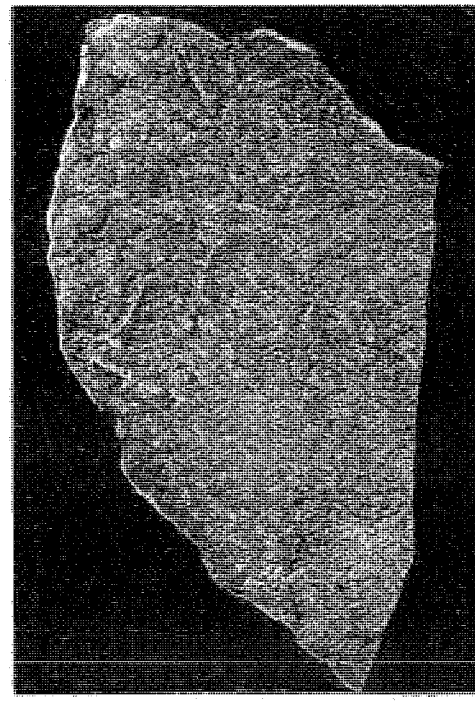

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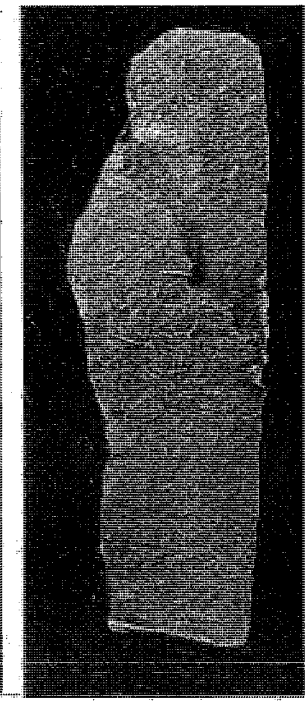

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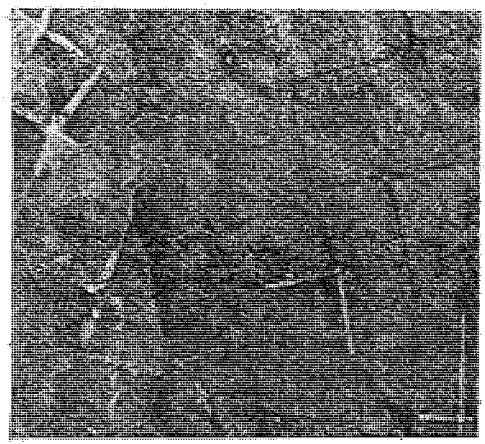

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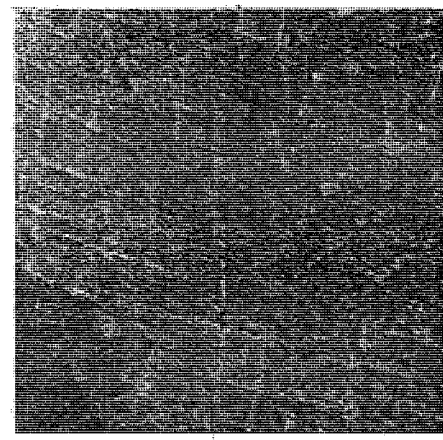

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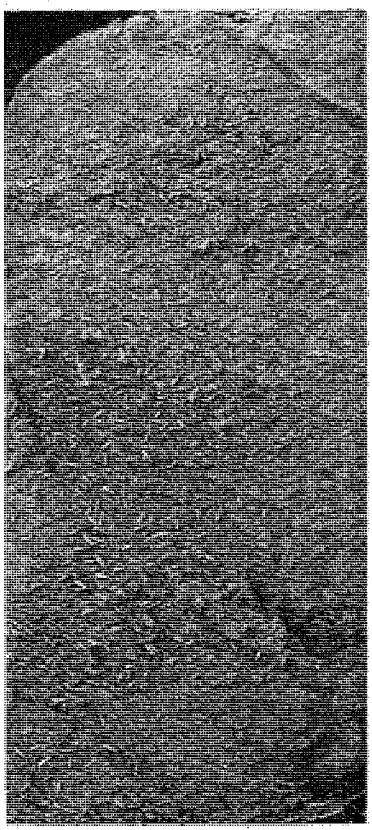

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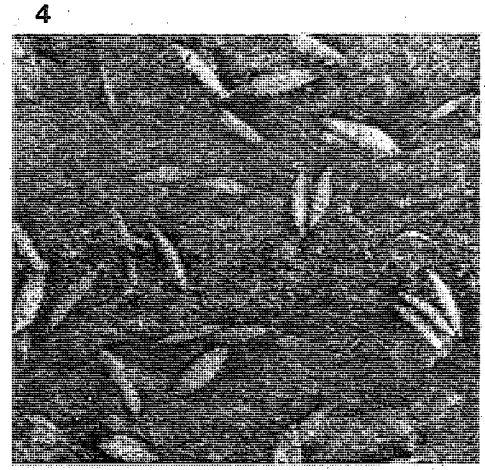

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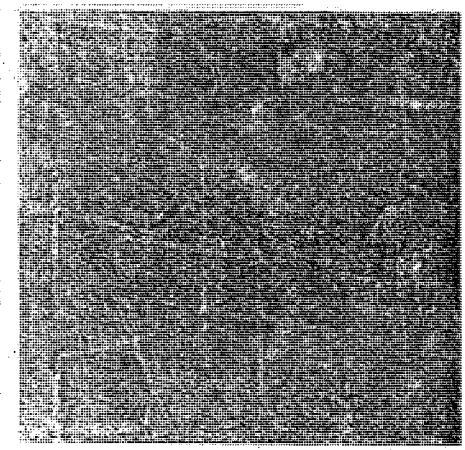

8

to produce confused criss-crossing relationship, or show only few first-order and smaller quadrules, with incised spicule impressions where once pyritic hexactines largely removed by weathering.

Discussion.—Species of *Protospongia* are known from the Cambrian to the Devonian, and range from spherical to steeply obconical or goblet-shaped. *Protospongia hicksi* Hinde, 1888, is a large sponge with first-order quadrules much larger than that seen in the tubular species here (Rigby 1966). The basal part of the Argentine species appears somewhat similar to the lower part of spherical *Protospongia tetranema* Dawson, 1889, named from Quebec, Canada. That Canadian species, however, does not have the cylindrical pipe-like upper structure, although it does have first-order quadrules approximately 5 mm square, within the general range of that seen in the form here. However, differences in shape clearly differentiate the species.

Protospongia mononema, Dawson, 1889, also described from the black shale at Little Métis on the lower St. Lawrence River in southeastern Quebec, is a spherical form and also has first-order quadrules approximately 5 mm square. However, it has a single, long, root-tuft spicule, in contrast to four root-tuft spicules in *Protospongia tetranema.* The root tuft, if one were present in the Argentina material, is not preserved nor differentiated. There is strong alignment of some vertical rays within the quadruled skeletal structure in the lower part of the hemisphere, however, which would suggest the presence of several tuft spicules if they were extensions of that structure. The structure is somewhat like that in *Diagoniella cyathiformis* Dawson, 1889, but in *Diagoniella* the quadrules are diagonally arranged with reference to the principal dimensions of the sponge, rather than parallel, as in the Argentine species and in other species of *Protospongia.*

Protospongia fenestrate, Salter, 1864, the type species of the genus from the Lingula-flags of Wales, was based on small fragments of the sponge skeleton. The quadruled first-, second-, and third-order spicules are clearly shown in the fragment, although somewhat diagonally arranged. They may have been distorted during burial and fossilization. The resulting first-order quadrules are approximately 4–5 mm across and high, within the general range of that seen in the Argentine species described here. Because nothing is known of the form of the Welsh sponge, it is difficult to compare it with other species in the genus and the rhomboidal, rather than rectangular, skeletal structure of some of the sponge fragment suggests it may not belong to *Protospongia* at all, as that genus is currently understood, but to *Diagoniella,* as that genus is currently defined.

Material.—Specimen PIL, 14.192 (PX 132), from Profile 2, Peña Negra section.

PROTOSPONGIA species B
Figure 3.3

Description.—Small fragment of moderately coarse protosponge, 20 mm high and 10 mm wide, composed of first-order quadrules approximately 5 mm high and 3.2–3.5 mm wide. First-order hexactines with proximal and distal nodes 0.25–0.28 mm in diameter and at most approximately 0.1 mm long. Vertical tangential rays 5–6 mm long and horizontal ones 2–4 mm long, both 0.28–0.30 mm in basal diameter. Rays overlap so quadrules bounded by double rays from spicules whose ray centers are corners of quadrules. Second-order quadrules faint impressions and appear to be approximately half size of first-order quadrules, separated by second-order spicules with rays approximately 3.0 mm long and 0.15–0.18 mm in diameter, but not regularly preserved. Other small irregularly preserved spicules, down to moderately well-defined ones with rays 0.5 mm long and 0.04 mm in basal ray diameter, occur in sample but in irregular orientation, suggesting perhaps additional two orders of spicules in reticulate net, following on nature of skeletons in related forms.

Material.—Sample PIL 14.193, (PZ 134) from the Volcancito Formation, late lower Tremodocian *Dictyonema* "facies" from Profile 2, Peña Negra section.

"FOSSILS" OF UNKNOWN AFFINITY
Figures 3.6 and 3.7

Abundant spindle-shaped isolated bodies range from 0.15–0.2 mm in maximum diameter and 0.5–0.6 mm long, to relatively robust spindle-like forms, 1.5 and 1.4 mm in maximum diameter at midlength. These are isolated or occur two or three side-by-side, or some may cross, but most are isolated. Surface smooth to marked by angular crystals that produce a microspinose surface where radiating fibers are best preserved in areas adjacent to matrix. These fibers may be 0.02–0.04 mm long and 0.01–0.02 mm in basal diameter, and appear to terminate in sharp tips almost like hairy fibrous gypsum crystals. In some respect, bodies appear like cross sections of poorly preserved gypsum crystals which may have resulted from oxidation of pyritic fossils to produce sulfates. Where two "spindles" nearly side-by-side, fibrous needle-like crystals extend between them, up to 0.035–0.04 mm long, and commonly smaller than 0.01 mm in diameter, but occasionally up to 0.02 mm in diameter, which is essentially diameter of micronodes on individual spindle-like structures. Micronodes not in rows nor geometrically aligned, but fairly regularly spaced.

"Spindles" occur in black siliceous siltstone associated with isolated hexactines with basal ray diameters up to 0.25 mm, but smaller spicules with rays approximately 0.08 mm in diameter and 0.5 mm long more common,

although neither are abundant nor organized into regular skeletal net.

Discussion.—At first glance, the spindle-shaped structures appear like small, robust, monactine spicules, but such spicules are unknown from the Cambrian. Their irregular, almost strewn occurrence, is reminiscent of some fecal pellet clusters, although they are certainly not arranged in any fashion, because they are irregularly oriented on the bedding plane, although long axes of the "spindles" are generally parallel to the bedding, if they are, indeed, three-dimensional, spindle-shaped rather than exposed tips of gypsum-like minerals diagenetically produced in the sedimentary rocks as a result of breakdown of the iron sulfide into calcium sulfate. The fibrous exterior of many would suggest a mineralogic, rather than a biologic, origin for the structures, or that they have been enlarged by the fine, fibrous, crystalline growth preserved in impressions around several of the "spindles."

Material.—Specimen PIL 14.194 (PZ 135), from Profile 2, Peña Negra section.

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