A Publication of the
Department of Geology
Brigham Young University
Provo, Utah 84602

Brigham Young University Geology Studies is published by the Department of Geology. This publication consists of graduate student and faculty research within the department as well as papers submitted by outside contributors. Each article submitted is externally reviewed by at least two qualified persons.

ISSN 0068-1016
2-93 600 2157

BRIGHAM YOUNG UNIVERSITY
GEOLOGY STUDIES

Volume 39, 1993

CONTENTS

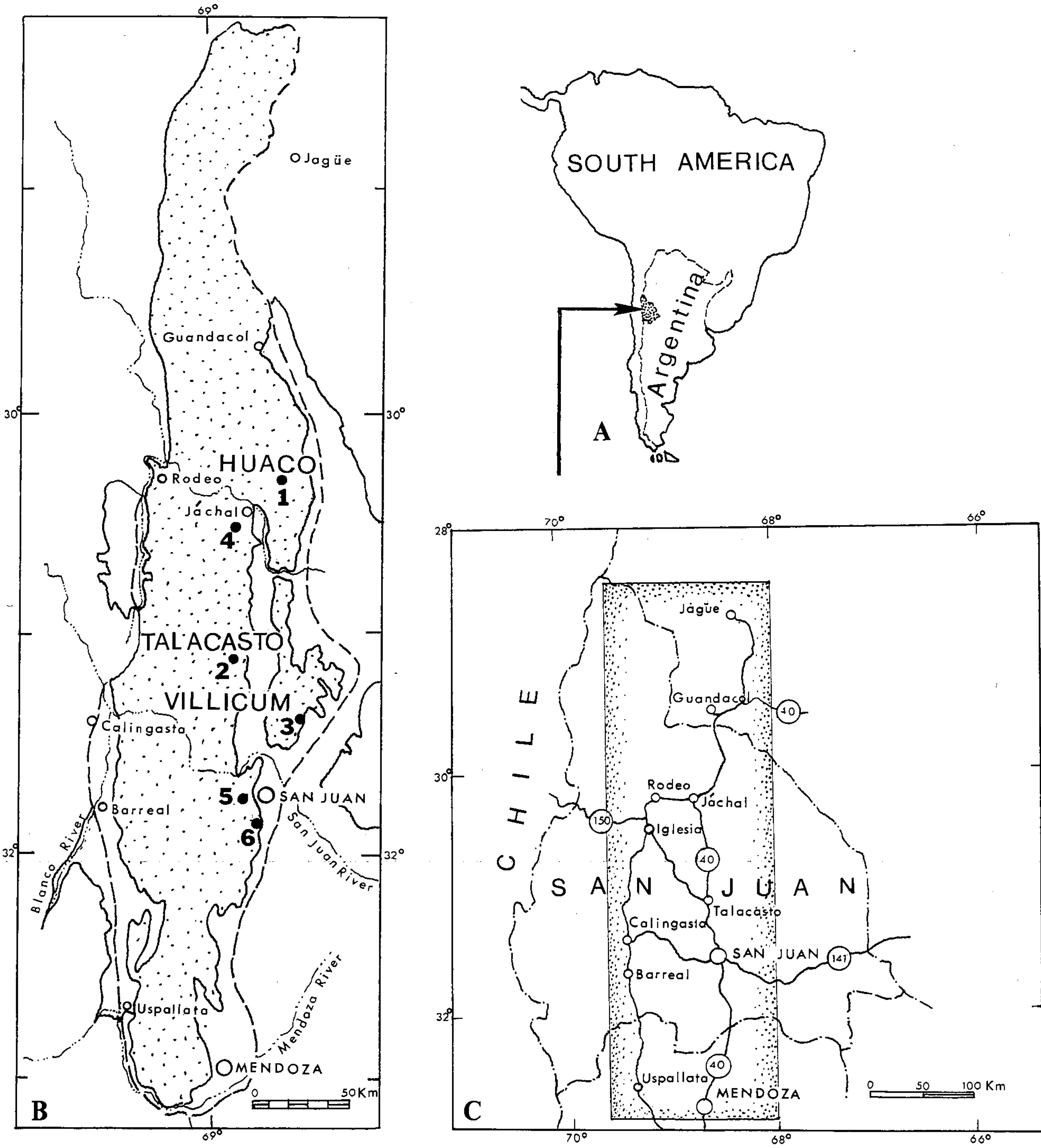


FIGURE 1.—*Index map to Ordovician sponge localities in Argentina. A—South America showing the position of the province of San Juan within Argentina (arrow). B—Sponge localities within the Precordillera (stippled) of central San Juan Province. Major localities (1–3) include: 1, the Huaco locality along sulfurous Agua Hedionda Creek, 30 miles east of Jáchal City; 2, Talacasto Gulch section in the Precordillera Central, approximately 89 km northwest of San Juan City; 3, Don Braulio Gulch in the Villicúm Range, approximately 40 km northwest of San Juan City. Other minor localities (4–6) include: 4, Loma del Piojo at San Roque Hill; 5, Las Lajas Gulch, west of San Juan City; 6, La Flecha Gulch in the Chica de Zonda Range, south of San Juan City. C—Map of San Juan Province showing the position of map B in the central part of the province.*

The Lower Ordovician Sponges of San Juan, Argentina

MATILDE S. BERESI
Centro Regional de Investigaciones Científicas y Tecnológicas, PRIBIPA, C.C. 131, 5500 Mendoza, Argentina
J. KEITH RIGBY
Department of Geology, Brigham Young University, Provo, Utah 84602

ABSTRACT

The most diverse sponge faunas known from the Ordovician of South America are described here from the Arenigian San Juan Formation, from the Precordillera region of San Juan Province, western Argentina. Faunas described were collected from Talacasto Gulch, about 90 km northwest of San Juan City; from Huaco along Agua Hedionda Creek, 165 km north of San Juan City; and from Don Braulio Gulch in the Villicúm Range, approximately 40 km northeast of San Juan City. Faunas are dominated by orchoclad lithistid demosponge genera, although hexactinellids are known from loose spicules and root tufts, and heteractinids are known from isolated octactine spicules. The new genus and species *Talacastonia chela* are reported from the San Juan Formation at Talacasto, in addition to the previously described species *Archaeoscyphia minganensis* (Billings 1859) and *Rhopalocoelia clarkii* Raymond and Okulitch, 1940. The new species from the Talacasto section include *Archaeoscyphia nana, Rhopalocoelia rama, Hudsonospongia talacastensis, Calycocoelia perforata, Aulocopium sanjuanensis, Patellispongia robusta, Anthaspidella inornata, Anthaspidella annulata,* and *Anthaspidella alveola.* Root tufts and isolated hexactine spicules are the only known representatives of the Hexactinellida, and a single loose octactine spicule is the only evidence of the Heteractinida at Talacasto Gulch. Talacasto Gulch is the most productive Ordovician sponge locality yet known from South America.

The sponge fauna from the Villicúm Range locality includes *Hudsonospongia cyclostoma* Raymond and Okulitch, 1940, and the new species *Calycocoelia perforata, Aulocopium sanjuanensis,* and *Psarodictyum magna.* These orchocladine demosponges occur with hexactine spicules, extensive hexactinellid root tufts, and an additional single, isolated octactine spicule that documents the presence of the Heteractinida. The previously described *Protachilleum kayseri* Zittel, 1877, and the new species *Archaeoscyphia nana* are the only sponges known at present from the Huaco locality.

The Argentine Ordovician sponge faunas show the most similarity to assemblages from North America, particularly to those from the northern Appalachian region and the Great Basin area. The sponges occur in limestone deposited in open subtidal environments on a stable carbonate platform environment along the western margin of Gondwana. They are associated with a well-preserved biota of brachiopods, bryozoans, nautiloids, gastropods, ostracodes, trilobites, crinoids, and algae.

INTRODUCTION

Well-preserved and diverse faunas of Arenigian sponges occur in limestones of the San Juan Formation in the Precordillera terrane of San Juan Province in western Argentina (fig. 1). These represent the most significant Ordovician sponge faunas known from South America and are described here for the first time. They provide the first extensive record of sponges derived from a stable carbonate platform along the now western margin of Gondwana in South America.

A total of 10 demosponge genera (one new) are described, and they include 15 species (11 new). Lithistid demosponges are the most diverse and include representatives of the suborder Orchocladina. In addition, isolated hexactine spicules and root tufts also occur. Heteractinid calcareous sponges are represented by only rare isolated and disassociated octactine spicules of astraeosponges.

GEOLOGIC SETTING

The Argentine Precordillera is a major geologic province in western Argentina and is located in the arid triangle of South America. The Precordillera province is approximately 400 km long, north-south, and is located between the Andes belt on the west and blocks of the central Argentine Craton on the east (fig. 1). Carbonate deposition in the Precordillera began in the Early Camchiopods, gastropods, and trilobites, including *Nileus* and *Triarthus*, and cosmopolitan forms such as *Mendolaspis salagastensis*. The black shales contain a graptolite fauna that includes *Paraglossograptus tentaculatus* (Cuerda and others 1985).

STRATIGRAPHIC RELATIONSHIPS

Sponge faunas described here occur in limestones and shaly limestones at three principal locations and at different stratigraphic levels within the San Juan Formation of the Precordillera. The greatest diversity of sponges occurs in two members of the formation at Talacasto Gulch (Locality 2 of fig. 1), one stratigraphically in the lower part and the other in the upper part of the San Juan Formation. Limestones of the formation are well exposed in Talacasto Gulch (plate 13, figs. 2, 5) in an asymmetric anticline that is faulted along its eastern flank. Sponges collected from Talacasto Gulch localities (table 1) include *Archaeoscyphia minganensis* (Billings 1859), *Aulocopium sanjuanensis* n. sp., *Anthaspidella annulata* n. sp., *Rhopalocoelia clarkii* Raymond and Okulitch, 1940, *Talacastonia chela* n. sp., and *Psarodictyum* from upper Talacasto outcrops. *Archaeoscyphia nana* n. sp., *Calycocoelia perforata* n. sp., and *Aulocopium sanjuanensis* n. sp. occur in lower units.

Talacasto Gulch is situated in San Juan Province, about 89 km northwest of San Juan City in the Precordillera Central (fig. 1). The stratigraphic succession exposed in the gulch area is composed of the Ordovician carbonate sequence and overlying clastic sediments of Silurian, Devonian, Carboniferous, and Tertiary ages.

The calcareous San Juan Formation section is 380 m thick and has been divided into seven members (Beresi 1981) at Talacasto Gulch (fig. 4). San Juan sponge faunas occur in the calcareous shaly limestone member in the lower part of the formation, and in the fossiliferous limestone member at the top of the calcareous sequence. The shaly limestone member is 45 m thick. It consists of a rhythmic sequence, alternating between argillaceous calcipelitic (lime mudstone) beds and thin fossiliferous limestone (skeletal wackestone) beds. The sponges are associated with articulate brachiopods, trilobites, gastropods, and bryozoans. The limestones from the San Juan Formation at Talacasto Gulch have yielded abundant and well-preserved conodont faunas. The lowest of these faunas corresponds to the *Oepikodus evae* Zone (Hünicken 1982) and occurs near the base of the sequence, which also contains the lowest level with sponges. The *Pygodus serra* Zone (Lozano and Hünicken 1990) occurs in the upper section. The upper occurrence of sponges is within this zone. The age of the San Juan Formation at Talacasto Gulch ranges from late early Arenigian *Oepikodus evae* Zone (Hünicken 1982) to the

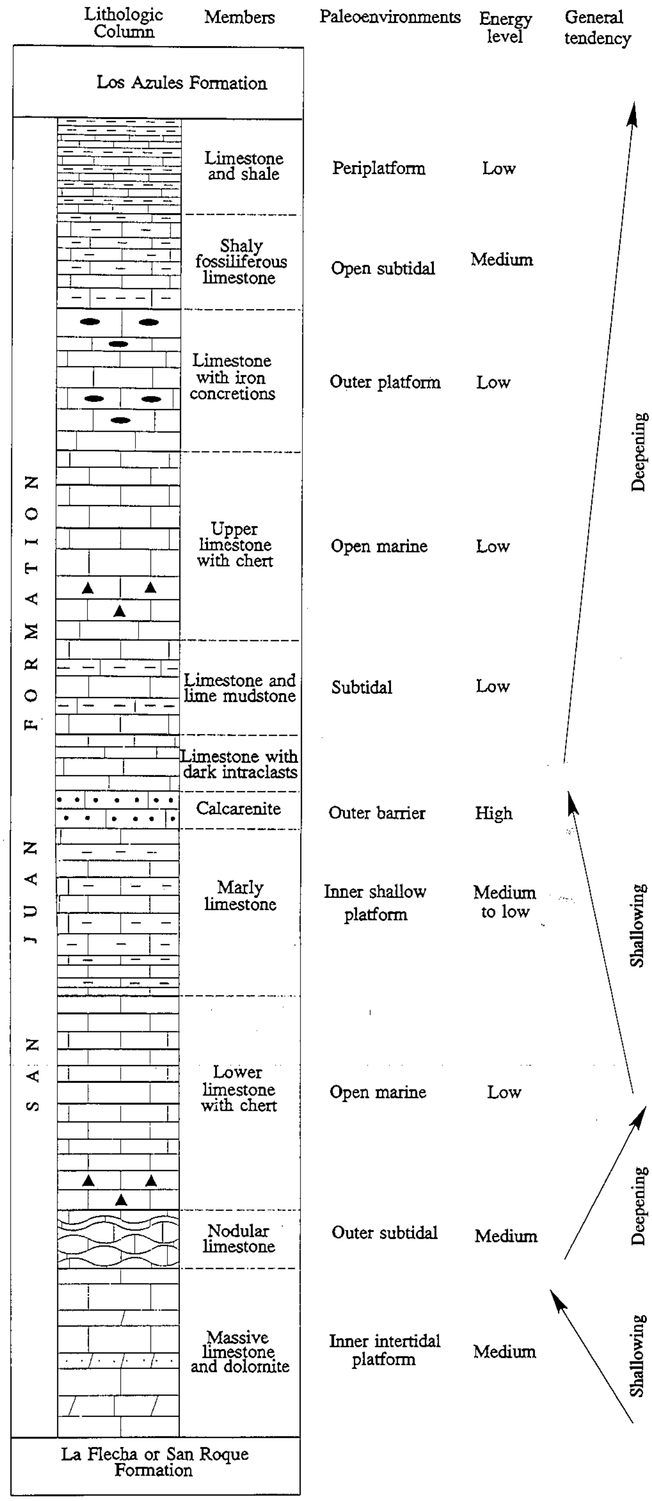


FIGURE 3.—*Generalized stratigraphic section of the San Juan Formation in the eastern part of the Precordillera in San Juan Province (modified from Beresi 1991a). Arrows on the right show two generalized cycles of shallowing and deepening, with much of the upper part of the formation deposited during the last deepening or transgressive part of the cycle. Black triangles, chert; black ovals, iron concretions.*

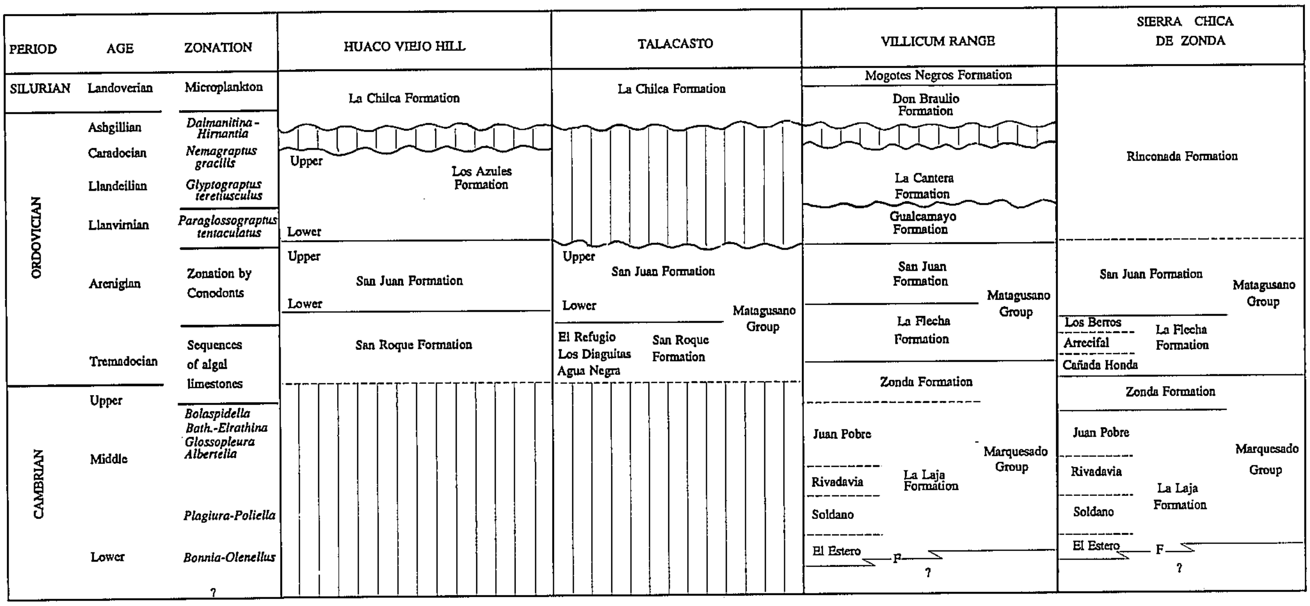


FIGURE 2.—*Correlation panel showing relationships and relative ages of formations exposed in the Huaco Viejo Hill, Talacasto Gulch, Villicúm Range, Sierra Chica de Zonda, and Mendoza localities (modified from Baldis and others 1989).*

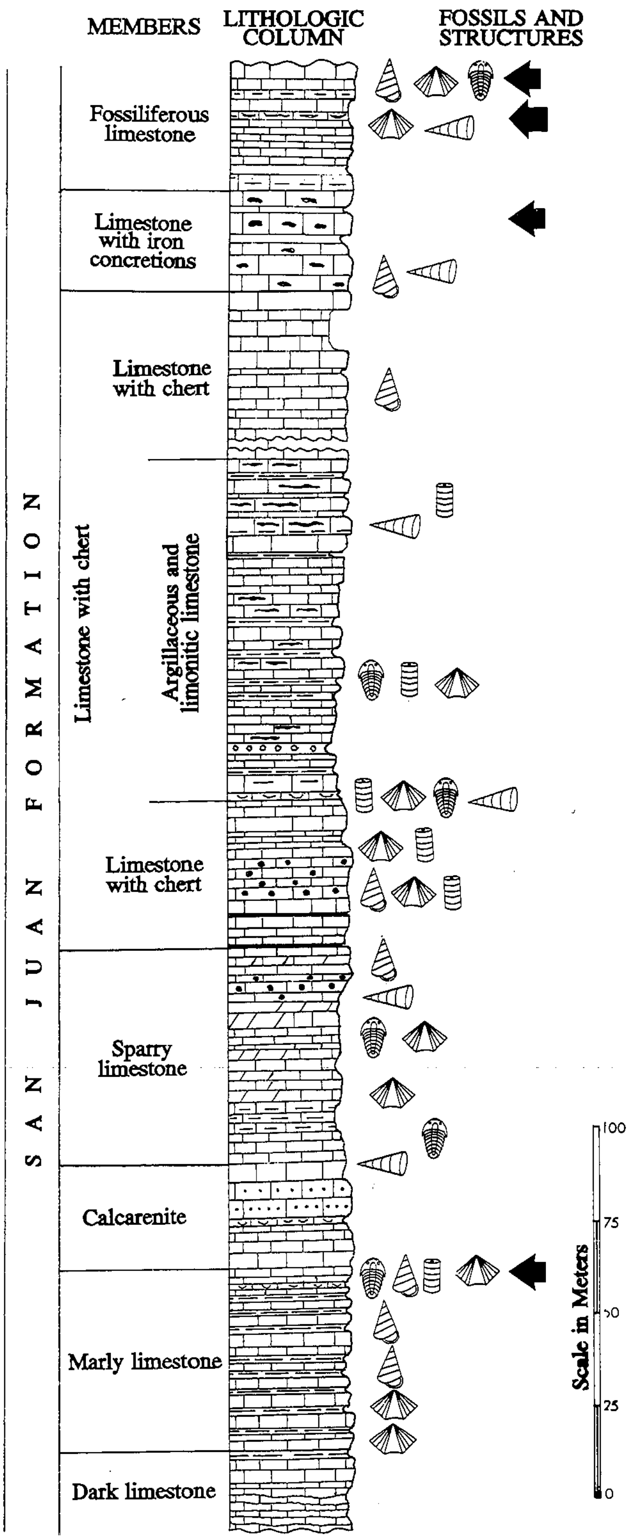
brian (*Olenellus* Zone, Bordonaro 1986) and extended to the Early Llanvirnian (*Pygodus serra* Zone, Lozano and Hünicken 1990) (fig. 2). Ranges of the province contain complete, thick sequences of lower Paleozoic rocks. Deposits of Ordovician carbonate basins occur in the central and eastern Precordillera (Aceñolaza and Baldis 1987, Baldis and others 1989). A carbonate platform evolved in the region during the Early Ordovician as a rapidly transgressive and cyclic sequence accumulated. That sequence contains numerous and diverse biotas.

Ordovician cyclic carbonates correspond stratigraphically to rocks of the Matagusanos Group (fig. 2) (Baldis and Beresi 1981, Baldis and others 1981), which includes the La Flecha Formation at its base, in the south, and the equivalent San Roque Formation, in the north, and the overlying San Juan Formation Limestone. This group ranges from Late Cambrian Tremadocian to Early Llanvirnian age in a conformable succession 1200 m thick. The basal part of the group starts with cyclic peritidal carbonates that include extensive development of microbial mats (Baldis and others 1981; Keller, Buggish, and Bercowski 1989). In contrast to that dominantly peritidal sequence, the overlying San Juan Formation was deposited in more open and deeper marine waters, and this thick sequence accumulated during a major sea-level rise (Beresi 1991a).

The San Juan Formation (Kobayashi 1937) is about 400 m thick and consists of two major limestone units that are subdivided into 11 members in a generalized section for the Precordillera region (fig. 3) (Beresi 1981, 1991a). A lower unit deposited during a shallowing-deepening-shallowing cycle includes nodular limestones, cherty limestones, and dolomitized limestones, with minor argillaceous beds. An upper unit deposited as a transgressive deepening sequence is mainly composed of skeletal wackestone and packstone, peloidal and bioclastic calcarenites, and thin shale beds. The lower unit accumulated in shallow subtidal to intertidal to open-marine environments, and the upper unit accumulated on the outer part of a platform edge (Beresi 1986a, 1987a). The upper unit corresponds to the Arenigian Series of Britain and to the upper Canadian (upper Ibexian) and lower Whiterockian Series of western North America. Conodont faunas indicate that the age of the San Juan Formation ranges from the *Paroistodus proteus* Zone (Hünicken and others 1990), at the base, to the *Pygodus serra* Zone (Lozano and Hünicken 1990) at the top of the carbonate sequence (Beresi 1988).

This formation is richly fossiliferous, with well-preserved biotas that include especially a variety of orthacean, strophomenid, clitambonitan, and rhynchonellacean brachiopods along with trilobites, ostracodes, bryozoans, bivalves, gastropods, cephalopods, echinoderms, microalgae, conodonts, and the sponge fauna here described. All elements of these faunas have been subjects of both early and recent studies. Such faunal and floral diversity speaks of stabilized environmental conditions on the shelf and of unrestricted communication with the open ocean. The extensive carbonate sedimentation on this platform is related to the equatorial-tropical location of the platform during the Arenigian.

A shaly transitional zone (Baldis and Beresi 1981) overlying the San Juan Formation contains faunas in the calcareous beds that include nautiloids, a variety of bra-



Zittel, 1877, occur with monactine and hexactine spicules in the dark limestone member. Sponges represent only 10% of the fossils in the locality.

The third locality of sponge-bearing limestone beds occurs in the upper part of the San Juan Formation at Don Braulio Gulch in the Villicúm Range (Locality 3 of fig. 1), approximately 40 km northeast of San Juan City. This locality has produced fewer sponges and a less diverse associated fauna than have the other two localities. There are some similarities in content, however; for instance, *Calycocoelia perforata* n. sp. and *Aulocopium sanjuanensis* n. sp. occur in the collection from both the Villicúm Range and Talacasto Gulch localities.

The limestone section of Don Braulio Gulch (fig. 6) is exposed on the extreme eastern flank of the Villicúm Range. This Ordovician section is the most complete, best-known, and paleontologically best-controlled locality in the Precordillera of San Juan. A continuous sequence of carbonates from Early Cambrian to early Llanvirnian ages is exposed there. The Ordovician sequence continues upward into the Ashgillian but becomes graptolite shales in upper beds. The San Juan Formation is 250 m thick at Don Braulio Gulch in the Villicúm Range (Beresi 1986a).

The sponges occur in the shaly limestone member of the formation. Hexactines and root-tuft spicules are present in a thin layer of limestone near the top of the sequence. In Don Braulio Gulch, the sponge beds are in the *Amorphognathus variabilis–Eoplacognathus suecicus* Zone (Sarmiento 1985), which indicates they are of an early Llanvirnian age.

The shaly limestone member is 10 m thick. It consists of fossiliferous, fine-grained limestones and calcipelitic beds. A shaly fauna composed of orthacean brachiopods, trilobites, and crinoids is common in the fine limestones. The lithistid sponges are associated with the other fossils, but root tufts do not occur associated with other sponges at the Don Braulio Gulch locality.

Micritic beds with *Archaeoscyphia* in growth position occur in the upper part of the San Juan Formation at Talacasto Gulch (Locality 2 of fig. 1); at San Roque Hill, in Jáchal (Locality 4 of fig. 1); in Las Lajas Gulch (Locality 5 of fig. 1); and at La Flecha Gulch in the Chica de Zonda

FIGURE 4.—*Profile of the San Juan Formation in the Talacasto Gulch section. Major occurrences of fossil sponges are shown by the bold arrows. Distribution of other common fossils in the section are shown by the small illustrations of crinoid stems, trilobites, gastropods, nautiloids, and brachiopods, using generalized forms. Most abundant forms are on the left and less abundant on the right. Irregular dark blebs, iron concretions; dark circles, chert concretions; black layers, bedded chert; dots in calcarenite, oolites.*

Table 1. Distribution of sponges from the San Juan Formation of Argentine Precordillera.

SPONGE TAXA	HUACO (1)	TALACASTO (2)	VILLICUM (3)
DEMOSPONGEA			
Archaeoscyphia minganensis Billings		+	
Archaeoscyphia nana n. sp.	+	+	
Calycocoelia perforata n. sp.		+	+
Rhopalocoelia clarkii Raymond and Okulitch		+	
Rhopalocoelia rama n. sp.		+	
Hudsonospongia cyclostoma Raymond and Okulitch			+
Hudsonospongia talacastensis n. sp.		+	
Aulocopium sanjuanensis n. sp.		+	+
Protachilleum kayseri Zittel	+		
Psarodictyum magna n. sp.			+
Patellispongia robusta n. sp.		+	
Anthaspidella inornata n. sp.		+	
Anthaspidella annulata n. sp.		+	
Anthaspidella alveola n. sp.		+	
Talacastonia chela n. sp.		+	
HEXACTINELLIDA			
Hexactine spicules		+	+
Root tuft			+
HETERACTINIDA			
Octactine spicule		+	+

+ present

Pygodus serra Zone (Lozano and Hünicken 1990) of the early Llanvirnian.

The upper fossiliferous limestone member is 25 m thick at Talacasto Gulch and is composed of thin calcareous beds and marl (mudstones and skeletal wackestones). It contains an abundant and diversified biota, including sponges, brachiopods, trilobites, gastropods, crinoids, cephalopods, bivalves, bryozoans, and microalgae, in a general ranking of relative abundance. Pyritized specimens of *Archaeoscyphia* occur in living position in the iron concretions limestone member, in the upper part of this sequence. Kayser (1925) found sponges at Talacasto Gulch, but they were only mentioned as undetermined "spongiae." A sponge spicule assemblage from the Lower Ordovician of the San Juan Precordillera was described by Gnolli and Seräpagli (1980).

The second major locality of sponge-bearing limestone occurs in Huaco Hill (Locality 1 of fig. 1) (Beresi 1987b). This locality is 165 km north of San Juan City, in the Precordillera Central. The section studied crops out on the eastern flank of the core of the anticline of Huaco, along sulfurous Agua Hedionda Creek (plate 13, figs. 1, 3). The anticlinal core exposes limestone of the San Juan Formation. There is a stratigraphic hiatus with a strong angular unconformity between the Arenigian San Juan beds and the overlying Carboniferous clastic units in the Huaco area (plate 13, fig. 4). Agua Hedionda Creek in the Huaco area is located 30 km east of Jáchal City in San Juan Province. The sequence crops out in an asymmetric anticline that has a north-south axis. It exposes lower and upper Paleozoic, Triassic, and Tertiary sedimentary rocks. The San Juan Formation is overlain disconformably by the Volcan Formation of Early Carboniferous age. The presence of the multielement conodont *Oepikodus evae* Lindstrom in lower and middle parts of the San Juan Formation establishes a late early Arenigian age for those rocks. A younger assemblage occurs in upper rocks of the Agua Hedionda Creek section and is referred to the *Baltoniodus triangularis* Zone of the lower upper Arenigian (Di Prinzio and Hünicken 1990). Conodont faunas indicate the San Juan Formation is of early late Arenigian age, in the *Baltoniodus navis* Zone (Lemos 1981), at the top of the carbonate sequence in the Huaco area.

The San Juan Formation is about 170 m thick in the Agua Hedionda Creek section (Beresi 1987b), Huaco locality (fig. 5). Sponges occur principally in the shaly limestone member in the limestone sequence. The sponges are associated with articulate brachiopods, trilobites, bryozoans, crinoids, and microalgae. The small sponges *Archaeoscyphia nana* n. sp. and *Protachilleum kayseri*

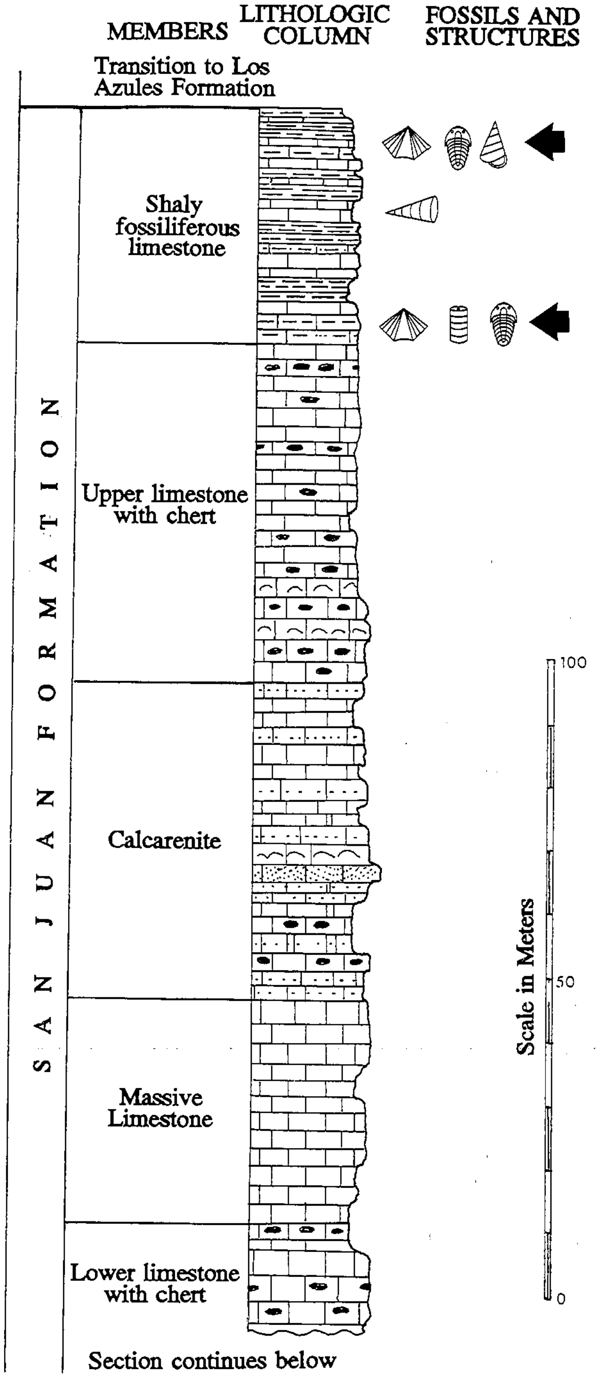


FIGURE 6.—*Profile of the stratigraphic section of the San Juan Formation exposed along Don Braulio Gulch in the Villicúm Range. Distribution of important sponge faunas is indicated by the bold arrows. Small symbols indicate the distribution of common fossils in other parts of the section. The symbols for them and lithology modifications are the same as those used in figure 4, except for a cross-bedded limestone and a convex upward arc for stromatolitic units.*

Small *Archaeoscyphia nana* n. sp. and *Protachilleum kayseri* Zittel, 1877, occur at Huaco area, together with crinoids, bryozoans, brachiopods, and nautiloids in marly limestones.

The lithistid Ordovician sponges are well known from North America, Australia, Europe, and Asia, and now are also known to be diverse and variable from South America. Generalized genera, such as *Archaeoscyphia, Patellispongia, Aulocopium, Hudsonospongia,* and *Hindia,* occur widely. Most other genera, however, show some provinciality. They are particularly diverse in North America and in the Upper Ordovician assemblages from New South Wales in Australia (Rigby and Webby 1988). They are common reef formers in Newfoundland (James and Klappa 1989, Klappa and James 1980) and the Mingan Islands of southeastern Quebec (Desrochers 1988, Desrochers and James 1989); in Vermont (Finks and Toomey 1968, 1972; Pitcher 1964) and southward through the Appalachian Mountains in eastern North America (Alberstadt, Walker, and Zurawski 1974; Walker and Ferrigno 1973); and in Utah, Nevada (Church 1974; Rigby 1966, 1971; Wyatt 1979), Texas, and New Mexico (Toomey and Nitecki 1979) in the western United States. They range from broad saucer-shaped or funnel-like forms to steeply obconical or cylindrical sponges and to gobletlike forms.

Hexactinellid sponges are characteristic of outer slope or inner euxinic environments. They appear to have been most common on outer margins of continental masses during the Ordovician (Rigby and Webby 1988). However, a few hexactinellid spicules do occur in the San Juan Formation collections, associated with lithistid demosponges.

PALEOGEOGRAPHY

South America formed part of the core of Gondwana during the Paleozoic, and combined with Africa, Madagascar, India, Antarctica, and Australia to produce the supercontinent. Paleogeographic restorations constructed by Scotese and McKerrow (1990, fig. 7) show the Precordillera region of Argentina (figs. 7 and 8) to have been near the equator during the Early Ordovician (Arenigian). These authors (1990, fig. 22), however, indicate cold temperatures for the western part of Gondwana, as determined from faunas and lithofacies, but show warm stable temperatures for western North America, which was located in the same equatorial-tropical zone. Carbonate rocks and associated faunas and floras in the San Juan Formation support a warm tropical environment of deposition for the formation.

Rocks of the Great Basin in the western United States are very similar to those of the Cambrian Basin in the Precordillera in types of carbonate rocks and benthic faunas (Baldis and others 1981). The San Juan Limestone

Range (Locality 6 of fig. 1). These occurrences of in-situ sponges have been interpreted as buildups (Beresi 1986c). Other accessory organisms in the massive beds include bryozoans and crinoids. One layer of pyritized *Archaeoscyphia,* in living positions, occurs in the iron concretions limestone member in the upper part of the San Juan Formation at Talacasto Gulch. Rocks of the San Roque Hill Jáchal localities have been described by Beresi (1987a), and those of Las Lajas Gulch locality in the Chica de Zonda Range by Beresi and Bordonaro (1984). Latitude and longitude positions of major Ordovician localities are shown in table 2.

PALEOECOLOGY

Distribution patterns of the sponges of the Argentine Precordillera suggest occurrences were strongly influenced by depth and current intensity on the carbonate platform (Beresi 1987a,b). The diverse San Juan sponge fauna of siliceous orchocladine lithistid demosponges and hexactinellids thrived in an open subtidal environment but were not successful in shallower, possibly more turbid waters. Diversity and abundance of other elements of the biota, in addition to the sponges, suggest excellent living conditions during accumulation of the widespread normal marine sediments. The sediments and abundant fossils suggest good water circulation in an open shelf, a mainly subtidal environment of carbonate deposition, and waters of normal salinity in which there was an adequate nutrient supply. Preservation of associated algae indicates that sediments in which they occurred accumulated in the photic zone.

Four general morphotypes of sponges are present in the assemblages: (1) columnar, cylindrical-shaped forms; (2) cup-, vase-, and funnel-shaped forms; (3) discoid to flattened saucer-shaped forms; and (4) pear- or hemispherical-shaped forms. Because of their relatively plastic morphology, shapes of the sponges may be indicative of their environments and are considered as good paleoenvironmental indicators.

1. Columnar or tubular forms occur where currents were moderately strong. The tubular form aids in "sucking" water through the system, like effluents up and out a chimney. Columnar or tubular sponges, as for example *Archaeoscyphia minganensis,* occur in the Talacasto Gulch locality.

2. Conical, cup-, or fan-shaped forms tend to be common in sediments of areas of intermediate current intensity. Sponges of cup-shape occur in the Villicúm Range, associated with a root tuft in the only limestone bed.

3. Saucerlike and hemispherical sponges occur in some beds at Talacasto Gulch and tend to be common in sediments that accumulated in only moderately agitated water.

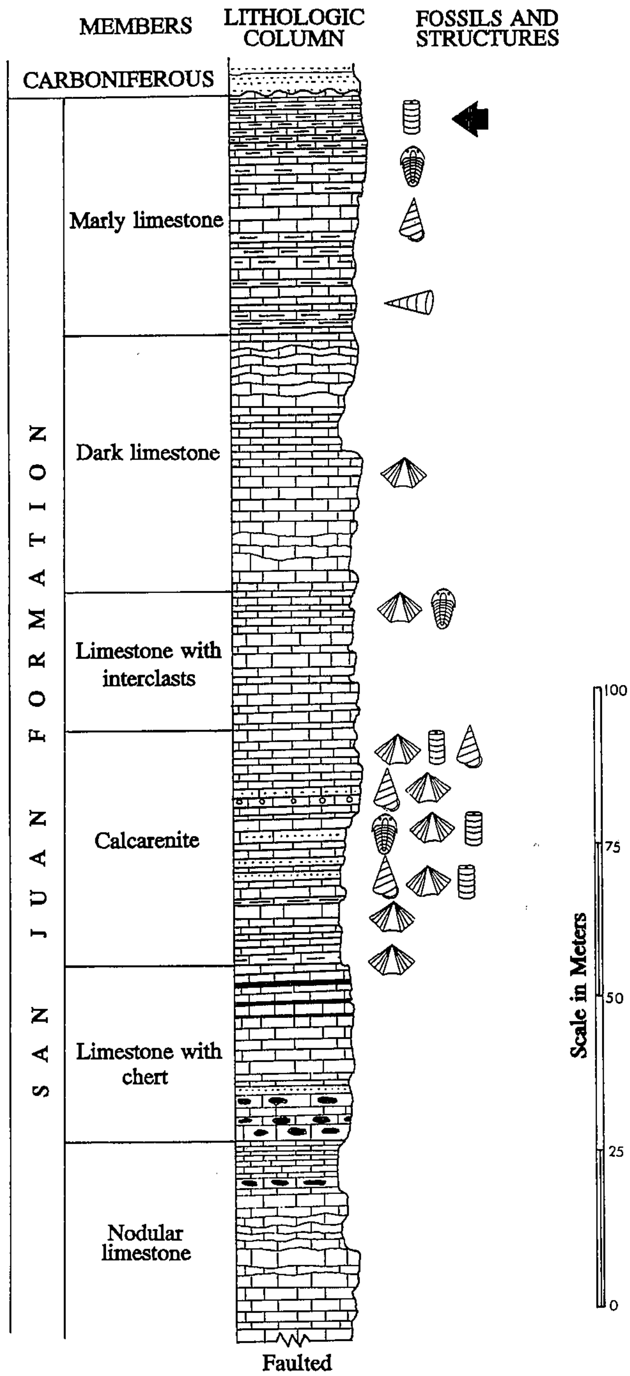


FIGURE 5.—*Profile of the Huaco section along Agua Hedionda Creek. Distribution of major sponge faunas in the upper part of the formation is indicated by the bold arrow. Distribution of common other fossils and lithologies uses the same symbols as in figure 4.*

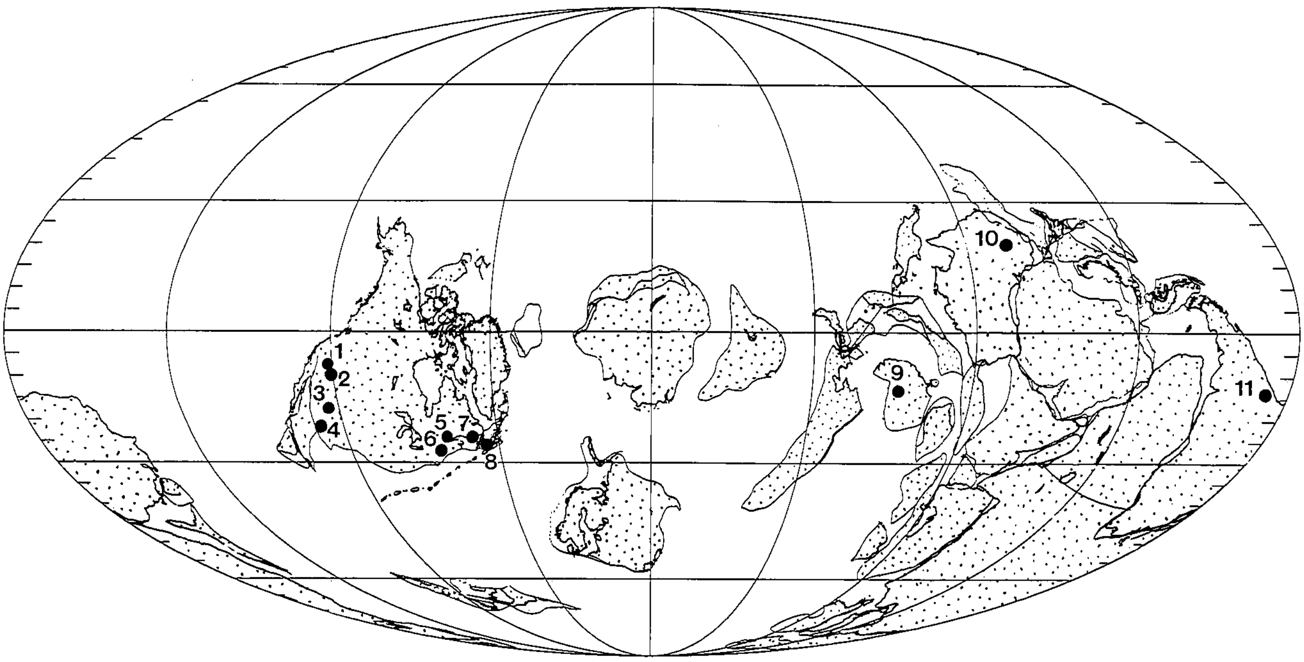


FIGURE 7.—*Paleogeographic map showing distribution of major Ordovician sponge faunas throughout the world. 1.—central and eastern Nevada (Bassler 1941); 2.—western and central Utah (Rigby notes); 3.—New Mexico; 4.—western Texas; 5.—eastern Ontario and southwestern Quebec (Wilson 1948); 6.—eastern New York and western Vermont (Raymond and Okulitch 1940); 7.—the Mingan Islands of Quebec (Billings 1859, Twenhofel 1938); 8.—western Newfoundland; 9.—the Yangtze River area of eastern China (Deng 1982); 10.—central New South Wales, Australia (Rigby and Webby 1988, Webby and Rigby 1985); 11.—San Juan Province, Argentina, the fauna described in the present paper. The paleotropical concentration of major Lower and Middle Ordovician sponge faunas is readily apparent from the distribution of localities plotted here. Late Ordovician faunas, not shown, also show the same general pattern of distribution. References not all inclusive (base map from Scotese and McKerrow 1990).*

landoceras, and *Endoceras* (Aceñolaza and others 1977, Borello 1961); ostracodes: *Anisochilina* (Beresi 1981); gastropods: *Ophileta* (*Ozarquispira*), *Hormotoma*, and *Liospira;* bivalves: *Modiolopsis* (Sánchez 1985); brachiopods: *Taffia anomala*, *Petroria rugosa*, *Platystrophia king* (Benedetto and Herrera 1986, 1987a), *Tritoechia azulensis*, *Tritoechia inaequicosta*, and *Pomatotrema talacastoensis* (Benedetto 1987b), and *Clitambonites* (Harrington and Leanza 1957); bryozoans: *Monticulipora argentina;* sponges: *Archaeoscyphia*, *Calycocoelia*, *Patellispongia*, *Hudsonospongia*, and *"Leptomitus"* (Beresi 1990, Carrera 1985); crinoids: *Cheirocrinus* (Contreras and Peralta 1990); and microalgae: *Nuia*, *Sphaerocodium*, *Kamaenella*, *Calciphona*, and *Asphaltina* (Beresi 1991b). The types of limestones most common are peloidal mudstones, skeletal and bioclastic wackestones, oolithic and bioclastic packstones, and algal intraclastic grainstones.

ACKNOWLEDGMENTS

We express our thanks to officers of Brigham Young University, the College of Physical and Mathematical Sciences, and to the Department of Geology for support through various phases of the project. Bevan Ott, associate academic vice president, made funds available through Dean Grant Mason of the College of Physical and Mathematical Sciences for logistical support, office space, and secretarial help during preparation of the fossils and examination, description, and illustration of the sponges. Dana Griffin, chair of the Department of Geology, was particularly helpful in making arrangements for facilities and materials.

Laureen Bird assisted in manuscript research and preparation. Bruce Ashton, in charge of Family Housing at the university, assisted in arranging housing for Beresi while she was at Brigham Young University as a visiting scholar. Thin sections were prepared by Scott Wagner of Wagner Petrographic, American Fork, Utah.

William Sill made some of the collections of sponges while he was a professor of paleontology at the University of San Juan. He sent some of the early-collected materials to Rigby for study during the five-year period that he occupied the post at San Juan. He is currently associated with the University of Texas at Austin, Texas. To all of these people we express our gratitude.

Funds for Beresi's visit to Brigham Young University in

Table 2. Latitude and longitude of main Ordovician sponge localities of San Juan.

LOCALITY	LATITUDE	LONGITUDE	TOPOGRAPHIC QUADRANGLE
Agua Hedionda	30°08′20″	68°31′00″	18C Jáchal
Talacasto Gulch	31°00′30″	68°45′30″	20C Ullúm
Villicúm Range	31°19′40″	68°33′00″	20C Ullúm

(Arenigian) faunas of brachiopods, trilobites, nautiloids, and sponges occur in faunas similar to those of the carbonate platforms of western North America (Utah, Nevada), to those of the Appalachian basin in eastern North America, and to those of Spitzbergen (Baldis and Beresi 1981).

During the Early Ordovician, carbonates were abundant in the present Precordilleran region of Argentina, which at the time was on the western margin of Gondwana. A rich and diversified benthic fauna flourished on the carbonate platform. The widespread normal carbonate sediments contain well-preserved biotas, and the combined evidence suggests good water circulation in an open shelf in waters of normal salinity. Abundance of organisms suggests an adequate nutrient supply, and occurrence of algae indicates accumulation in the photic zone. All evidence indicates the region experienced warm to hot temperatures in a tropical zone (Beresi 1981, 1986a,c; Seräpagli 1973, 1974).

Berry (1979, p. 105–9) concluded that northern Argentina, in the Early Ordovician, was in the Atlantic faunal province, based on graptolites, but that western Argentina was in the Pacific faunal province, along with Australia, Asia, and North America. He concluded that the primary differences were temperature controlled and that the Pacific province was tropical and subtropical. He also concluded that wide distribution of water with similar temperature indicators suggests oceanic currents were weak, which may have allowed continued province integrity until a major shift of land relationships developed in the Llanvirnian-Llandeilian.

Reconstruction of paleogeographic relationships for the Arenigian by Scotese and McKerrow (1990) shows most Pacific faunal regions of Berry (1979) along the northern side (tropical side) of land clusters and shows that areas with sponge faunas most similar to those of Argentina also occur in warmer regions. These were generally bathed by tropical currents (fig. 8), as we have reconstructed them, and located away from the cooler regions shown in the southern hemisphere by Berry and Wilde (1990, fig. 1, p. 130).

Arenigian sponge faunas are so poorly known, from so few localities, that they can contribute little additional to our understanding of Ordovician paleogeography.

Scotese and McKerrow (1990, figs. 2–7) determined the South Pole was located 20°–40° to the south of present-day North Africa during the Cambrian and Early Ordovician. The orientation of Gondwana used by Scotese and McKerrow was based on the apparent polar wander (APW) path determined from paleoclimatic rather than paleomagnetic data.

Scotese and McKerrow (1990, fig. 22), in their discussion about climatic changes during the Paleozoic, suggested that the western part of Gondwana had cold temperatures, as suggested by faunas and lithofacies, yet in their fig. 7 (p. 8), they show present extreme southern South America was in an equatorial position and much of Argentina was at least tropical. Scotese and Barrett (1990, fig. 6) determined that the South Pole was located just off the coast of North Africa during the Late Cambrian and Middle Ordovician (35°N, 10°W), based on distribution of climatically sensitive lithofacies. The Precordillera area of the San Juan and Mendoza Provinces would have been located about 15°S, using their reconstruction.

Cycles of carbonates accumulated in the present Precordillera region from the Early Cambrian (*Olenellus* Zone, Bordonaro 1986) to the early Llanvirnian (*Pygodus serra* Zone, Lozano and Hünicken 1990). During the Arenigian, limestones of the San Juan Formation accumulated to a thickness of about 400 m. These beds are richly fossiliferous, with well-preserved benthic and nektonic biotas. The widespread normal carbonate sediments with a rich and diverse benthic fauna indicate good water circulation on an open shelf with normal salinity and adequate nutrient supply in the photic zone. Temperatures were warm in this tropical zone (Beresi 1986a,c).

The Ordovician limestones gradationally overlie the Cambrian peritidal carbonate with microbial mats. Uppermost limestones of the San Juan beds interfinger with pelitic layers with graptolite faunas of the *Paraglossograptus tentaculatus* Zone of the Lower Llanvirn (Cuerda 1985, Cuerda and others 1989). The realm of the carbonate platform was dominated by a diversified fauna of the articulated brachiopods *Orthidium, Nanorthis, Platystrophia minuta, Tritoechia* sp., *Sanjuanella aplicata* (Herrera and Benedetto 1989), and additional strophomenid, clitambonitacean, rhynchonellacean, lingulid, and acrotretid brachiopods. Other fossils previously reported include trilobites: *Annamitella tellecheai, Illaenus*, and *Amphyx* (Baldis and Blasco 1975, Harrington and Leanza 1957); nautiloids: *Curtoceras kayseri, Oe-*

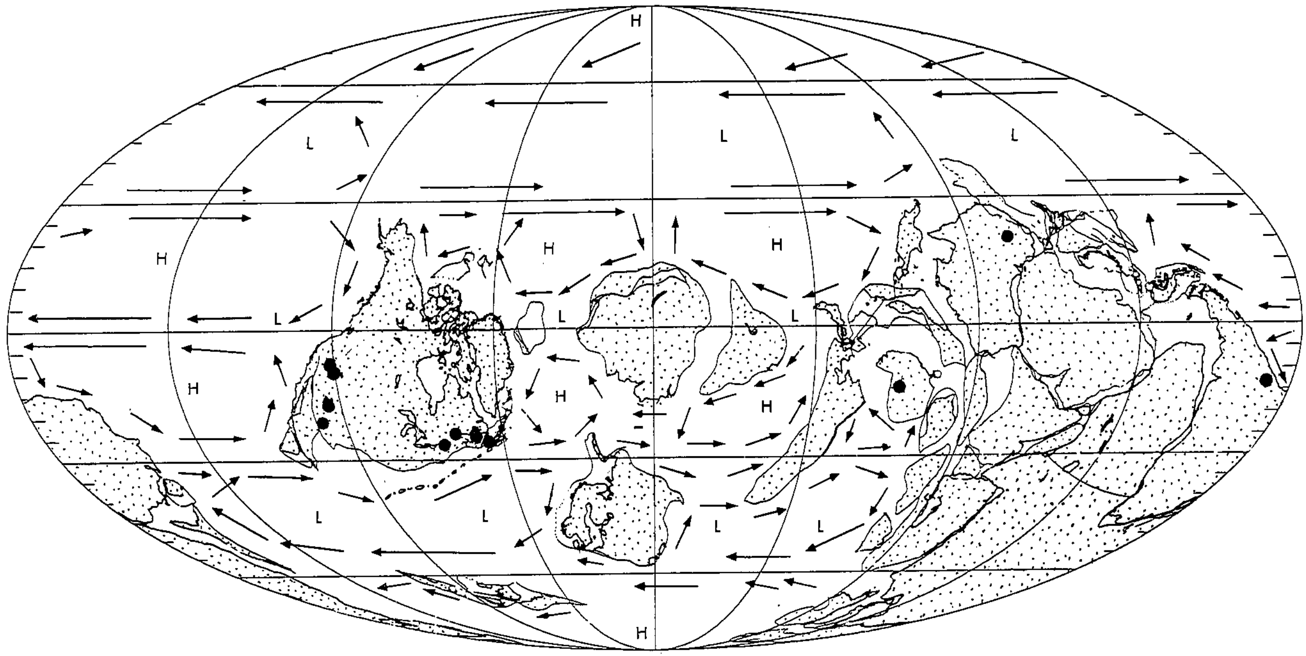


FIGURE 8.—*Generalized wind patterns and hypothesized circulation of major oceanic cells in a Lower Ordovician paleogeographic setting. Moderate distances separate the Argentine localities from the other major Lower and Middle Ordovician sponge faunas of the world. Dark circles indicate major sponge faunas known to date. The apparently isolated faunas of Argentina, Australia, and China suggest that the record for fossil sponges for this particular time is inadequate, and that other faunas in areas between might provide connections not now apparent. Base map from Scotese and McKerrow (1990). H.—high pressure area; L.—low pressure area, using a model of a modified ideal global circulation pattern.*

the United States were largely obtained through a fellowship from the Organization of American States. Other funds were from grants made available to Rigby. Later stages of manuscript preparation and illustration were partially covered by National Science Foundation Grant EAR 9116202 to Rigby.

CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas) of Argentina made it possible for early planning and provided some transportation costs. We thank Dr. Bruno A. Baldis, professor at San Juan University and researcher at CONICET, and Dr. Osvaldo Bordonaro, professor at San Juan University, who accompanied Beresi during fieldwork, for their help and encouragement. We also thank Dr. Wolfgang Wolkheimer, director of Geological and Palaeontological Projects in CRICYT-Mendoza (Centro Regional de Investigaciones Científicas y Tecnológicas). Appreciation is extended to colleagues of the PRIBIPA at CRICYT-Mendoza for discussions concerning paleoecology, environments of deposition, and stratigraphy.

Beresi expresses appreciation to her family. Juan Carlos Delgado, her husband, supported her research activities in the field and her stay at Brigham Young University. Carlos Beresi, her brother, accompanied her during fieldwork and collection of the specimens.

DEPOSITORIES

Sponges are deposited in systematic fossil collections of the Centro Regional de Investigaciones Científicas y Tecnológicas (CRICYT), Mendoza, Argentina, and the U.S. National Museum (USNM), Washington, D.C., USA.

SYSTEMATIC PALEONTOLOGY

Class DEMOSPONGEA Sollas, 1875
Order LITHISTIDA Schmidt, 1870
Suborder ORCHOCLADINA Rauff, 1895
(nom. transl. Reid, 1963)
Family ANTHASPIDELLIDAE Miller, 1889
Genus ARCHAEOSCYPHIA Hinde, 1889

Discussion. Archaeoscyphia is one of the most widespread genera within the family. It was initially described as *Petraia minganensis* by Billings (1859) and was included within *Archaeocyathus* in early papers, but in 1889 Hinde erected the genus *Archaeoscyphia* to include that species. Since then the genus has been broadly reported throughout eastern North America and Europe. Rigby and Webby (1988) described a single specimen of the genus and species from the Malongulli Formation of

New South Wales in Australia. In 1927, and again in 1941, Bassler described *Nevadocoelia* from Early Ordovician rocks from central Nevada. He proposed, in addition to others, the species *Nevadocoelia wistae* and *Nevadocoelia grandis*. These sponges should probably be considered within the genus *Archaeoscyphia*. Whether the species of *Archaeoscyphia* and *Nevadocoelia* are distinct species remains yet to be determined, following a currently underway intensive review of that Nevada Early Ordovician sponge fauna. To these occurrences now should be added the common occurrence of *Archaeoscyphia* in the middle Arenigian-Ordovician rocks of Talacasto Gulch, in the Precordillera Central in northern San Juan Province.

Type species. Petraia minganensis Billings, 1859.

ARCHAEOSCYPHIA MINGANENSIS (Billings 1859)

pl. 1, figs. 1, 3, 5, 7; pl. 2, fig. 4; pl. 7, fig. 4; pl. 8, figs. 1, 2

Synonymy. Petraia minganensis Billings, 1859, p. 345; Hitchcock, 1861, p. 217–18.

Archaeocyathus minganensis (Billings). Billings, 1861, p. 5; Billings, 1865, p. 354–57, figs. 342a, b, 343a, 344; Nicholson, 1872, p. 68, fig. 15; Dawson, 1875, p. 152, fig. 38; Roemer, 1876, pl. 2, fig. 2a; Miller, 1877, pl. 154, figs. 2a–b; Roemer, 1880, p. 299, pl. 2, figs. 2a–b; Zittel, 1880, p. 173, 728; Hinde, 1884, p. 835; Walcott, 1887, p. 142–46; Hinde, 1888, p. 226–27; Chamberlain and Salisbury, 1907, p. 363, fig. 168c; Okulitch, 1935, p. 99–100.

Ethmophyllum minganensis (Billings). Walcott, 1886, pl. 72, figs. 6–8; Miller, 1889, p. 159; Lesley, 1889–90, p. xxii, 225.

Archaeoscyphia minganensis (Billings). Hinde, 1889, p. 143, pl. 5, figs. 12–14; Rauff, 1894, pl. 1, figs. 1–10; Dana, 1895, p. 474; Schuchert and Twenhofel, 1910, p. 687; Boucart and Le Villain, 1931, p. 13; Schuchert and Dunbar, 1934, p. 68; Twenhofel, 1938, p. 34; Shimer and Shrock, 1944, p. 51, pl. 15, figs. 5, 6; de Laubenfels, 1955, p. E53–E54; Bolton, 1960, p. 8; Williams, 1976, p. 49–50; Toomey and Nitecki, 1979, p. 113, figs. 55a–b; Rigby, 1983, p. 22, fig. 7b; Rigby and Webby, 1988, p. 29–31, pl. 8, figs. 1–6, text fig. 9; Rigby and Chatterton, 1989, p. 14–15, pl. 2, figs. 1, 2, pl. 3, figs. 1, 2; de Freitas, 1989, p. 1874–75; figs. 6m, 7b, 7c.

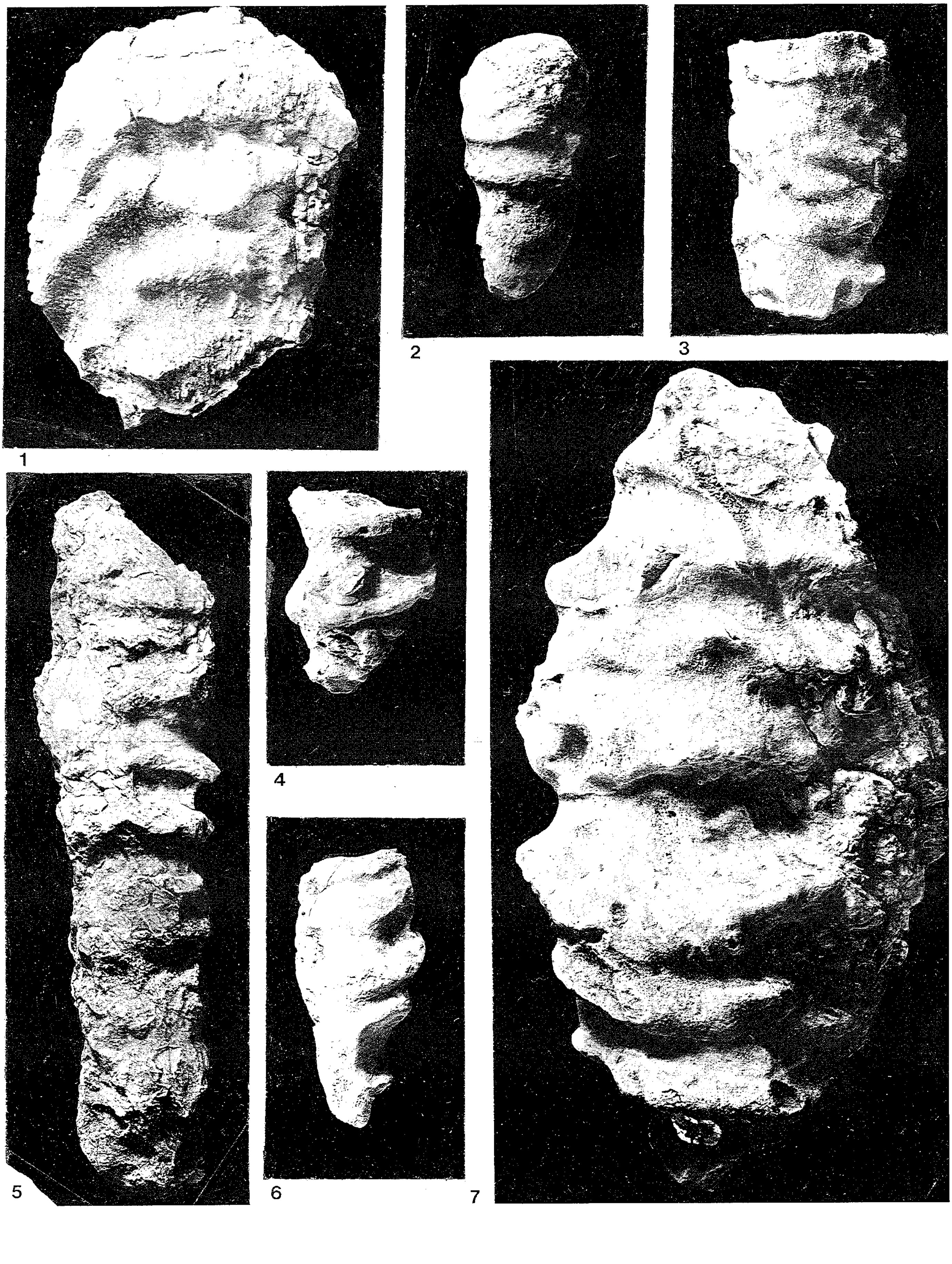
Archaeoscyphia annulata Cullison. Beresi, 1981, p. 405, fig. 1, p. 416.

Diagnosis. "Annulate, tubular, large anthaspidellid sponge with smooth, conical to subcylindrical spongocoel. Exterior marked by horizontal ringlike annulations. Skeleton typically anthaspidellid with trabs produced by ladderlike series of dendroclones. Surface of pinnation approximately at one-third wall thickness in from gastral margin. Trabs rise inward to meet the gastral margin at a high angle and outward to meet the exterior either steeply inclined, or subhorizontally in the annulations. Gastral layer little differentiated although a thin dermal layer is defined, particularly along margins of some annulations. Three canal series are evident—most prominent is a vertically stacked radial series that arches upward from exterior and slopes downward into gastral part of sponge. A second series of subvertical interior canals arch upward and outward, roughly parallel to trabs. Smaller canals interconnect two large series" (Rigby and Webby 1988, p. 299).

Description. Five moderately complete and eight other more fragmental specimens of this coarse-textured *Archaeoscyphia* occur in the collection. They range from a nearly complete form, 20 cm tall, to the smallest fragment only 7.5 mm tall. All show the prominent horizontal annulation so characteristic of the genus and species. Most appear subcylindrical to steeply conical-cylindrical and have diameters that range 40–52 mm in the con-

EXPLANATION OF PLATE 1

Archaeoscyphia minganensis (Billings 1859) and *Archaeoscyphia nana* n. sp. Figs. 1, 3, 5, 7.—*Archaeoscyphia minganensis* (Billings 1859), San Juan Formation at Talacasto Gulch, shows the general range of the species; *1*, CRICYT T-1/44, X1; *3*, CRICYT T-1/30, X0.5; *5*, the largest and most nearly complete specimen of the species in the San Juan collection; it shows a characteristic annulate, tall, cylindrical form of the species most clearly, although in part matrix-covered, particularly on the left, CRICYT T-1/16, X0.5; *7*, moderately robust specimen showing irregularity in annulations and the regularity of the skeletal net, particularly on ridge in the middle and lower part of the sponge, CRICYT T-47, X1. Figs. 2, 4, 6.—*Archaeoscyphia nana* n. sp., San Juan Formation; *2*, holotype shows the relatively small size and annulate form of the relatively delicate sponge; a shallow depression in matrix at the summit is upper end of the spongocoel, which extends through most of the sponge length; thin sections were made of the specimen to show internal structure, Talacasto Gulch, CRICYT T-13, X1; *4*, paratype shows characteristic broad annulations with sharp crests above the broad, rounded interridge areas, Huaco locality, CRICYT H-20, X1; *6*, paratype shows the conico-cylindrical form of the species, the broad and moderately irregularly placed annulations and the relatively delicate nature of the skeletal structure, Huaco locality, USNM 463470, X1.


1
2
3
4
5
6
7

stricted areas between the prominent annulations. These generally are rounded, broad depressions, considerably wider than the moderately sharp crested ridges that expand the sponge to diameters up to 80 mm, although most appear to be 60–70 mm in diameter at ridge crests.

Horizontal ridges rise 9–13 mm high above the general tubular basic form of the sponge. They have broad sweeping bases but become moderately narrow, only 4–5 mm wide, on their rounded outer edges. Ridges of the annulations appear as prominent, almost flaring, collarlike features. They are spaced such that five to six ridges occur per 10 cm. In general, the annulations continue uninterrupted around the circumference of the sponge, but in one small specimen the annulations are interrupted and each is offset slightly. In the middle part of one large specimen, one annulation splits into two and then recombines as it is traced around the sponge, but this is unusual.

The largest specimen has a broken base and oscular margin. The entire complete sponge could be several centimeters taller than the maximum in the collection. On none of the specimens at hand do we see a complete osculum or what is considered a likely complete conical tip.

Where evident, walls of the sponges are 7–14 mm thick around the continuous spongocoel but only 9–12 mm thick in the broken lower parts of the sponges. In the large specimen the spongocoel is 48 × 73 mm across, and in another large fragment the spongocoel is 32 × 34 mm across. Only partial diameters are evident in the other small fragments that do not include their full circumferences. In general, the gastral surface of the wall appears to be smooth, so that the central opening tends to be smoothly tubular and does not reflect the annulations that are so prominent on the exterior.

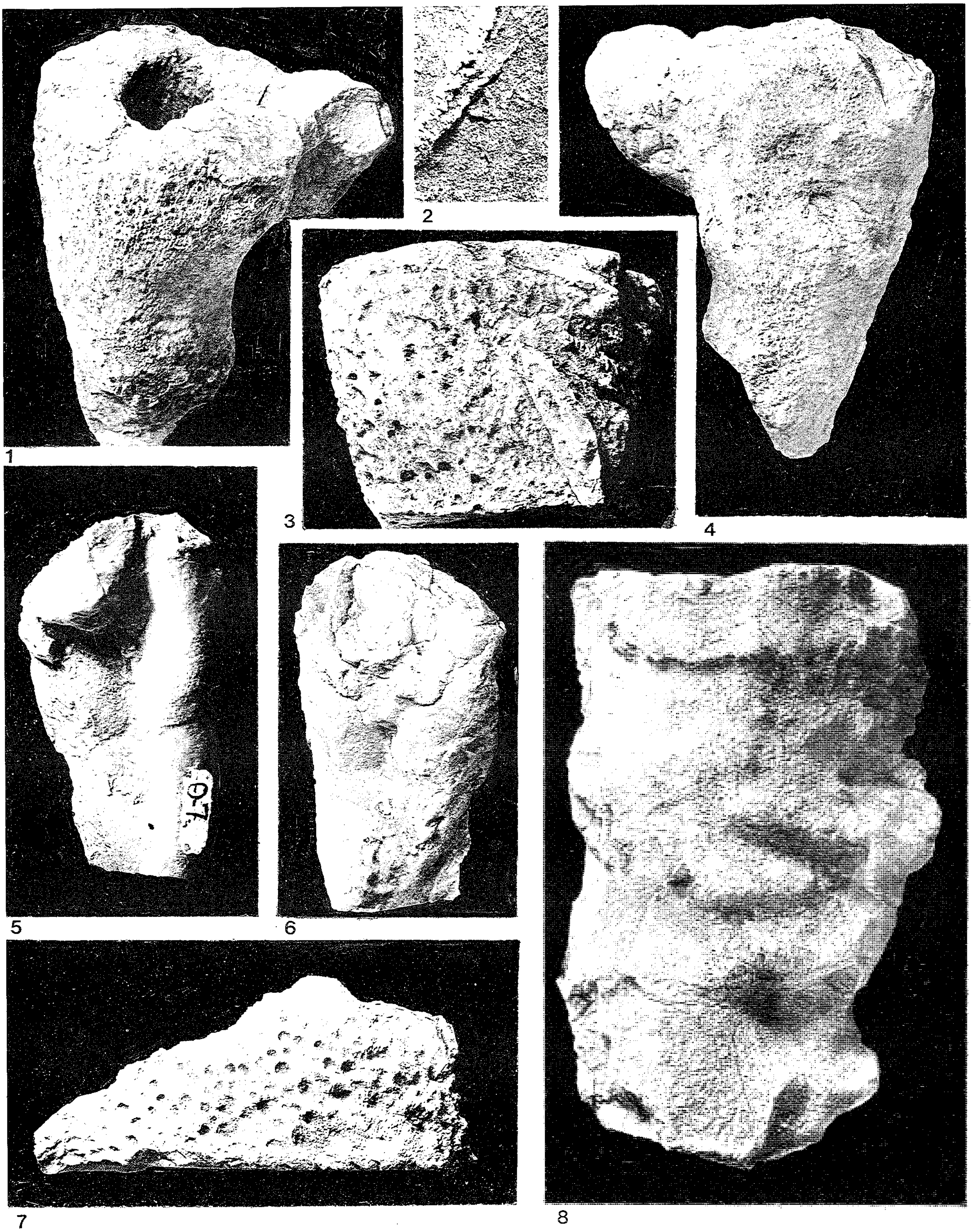
Small circular dermal ostia are arranged in vertically stacked series on the exterior, in a pattern common in this species and many others in the family. These dermal ostia generally range 1.2–2.0 mm in diameter and open into the radial canals that are so prominent in the almost coral-like-appearing cross sections of the walls of the sponge. Other dermal ostia, 0.8 mm and as small as 0.2 mm in diameter, also occur. The larger openings tend to be in regularly arranged series, but the smaller openings are more irregular in their placement.

On one particularly well-preserved specimen, dermal ostia range 0.4–0.8 mm in diameter, with most approximately 0.6–0.7 mm across. They tend to be circular to slightly elongate, vertically, and those are only slightly higher than wide. These ostia occur four to six per cm^2 on the exterior and may be essentially side by side or occur approximately one per mm in a single, vertical series. They may be horizontally similarly spaced, five to six series per 5 mm, measured on the surface. In general, ostia are side by side, separated only by one or at the most two trab complexes on the exterior. Ostia may occur in diagonally alternating positions.

The generally straight radial canals are prominent; they may branch radially to maintain a uniform size and spacing, but in general the canals pierce completely through the thick wall. They rise slightly, perhaps 20°–30° from the dermal surface, particularly in outer parts of the annular ridges. These canals become subhorizontal at midwall and slope downward into the spongocoel. There are no major coarse canals parallel to the trabs, and simi-

EXPLANATION OF PLATE 2

Archaeoscyphia, Calycocoelia, Rhopalocoelia, and a heteractinid spicule from the San Juan Formation at Talacasto Gulch and the Villicúm Range. Figs. 1, 4.—*Hudsonospongia cyclostoma* Raymond and Okulitch, 1940, from the Villicúm Range locality; showing the general growth form of the species and the moderately coarse trab-based anthaspidellid skeleton that forms thick walls around the large spongocoel, CRICYT VI-2, both X1. Fig. 2.—Single, moderately well preserved octactine heteractinid sponge spicule; three upper tangential rays and the nodelike base of a radial ray are moderately well preserved; the three lower tangential rays are less well preserved; this is only one of two such spicules known from the collection; it occurs in matrix on the gastral side of a large paratype of *Patellispongia robusta* n. sp. (USNM 463464) from the San Juan Formation at Talacasto Gulch. Figs. 3, 7.—*Calycocoelia perforata* n. sp.; 3, paratype shows the smooth dermal surface of the subcylindrical to conico-cylindrical species, with a moderately thick wall perforated by coarse ostia of radial canals and with a moderately regular anthaspidellid skeleton interrupted by pores of smaller canals, San Juan Formation, Villicúm Range, CRICYT VI-2, X1. 7, holotype, view of gastral surface shows coarse gastral ostia interrupting the prominent anthaspidellid skeletal net in the gently arched fragment, San Juan Formation, Villicúm Range, CRICYT VI-F1, X1. Figs. 5, 6.—*Rhopalocoelia rama* n. sp., holotype, showing moderately cylindrical to weakly annulate branches; the smooth surface suggestive of the fine skeletal net, San Juan Formation, Talacasto Gulch, CRICYT T-07, X1. Fig. 8.—*Archaeoscyphia minganensis* (Billings 1859), side view shows irregular ridges and annulate growth form, with moderately coarse skeleton shown by the regular vertical structure of the ladderlike trabs and aligned ostia of radial horizontal canals, San Juan Formation, Talacasto Gulch, CRICYT T-1/30, X1.


1
2
3
4
5
6
7
8

larly lacking are other vertical canals. Canals of the wall are essentially only the subhorizontal radiating series. In transverse section the prominent radial development of the skeletal structure and the canal system is particularly evident. Most of the canals appear as openings not much larger than those skeletal pores between normally situated trabs, but canals are evident in horizontal sections by absence of bridging dendroclones at the level of the canals and by moderately long bridging dendroclones, both below and above the canals in their stacked series.

Ostia on the gastral surface appear circular and approximately 1.0–1.2 mm high. On the weathered surface of the same specimen, gastral ostia occur in vertically stacked series, spaced so that they occur approximately one per mm, measured horizontally around the surface, and occur two to three per 5 mm, measured vertically in a single series. They are generally circular but may be slightly elongate vertically, indicating that some may enter the spongocoel at a slight angle. Such ostia may be locally up to 1.5 mm high and 1.0 mm wide, but most are circular and approximately 1 mm in diameter.

The circular large pores apparently interconnect adjacent vertical skeletal pores that are parallel to the trabs. They are openings within or through the dendroclone series and are usually circular to somewhat rounded prismatic. These openings range 0.28–0.50 mm high, with most approximately 0.32–0.36 mm high. These are also the pores that apparently connect skeletal openings, parallel to the trabs, to the major radial horizontal canals.

Individual trabs are moderately continuous, subcylindrical structures and range 0.10–0.20 mm in diameter, with most approximately 0.15–0.18 mm across. Variation in diameter is related to numbers of dendroclone series that converge to make a particular trab. They are spaced 0.20–0.48 mm apart radially and somewhat more widely than that parallel to the gastral or dermal surface.

Moderately porous natures of the trabs are evident in areas where skeletal structure is particularly well preserved and where trab origin as combined tips of multiple dendroclone spicules is particularly evident. Spicule tips show prominently as rounded cross sections in transverse sections, in particular. In some areas the almost clawlike appearance of some cladome tips shows moderately well.

The surface of pinnation is approximately in the middle of the wall in vertical thin sections of a specimen from Talacasto. Trabs in the gastral part of the wall diverge from that surface at about 10°–15° and meet the gastral surface with essentially those angles. Trabs on the dermal surface, however, curve upward and outward, diverging at 10°–15° in the millimeter or so near the surface of pinnation, but curve increasingly sharply upward so that in the interridge indented areas they may meet the dermal surface at approximately 30°. But they swing abruptly outward within the ridges, so that along a ridge crest they may meet the dermal surface at 60°–70°.

Most spicules are simple I- and Y-shaped dendroclones, with long, smooth shafts and short, bifurcating clads. Shafts range 0.25–0.68 mm long and 0.05–0.10 mm in diameter, with the narrowest part generally near the brachyome expansion. Longest spicules bridge concentrically across canals, and shorter spicules occur in radiating series. In a single ladderlike series, three to six horizontal dendroclones occur per millimeter, vertically, but generally occur three to four per millimeter.

Clads of the cladome are 0.12–0.20 mm long and range 0.04–0.10 mm in diameter, essentially like thicknesses of shafts. Most appear to be approximately 0.2 mm long and to have diameters of approximately 0.08 mm. Clads of the cladome commonly diverge at approximately 60°, but with considerable variation. Cladome ends are generally obscured in the somewhat massive calcareous replacement. Evidence available suggests no coring oxeas occur within the trabs.

A few prominent equal-rayed, Y-shaped dendroclones are evident. These have rays approximately 0.25 mm long and diameters of approximately 0.1 mm near their common ray junctions. The rays taper abruptly radially to approximately 0.05 mm in diameter before flaring into prominent articulating tips, which may be up to 0.15 mm across. These moderately rare spicules bridge some of the wider canals, particularly in areas where canals converge at midwall.

Dendroclones outline elliptical skeletal pores that are 0.12–0.16 mm wide. Heights of these pores between the dendroclones vary considerably. For example, where only three dendroclones occur per millimeter, pores may be up to 0.5 mm high, but elsewhere, where spicules are closely spaced, the pores may be as small as 0.1 mm high.

As in many genera within the family, there appear to be alternations of brachyome and cladome orientation in the ladderlike series so that occurrence along a single trab shows alternating cladome, brachyome, cladome, brachyome in a series.

There is no evidence of differentiation of a gastral or a dermal layer in the cross section, but normal-size dendroclones and trabs appear to extend to edges of the walls.

Discussion. The San Juan material is similar in overall dimensions to the type material from the Mingan Islands, although the sponges from Argentina may have somewhat smaller diameters. Nonetheless, the overall appearance, the nature of the skeleton, and nature of the canals indicate that the material from San Juan should be included within *Archaeoscyphia minganensis* (Billings 1859).

Archaeoscyphia annulata Cullison, 1944, has the same general growth form, that of an annulate conical-cylindrical sponge, but *A. annulata* has annulations considerably more widely spaced than seen here. The wall in *A. annulata* is also much thinner in areas of the same diameter.

In general proportions, the San Juan material is like the specimen of *Archaeoscyphia minganensis* described by Rigby and Webby (1988) from Australia, except in the San Juan material the ridges are considerably more exaggerated and the canals in the San Juan sponges tend to be simply arcuate upward, rather than having the curved sickle-shaped paths illustrated by Rigby and Webby (1988, text fig. 9). Those curved outer paths may have been produced by intersections of the radial canals and a series more or less parallel to the skeletal trabs. In addition, the San Juan material apparently does not have a dermal layer, like that noted by Rigby and Webby (1988) in the Australian material.

De Freitas (1989) concluded from examination of the abundant anthaspidellid orchoclad lithistids of the Silurian of Arctic Canada that many genera previously recognized as distinct should be synonomized under the genus *Archaeoscyphia*. He included *Calycocoelia* Bassler, 1927; *Rhopalocoelia* Raymond and Okulitch, 1940; *Somersetella* Rigby and Dixon, 1979; and *Steliella* Hinde, 1889, under the genus *Archaeoscyphia* Hinde, 1889. He suggested that these sponges show an almost continuous morphologic gradient. However, taking that step reduces the ability to separate what we consider to be distinct forms, and we continue to separate *Calycocoelia* and *Rhopalocoelia*, etc., as distinct genera, even though there may be some overlap in particular morphologic aspects with the genus *Archaeoscyphia*. *Calycocoelia* is a goblet-shaped form described from the Ordovician of Nevada, and *Rhopalocoelia* was described from the Ordovician of the New England region. These are both relatively smooth, tubular forms and have a simple spongocoel like that characteristic of *Archaeoscyphia* but lack the prominent annulations that figure so extensively on the dermal surface of Ordovician and Silurian species of that genus.

De Freitas (1989) placed *Calycocoelia annulata* Rigby, 1973, and *Somersetella conicula* Rigby and Dixon, 1979, into the combined *Archaeoscyphia annulata* (Rigby and Nitecki 1973). This name is not available because Cullison (1944) proposed the species *Archaeoscyphia annulata* from the Ordovician of Missouri. A new name would be necessary for that combination. However, we have not followed de Freitas' suggestions and have maintained the various genera as distinct forms. Such separation best describes what we think are significant differences between *Archaeoscyphia*, *Calycocoelia*, and *Rhopalocoelia*.

Material. Twelve specimens occur in the collection from the San Juan Formation; all are from Talacasto Gulch in the Precordillera Central, San Juan Province. Most are fragments, but one is a nearly complete specimen. Figured specimens CRICYT T-1/16, T-47, T-1/30, and T-1/44; additional reference specimens USNM 463477–463484.

ARCHAEOSCYPHIA NANA n. sp

pl. 1, figs. 2, 4, 6; pl. 8, figs. 3, 4

Diagnosis. Small, conical-cylindrical, annulate, anthaspidellids with a prominent, simple, open spongocoel; annulation ridges spaced approximately 1 cm or less. Individual specimens to approximately 6 cm tall, expand upward from pointed base to rounded upper oscular margin; ostia and arched horizontal canals 0.2–0.5 mm in diameter in stacked series, skeleton of small dendroclones, trabs 0.08–0.15 mm in diameter.

Description. The holotype and most complete specimen is 5.8 cm tall and marked by prominent, subhorizontal to sloping, annulate ridges that extend outward up to 8 mm above rounded intervening annular constrictions. The holotype has a broken basal diameter of approximately 1 cm, but that base must be near the ultimate attachment point. The sponge expands upward in its basic conical-cylindrical diameter to 13–16 mm. The rounded annular ridges are moderately sharp and are approximately 6 mm wide at the rounded crests. Their surfaces rise in sweeping fashion above the broadly rounded troughs of the annulations. Ridges produce diameters of up to 25 mm from crest to crest. Ridges are spaced 6–8 mm apart, in contrast to the significantly wider spacing in the larger species. Some annular ridges have minor radial nodes as weak culminations on ridge crests.

All specimens are perforated by a simple, circular to slightly elliptical tubular spongocoel that ranges from approximately 5.6 × 8 mm across to 12 × 16 mm across. These elliptical openings help produce walls of somewhat irregular thickness, with walls only 1 mm thick opposite the narrow dimensions of the spongocoel but up to approximately 6 mm thick opposite long ends of the elliptical openings. Variation in thickness is a result of growth and not of burial distortion or erosion, because annulations are well preserved external to both short and long dimensions of the spongocoel ellipse.

Ostia on dermal surfaces generally range 0.2–0.5 mm in diameter, with most approximately 0.25–0.30 mm across. As in larger species of the genus, these are arranged in vertically stacked series, parallel to the major trabs of the skeleton.

Moderate clusters of vertical canals lead up into the base of the spongocoel. These canals are generally subcircular and 0.6–0.8 mm in diameter. They apparently are upturned inner ends of the essentially horizontal small canals that pierce the sponge wall. These latter canals are not well defined in vertical sections but do show as distinct radial interruptions in the skeletal net in horizontal ones. Part of the reason for their obscurity is that they are of the same general dimensions as vertical skeletal pores between the trabs. These gently uparched to horizontal canals are generally 0.4–0.5 mm wide and are only moderately well defined as radial openings. These canals have gastral ostia approximately 0.5–0.6 mm in diameter, in the spongocoel margin, and are essentially side by side, separated only by a single trab series.

Trabs range 0.08–0.15 mm in diameter, with most approximately 0.10 mm across, internally and at the dermal surface. Many trabs have a moderately porous appearance, with apparently only a few ladderlike dendroclone series articulating to form the trabs. Internally trabs are radially spaced 0.25–0.40 mm apart, but on the dermal surface they are spaced 0.2–0.5 mm apart, horizontally, with trabs bounding the vertically stacked series of ostia.

Trabs have a surface of pinnation about one-third the thickness of the wall in from the dermal layer. Individual trabs arch upward and outward and meet the dermal surface at 50°–60° from vertical. Trabs are subparallel to lower edges of the annulate ridges and meet upper edges of the ridges at high angles. Trabs diverge only 10°–15° from the surface of pinnation toward the gastral surface, so they are moderately subparallel margins of the spongocoel.

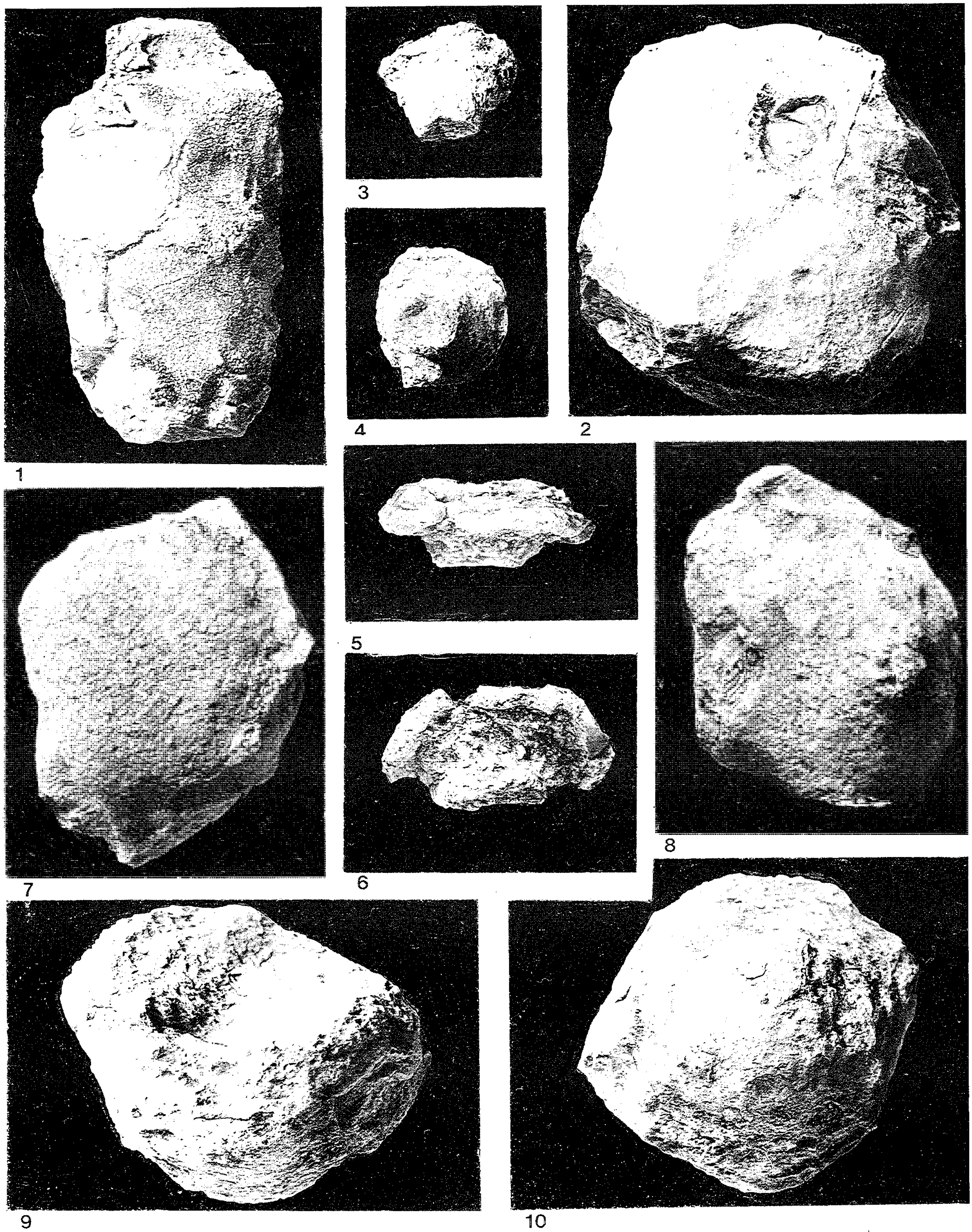
Principal spicules in the skeletal net are Y-shaped and I-shaped dendroclones. These are all moderately small spicules with smooth shafts and prominent cladomes. Characteristic Y-shaped dendroclones have shafts up to 0.4 mm long, and many have long clads, up to 0.2 mm long. Shafts of Y-shaped spicules are 0.04–0.05 mm in diameter and taper to approximately 0.03 mm in diameter before expanding abruptly into the brachyome. Clads have basal ray diameters of approximately 0.04 mm before tapering to approximately 0.03 mm in diameter at their narrowest near the abrupt handlike expansion of the zygome tips as they articulate with other spicules to form the trabs. Details of that articulation are lost in the coarse calcareous preservation. These long clads commonly diverge at approximately 90° from each other or at a mutual 45° from the shaft axis.

A few equal-rayed, Y-shaped spicules are also present. These have rays 0.30–0.35 mm long and uniformly radiating at approximately 120°. They have basal ray diameters approximately 0.04–0.05 mm across, and they generally taper abruptly from the ray junction to subcylindrical shafts only approximately 0.03 mm in diameter. Rays expand into rhabdomelike terminations that may be 0.04–0.05 mm long, and their expansions may be up to 0.06 mm across as they articulate with ray tips of adjacent spicules in the trabs.

Small oxeas, 0.02–0.3 mm in diameter, occur as coring spicules within the trabs, generally only one or two per cross section. These appear to be smooth, doubly tapering spicules that are probably 1–2 mm long, but their full length was not preserved in the high tangential sections where they are particularly evident in longitudinal thin sections. One oxea fragment is approximately 1.2 mm

EXPLANATION OF PLATE 3

Rhopalocoelia, Hudsonospongia, Aulocopium, and *Protachilleum* from the San Juan Formation. Fig. 1.—*Rhopalocoelia clarkii* Raymond and Okulitch, 1940, showing the characteristic subcylindrical form of the species, the relatively smooth wall, and moderately coarse anthaspidellid skeleton; light-colored matrix in the upper part partially fills the spongocoel in front of a gastral view of a wall fragment; thickness of the wall is suggested by the same upper extension of the sponge, San Juan Formation, Talacasto Gulch locality, CRICYT T-1/27, X1. Figs. 2, 9, 10.—*Hudsonospongia talacastensis* n. sp., 2, paratype with a relatively small spongocoel in the crest of the thick-walled conical form; moderately regular anthaspidellid skeleton shows in the lower center, but in general the internal structure is obscure in the fractured surface on the left, San Juan Formation of Talacasto Gulch, CRICYT T-1/32, X1; *9, 10,* holotype, *9,* oblique side view shows the relatively thick walls, a broad shallow spongocoel on the upper surface, and the broad bowl-like obconical form of the species; *10,* basal view showing the smooth rounded base and walls of the broadly obconical species, San Juan Formation, Talacasto Gulch locality, CRICYT T-1/10, X1. Figs. 3, 4, 5, 6.—*Protachilleum kayseri* Zittel, 1877, figured specimens from the San Juan Formation, Huaco locality, the type locality for this species; *3, 4,* figured specimen, CRICYT H-43; *3,* side view showing relatively stubby base and only incipient flaring of the upper part of the sponge, with vertical canals aligned in the base; *4,* basal view shows dimensions of the lower stem and the gently upward-expanding form of the specimen, both X1; *5, 6,* figured specimen, CRICYT H-42; *5,* side view shows the subcylindrical basal stem and the upper flared and recurved, cake-platter-like part of the sponge; upper surface covered with matrix; *6,* diagonal basal view with the subcylindrical stemlike part of the sponge, partially separated from the thin cake platterlike overhanging upper part of the sponge by adhering matrix, both X1. Figs. 7, 8.—*Aulocopium sanjuanensis* n. sp., paratype shows broadly obconical to subcylindrical form of the species with its smooth exterior perforated only by ostia of the radial canals; base broken and the shallow spongocoel filled with matrix as seen in *8,* from San Juan Formation, Talacasto Gulch locality, CRICYT T-1/22, both X1.


1
2
3
4
5
6
7
8
9
10

long, but details of its terminations are lost. The small oxeas appear as light, continuous, uniform-diametered cores or as dark matrix-fills of pores between rays of cladomes that articulate with the oxeas. In a few instances, uncovered ostia segments mark positions of new trabs where they diverge from the surface of pinnation, trabs that become much more complex a millimeter or so away from that surface.

In only a few trab complexes are numbers of dendroclones per millimeter evident; they tend to occur three or four per mm in most series and define small skeletal pores, approximately 0.2–0.3 mm high. Pores between individual dendroclones are generally round to rounded-elliptical. They open through the ladderlike spicule series and interconnect triangular skeletal pores that parallel the trabs.

Discussion. These small sponges have the annulate growth form, a dendroclone-based skeleton, and the simple open tubular spongocoel characteristic of *Archaeoscyphia*. However, they are uniformly smaller in dimensions than *Archaeoscyphia minganensis* (Billings 1859) and *Archaeoscyphia annulata* Cullison, 1944, and because of this they are separated as a distinct species.

Material. Holotype, CRICYT T-13, paratypes, CRICYT T-14, T-15, and T-16, are from Talacasto Gulch; paratype CRICYT H-22 is from the Huaco locality. An additional three reference specimens, USNM 463467–463469, are from Talacasto Gulch, and two, USNM 463470 and 463471, are from the Huaco locality. All came from the San Juan Formation.

Etymology. Nana, L., dwarf, referring to the small size of the species.

Genus CALYCOCOELIA Bassler, 1941

Diagnosis. Goblet-shaped, smooth-walled sponges with a prominent stem, expanding uniformly upward and outward from the upper part of the stem to a barrel or tubular shape; rounded summit with major deep central spongocoel. Ostia in closely spaced vertical rows parallel to coarse trabs. Skeleton with surface of pinnation of trabs at midwall, spicules mainly long-shafted dendroclones. Horizontal canals radial and regular, end in gastral ostia or upward flexed, coarse vertical canals of axial clusters. Gastral layer may be developed. Coring oxeas present.

Type species. Calycocoelia typicalis Bassler, 1941.

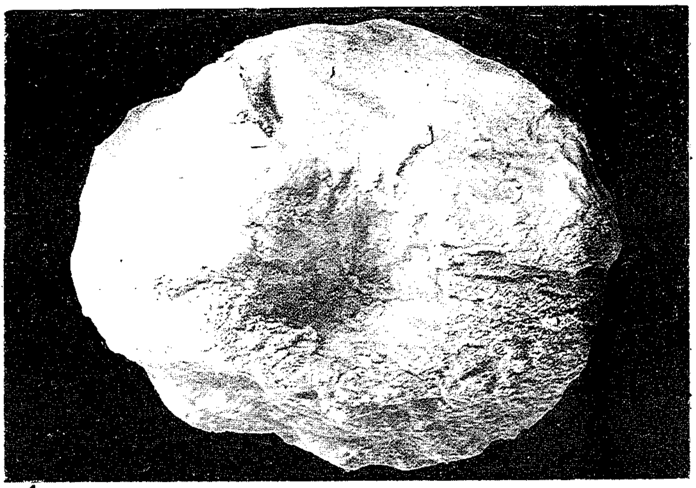
CALYCOCOELIA PERFORATA n. sp.

pl. 2, figs. 3, 7; pl. 8, figs. 5, 6

Diagnosis. Relatively thin-walled *Calycocoelia* with coarse pores in both gastral and dermal surfaces; exterior lacks annulation or ridges. Total shape of sponge unknown because species known only from fragments. Curvature of fragments suggests spongocoel may have been 8 cm in diameter, but that is uncertain. Coarse ostia on exterior interrupt trab-based skeleton and range to 2.6 mm in diameter, occur 1–4 mm apart; intermediate ostia mostly 1.2–1.4 mm across and spaced approximately 1 mm apart; small circular openings generally 0.6 mm in diameter, moderately common, four per cm^2. Gastral ostia to 3 mm in diameter. Surface of pinnation about midwall; trabs prominent, approximately 0.2 mm in diameter and composed of tips of long Y-shaped dendroclones with smooth shafts to 0.6 mm long and 0.18 mm in

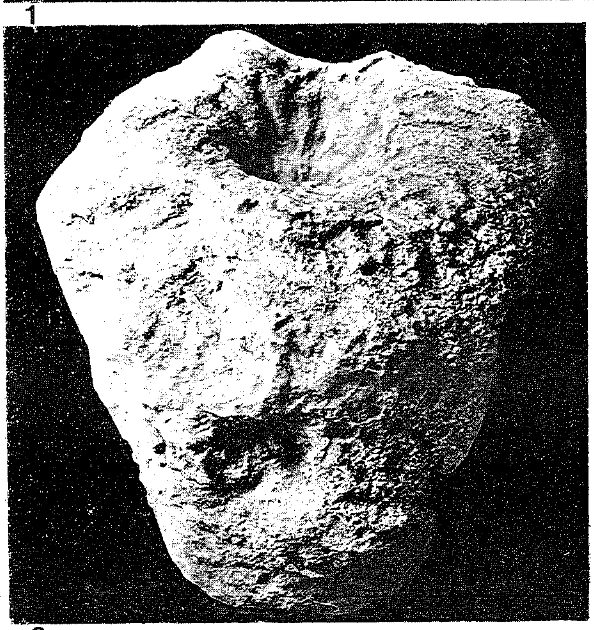
EXPLANATION OF PLATE 4

Aulocopium, Psarodictyum and *Patellispongia* from the San Juan Formation of Argentina. Figs. 1, 2, 3.—*Aulocopium sanjuanensis* n. sp., holotype; *1,* vertical view into the shallow spongocoel of the summit showing grooves produced by aligned gastral ostia, on the inside of the thick wall, and example of the moderately continuous straight radial canal series perforating the wall, in the lower right; *2,* oblique side view shows the general obconical form of the species; its moderately smooth surface perforated only by circular ostia of the large generally subhorizontal radial canals, which are seen with an upward arcuate course in the upper right of the specimen; nature of gastral ostia shows in the wall of the spongocoel, in the upper center, and the moderately coarse anthaspidellid trab-based skeletal net shows in the lower center of the sponge; *3,* the other side of the sponge from that shown in *2,* showing the smooth wall with moderate ribs of trabs of the skeletal net in the upper center, CRICYT VI-13, all X1. Fig. 4.—*Psarodictyum magna* n. sp., holotype, nature of the coarse skeletal net of trabs interrupted by limited canals and with prominent canals subparallel to the trab parts of the skeleton of the palmate or frondlike species, San Juan Formation, Villicúm Range; CRICYT VI-44, X1. Fig. 5.—*Patellispongia robusta* n. sp., side view of obconical, moderately thin-walled paratype shows the nature of the skeletal net, the regular perforations of ostia through the moderately thin wall and a nonannulate appearance of the species, San Juan Formation, Talacasto Gulch locality, CRICYT T-1/15 X1.

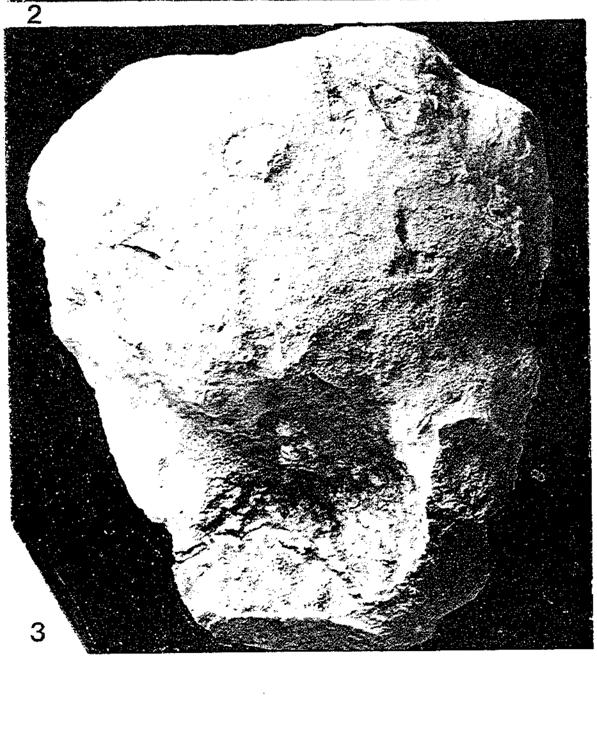


1

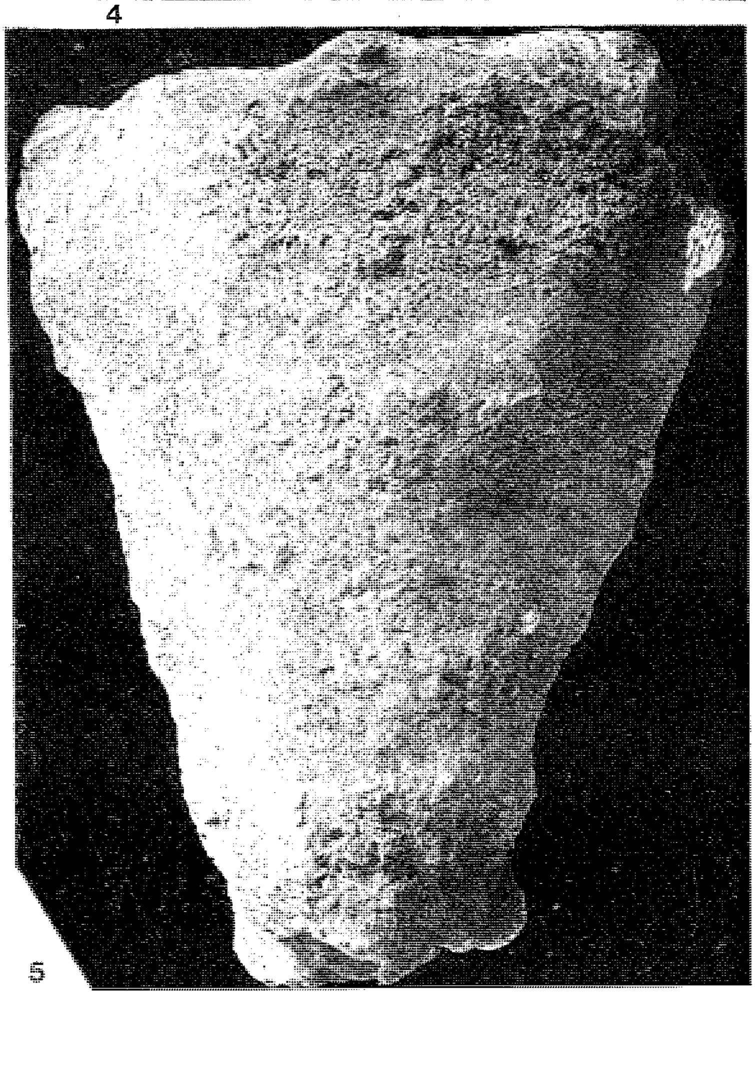
4



2



3



5

diameter. Oxeas present as coring spicules. Gastral surface with shallow, irregular, tangential canals to 2 mm wide. Differentiated gastral layer irregular reticulate perforate net 0.5 mm thick, but spicules of fused structure unknown.

Description. Only two fragments of the species occur in the collection. Both represent curved, roughly horizontal parts of what may have been upward expanding conical or palmate sponges. One fragment, CRICYT VI-F1, is approximately 9 cm wide and approximately 4 cm tall. It includes only a small part of a sponge that was probably several times that high. The total shape, whether a closed funnel-like form or an open palmate form, is unknown—although one side appears to be rounded and perhaps complete, the other sides appear broken, and the base of the specimen has been cut. Fragment CRICYT VI-2 is approximately 51 mm tall but broken on all four surfaces. It is approximately 45 mm across the base and 65 mm wide at the top and shows dermal and gastral surfaces well. The curvature suggests a spongocoel may have been 7 or 8 cm in diameter. Both fragments represent approximately one-fifth of the circumference of a sponge, if they were conical-cylindrical or steeply conical sponges.

The moderately complete thickness of the wall appears to approach 2 cm, although from that thickness the walls taper to less than 1 cm thick at the edges, if either of the margins of the fragments are complete.

The exterior lacks annulations or ridges but is deeply pitted by numerous moderately irregularly placed ostia. These large ostia interrupt the normal trab-based skeletal net. Largest ostia on the exterior range approximately 2.0–2.6 mm in diameter. These are circular, and most appear to be approximately 2.2–2.4 mm across. They occur three to five per cm^2 and vary in their spacing from 1 mm to 3–4 mm apart and are separated by trablike skeletal nets.

Ostia of an intermediate-sized series range approximately 1.0–1.9 mm in diameter, with most approximately 1.2–1.4 mm across. They are circular and are somewhat more rare than the large openings, for this series occurs two to three per cm^2 in the same general area and are spaced approximately 1 mm apart.

The smallest circular dermal openings range 0.4–0.9 mm in diameter, with most approximately 0.5–0.6 mm across. These occur four per cm^2 in some areas, because most of the surface is taken up by the large canals. In other areas where there is more skeletal tract space between the large ostia, these small openings may occur up to 10 per 25 mm^2, so they are moderately common. Smallest openings grade into skeletal pores or openings between the trabs and dendroclones in the ladderlike series.

A few large, vertically elongate ostia on the exterior range 1.8 × 3.4 to 2.2 × 3.0. They may represent points of subdivisions of the horizontal radial canals that make the large circular openings. In addition to the elliptical openings, some are 8-shaped, which suggests incipient branching.

Gastral ostia range 1.4–2.4 mm in diameter, with most approximately 1.5 mm across as circular openings. Elliptical openings also are well developed, and these generally range 1.0 × 3.2 mm up to 2.2 × 3.4 mm. They are generally higher than wide, which suggests that the canals rise as they enter the spongocoel.

A few irregular, shallowly indented, subvertical, tangential gastral canals are impressed on the concave or gastral surface. These canals are weakly meandering or anastomose and are indented approximately one-third their diameter or width, which ranges 1 mm to almost 2 mm wide, with some irregularity. Where most prominent, they appear to be impressed into a moderately dense gastral layer and are separated by 1–2 mm of dense skeleton.

Horizontally elliptical skeletal pores within the ladderlike spicule series range 0.16–0.40 mm high and 0.20–0.48 across. Characteristic openings are 0.16 × 0.24 or 0.20–0.24. Larger openings appear to represent pores that interconnect the skeletal pores parallel to the trabs.

Trabs are prominent in the skeletal net and have a surface of pinnation at about midwall, 4–5 mm in from the dermal surface. Trabs generally range 0.08–0.20 mm in diameter in the interior and approximately 0.2–0.3 mm in diameter on the dermal surface. Most trabs appear to be approximately 0.2 mm across, although there is considerable irregularity vertically along a single trab series, dependent upon numbers of dendroclones that combine to produce the trabs. Annulate appearances may be moderately common in single trabs, rather than the smooth cylindrical trabs seen in some other species. Trabs are spaced 0.3–0.5 mm apart, with moderately uniform spacing.

The major, dominantly Y-shaped dendroclones have long, simple, smooth shafts 0.12–0.80 mm long, with most approximately 0.5–0.6 mm long, from the flare of the brachyome to the divergence of the clads. These shafts have diameters of 0.08–0.18 mm in the interior, but in some areas affected by diagenesis, shafts may range up to 0.2 mm in diameter. In a few moderately well preserved spicules, clads range 0.12–0.20 mm long and 0.04–0.10 mm in diameter. Oxeas are present as coring spicules. They have diameters of approximately 0.05 where evident on the exterior.

The differentiated gastral layer is composed of an irregular reticulate or perforate net and is approximately 0.5 mm or less thick. Small pores, approximately 0.1 mm in diameter, are separated by skeletal elements half that width. As a result, the entire structure is minutely and regularly perforate, although without a predictable geometric pattern. Individual skeletal elements within that net are so systematically fused that it is difficult to identify the basic spicule shape. They are not aligned like dendroclones, and they may consist of irregular chiastoclones that drape across conical tips of trabs. However, they have generally obscured the trabs so that only the irregular network perforated by moderately closely and uniformly spaced circular pores characterize the structure. That dense layer is most prominent on ridges between the impressed canals, but does occur in the base of the canals in some areas. The gastral layer is not a sharply nodose dermal layer, as in *Gleesonia porosa* Rigby and Webby, 1988, from Australia, but it does appear somewhat similar to the confused small dendroclones and rhizoclones of the basal layer of that species. It is most similar to the dense gastral layer on *Patellispongia australis* Rigby and Webby, 1988, which is also irregularly and minutely perforate. Nodes on the surface of that species are produced by globular expansions of ray tips of subtangential dendroclones. As in the Australian material, however, details of individual spicules are largely destroyed by their lateral fusion.

Discussion. The most distinctive features of the sponge fragments are the numerous, large, irregular ostia on the exterior, the dense gastral layer, and the impressed meandering tangential canals on the upper interior part of the sponge. In comparison with *Hudsonospongia* described from Australia (Rigby and Webby 1988), perhaps the overall irregularity of canals in the upper part of *Hudsonospongia* may be most similar, but *Hudsonospongia* seems to lack the dense gastral layer so well defined on the specimens available here. The skeletal net appears distinctly more regular than that in *Streptosolen* (Miller 1889; Ulrich and Everett 1890) or *Allosaccus* (Raymond and Okulitch 1940) and some of the other irregular genera within the family.

Material. Holotype, CRICYT VI-2, and paratype, CRICYT VI-F1, are from the San Juan Formation in Don Braulio Gulch, Villicúm Range, in the Precordillera Oriental, and a reference specimen is from the lower San Juan Formation beds at the Talacasto Gulch locality in the Precordillera Central, both in San Juan Province. The specimens were collected by Matilde Beresi.

Genus RHOPALOCOELIA Raymond and Okulitch, 1940

Emended Diagnosis. Cylindrical, tubular, or conicocylindrical to club-shaped sponges with simple axial spongocoel that reaches almost to sponge base. Numerous large, essentially horizontal canals extend dermal surface to gastral surface, some may form branching or converging system. Exterior surface smooth to weakly nodose. Skeleton characteristically anthaspidellid with prominent relatively loosely packed trabs that diverge upward and outward from surface of pinnation essentially at midwall. Major spicules I-shaped and long, Y-shaped dendroclones with smooth shafts, although X-shaped and equal-rayed, Y-shaped spicules also occur; differentiated thin dermal layer may be present.

Discussion. The genus *Calycocoelia* was proposed by Bassler (1927) for goblet-shaped sponges with relatively thin walls composed of long, narrow-rayed dendroclones. These sponges expand upward from a stem into an upper barrel-like or subcylindrical part. The initial description was expanded somewhat by Bassler (1941), and some measurements were given of the type species *Calycocoelia typicalis* Bassler.

Rhopalocoelia was proposed as a new genus by Raymond and Okulitch (1940, p. 210) for cylindrical to club-shaped sponges that have a wide axial spongocoel. The relatively thin walls are pierced by large canals that are essentially horizontal and perpendicular to the dermal surface. Raymond and Okulitch compared *Rhopalocoelia* with *Aulocopium* and noted that *Aulocopium cylindraceum* Roemer (Rauff 1895, p. 394) should be removed from *Aulocopium* and included within their new genus *Rhopalocoelia* but did not describe the species. *Rhopalocoelia clarkii* appears distinctly similar to *Calycocoelia* in spicular character and in dimensions.

However, Raymond and Okulitch (1940) differentiated the new species *Rhopalocoelia regularis* from *R. clarkii* and noted that the very large radial canals in *R. regularis* were apparently utilized to differentiate the two species. Canals of the size they figured (Raymond and Okulitch 1940, text fig. 4) would separate *Rhopalocoelia regularis* from most other species within the family Anthaspidellidae. They also noted that these large radial canals connect to rounded chambers near the inner wall in a structure not seen in other sponges within the family. They also observed that *Rhopalocoelia clarkii* was moderately weakly annulate, which contrasts with the more tubular nature of other species of *Rhopalocoelia* and, for that matter, of species *Calycocoelia*.

De Freitas (1989) concluded that *Calycocoelia* Bassler, 1927, and *Rhopalocoelia* Raymond and Okulitch, 1940, are synonyms, as are *Somersetella* Rigby and Dixon, 1979, and *Steliella* Hinde, 1889. He included all of these genera under *Archaeoscyphia* Hinde, 1889. We think that perhaps *Rhopalocoelia* and *Calycocoelia* may be synonyms, and, if so, *Calycocoelia* then becomes the senior synonym. We prefer to maintain the moderately smooth gobletlike to cylindrical forms as distinct from the sculptured annulate *Archaeoscyphia*. These genera are under intensive review as part of a major reexamination by Rigby of all North American Ordovician sponges.

Type species. *Rhopalocoelia clarkii* Raymond and Okulitch, 1940.

RHOPALOCOELIA CLARKII Raymond and Okulitch, 1940

pl. 3, fig. 1; pl. 8, figs. 7, 8; pl. 11, fig. 1; pl. 12, fig. 2

Synonymy. Rhopalocoelia clarkii Raymond and Okulitch, 1940, p. 210–11, pl. 5, figs. 1–4, text fig. 3.

Diagnosis. Large, high, club-shaped sponges with irregularly oval cross section and large, deep tubular spongocoel; surface smooth; radial canals numerous, 0.6–0.8 mm in diameter, occur in vertically stacked series; other ostia, 0.2–0.3 mm in diameter, of skeletal pores. Surface of pinnation approximately midwall; trabs meet gastral and dermal surfaces at 20°. Trabs approximately 0.2 mm in diameter in anthaspidellid skeleton. Spicules I-, Y-, and X-shaped dendroclones with shafts to 0.7 mm long. Smooth oxeas may occur in trabs as coring spicules.

Description. Several segments of the lower part and middle loglike part of *Rhopalocoelia* occur in the collections. They range from upward-expanding conico-cylindrical lower parts to subcylindrical upper parts and include fragments from approximately 4.8 cm long to approximately 12 cm long.

Perhaps the best-preserved specimen (CRICYT T-1/27) demonstrates the characteristics of the species best. It is approximately 6.5 cm high and expands upward from a nearly complete but broken basal diameter of 16 mm to a maximum diameter of approximately 40 mm near the top. It has a curved upper oscular margin, which is only about 22 mm in diameter, in which the upper osculum, 12 × 16 mm across, is surrounded by a relatively narrow rim. A simple spongocoel with essentially that diameter extends to the base of the fragment and, thus, to virtually the base of the entire specimen. It tapers slightly through approximately two-thirds of the distance and then moderately abruptly to a diameter of 4 × 5 mm at the base of the preserved fragment.

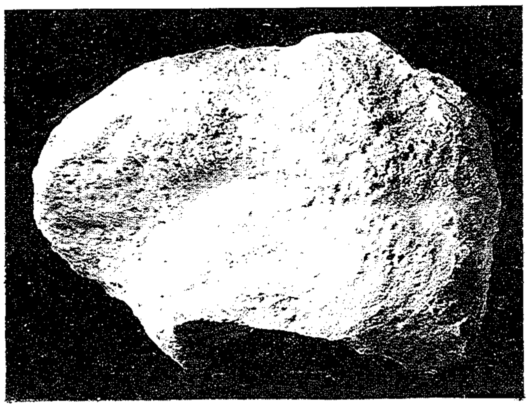
The gastral surface is smooth, perforated by only moderately well aligned and vertically stacked series of ostia. The same is true of the dermal surface, but the prominent annulate ridges of *Archaeoscyphia* or nodes of forms such as *Nevadocoelia* are lacking on the exterior. The surface is perforated by moderately large ostia that interrupt the thin dermal layer. There is no differentiated gastral layer.

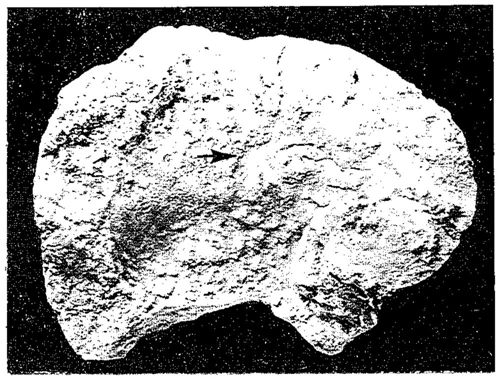
A thin dermal layer 0.15–0.20 mm thick does occur locally. It is a moderately dense layer of fairly tightly spaced small spicules around much of the exterior on some of the specimens. These small spicules appear to be Y- and X-shaped dendroclones, in large part, with shafts up to only 0.15 mm long and prominent clads up to 0.10 mm long. The spicules are only 0.02–0.03 mm in diameter and are packed such that they occupy approximately 15% of the volume of the outer layer. This produces a moderately dense net compared with the relatively open net of long-shafted dendroclones in the interior.

EXPLANATION OF PLATE 5

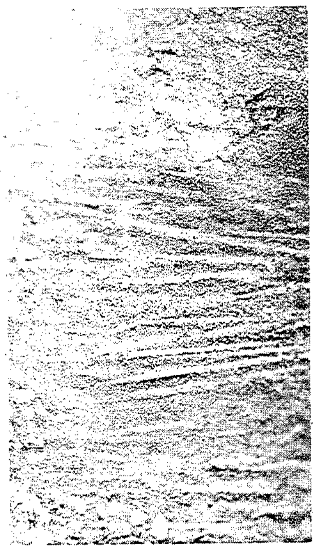
Patellispongia, Anthaspidella, root tufts, and *Talacastonia,* all from the San Juan Formation, at the Talacasto Gulch locality. Figs. 1, 4, 6.—*Patellispongia robusta* n. sp.; *1,* gastral surface of paratype shows the relatively robust trabs and the subparallel, moderately coarse, canals on the gastral surface; a small octactine heteractinid spicule occurs in the upper center (arrow) beneath the upper calcite vein; thin-walled nature of the species is shown by the near profile on the right, USNM 463465, X1; *4,* paratype shows the other side of the specimen in plate 4, figure 5, demonstrating the thin-walled nature of the sponge, as indicated by the wall to the left of the fracture (arrow), at the matrix-wall contact, in the conical form of the species; the basal stem is enfolded to nearly form a subcylindrical stem, but is interrupted by coarse matrix in part of the circumference, CRICYT T-1/5, X0.5; *6,* holotype, gastral view shows the relatively coarse nature of the skeleton with aligned trabs and subparallel coarse canals that interrupt the trabs in the broad, frondlike, species; subcylindrical enfolded base; oblique sections in the lower left and right demonstrate the moderately thin-walled nature of the species and genus, CRICYT T-45, X0.5. Figs. 2, 3.—*Anthaspidella inornata* n. sp., holotype; *2,* dermal view of thin walled sponge shows aligned trabs in the upper left and the coarse dermal ostia of radial canals that lead essentially directly through the wall; *3,* gastral view shows a faint subtangential canal (arrow) that marks the surface in the upper center; coarse gastral ostia in the upper right, and the somewhat matrix-filled, lower part of the shallow spongocoel in the lower center; a section of the relatively thin wall is broken across on the left, CRICYT T-48, X1. Fig. 5.—Photomicrograph of root tuft showing relatively delicate oxea spicules and their distribution in the somewhat silty carbonate matrix, San Juan Formation, Villicúm Range, CRICYT VI-4, X10. Fig. 7.—*Anthaspidella annulata* n. sp., holotype dermal surface showing annulate nature of the sponge, its relatively delicate anthaspidellid skeleton, most apparent in the upper center, and the thin wall of the sponge, as shown by the broken surface in the upper left, San Juan Formation, Talacasto Gulch locality, CRICYT T-49, X1. Figs. 8, 9.—*Talacastonia chela* n. sp., holotype; *8,* horizontal section through elliptical cross section shows the moderately thin wall and elliptical spongocoel (*S*) filled with light gray matrix; irregular dark nodules of limonite after pyrite are in the lower center; *9,* side view shows the relatively robust compound medium gray trabs, typical of the genus and species, separated by light gray matrix fillings of canals in the nearly smooth subcylindrical species; San Juan Formation, Talacasto Gulch locality, CRICYT T-53.


1


2

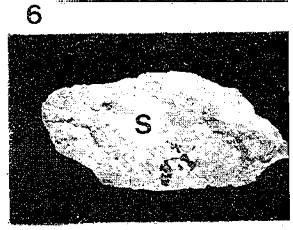

3


4

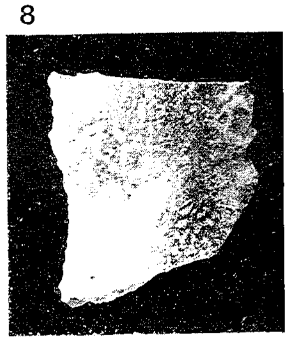

5


6


7



8


9

Ostia in the dermal layer are outlined by spicules with long dimensions that essentially define circumferences of the circular openings. Individual rays are subparallel to that outer surface and are closely spaced to produce a dense layer.

Dermal ostia are of principally two major ranks: one 0.5–0.7 mm in diameter, and the other only 0.2–0.3 mm across. The larger openings are ostia to the essentially horizontal canals that pierce the wall in a regular radial fashion. These canals are 0.6–0.8 mm in diameter in the interior. They are horizontal to slightly arcuate upward and are mostly straight radiating openings, although a few do converge from the dermal area into the midwall, merge, and then continue on through the interior of the wall to open as ostia on the gastral surface, where they are closely spaced, virtually side by side, openings 0.7–0.8 across. These canals are separated from each other by only a single trab series so that the gastral wall is a porous part of the sponge. There is little expansion of the canals once inside the slightly restricted ostia through the dermal layer. Canals remain essentially cylindrical or tubular through most of the wall. They occur approximately five ostia per mm^2 in the dermal layer. They are spaced such that five or six occur per 5 mm, measured horizontally around the circumference of the spongocoel and in a vertical series as well; locally, however, that number may drop to as few as three or four per 5 mm in the lower juvenile part of the sponge.

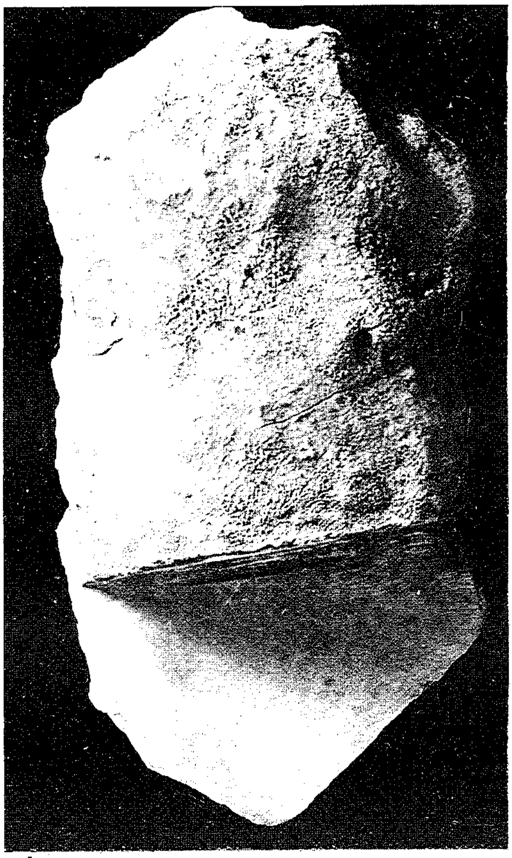
Prominent, relatively thick, open-textured trabs form the most well preserved part of the skeletal net. Trabs diverge upward and outward from a surface of pinnation that is at midwall to one-third the wall thickness in from the gastral margin. Trabs meet the dermal surface at angles of up to approximately 20° from vertical and meet the gastral surface at 10°–15° from vertical. Individual trabs appear as long, continuous, only gently curved elements once outside the immediate zone of pinnation. Trabs range 0.12–0.25 mm in diameter, with most approximately 0.20 mm across. They show moderate irregularity in diameter along individual trends and are generally largest immediately above canals where horizontal skeletal pores interconnect with the major horizontal radial canals.

Trabs are spaced one to three per mm in vertical section, with most approximately two per mm. They border the horizontal skeletal pores between the runglike dendroclones. Those pore series range 0.3–0.6 mm wide in a single series, with most approximately 0.5 mm wide. They range up to 1 mm high, but most are approximately 0.2 mm high and, thus, form broadly elliptical, horizontally elongate openings. The large openings tend to be subquadrate and are lateral interruptions in the skeletal net. In uninterrupted areas dendroclones are spaced 0.10–0.20 mm apart, and this is what determines the spacing of the openings between the steplike rungs of the ladder.

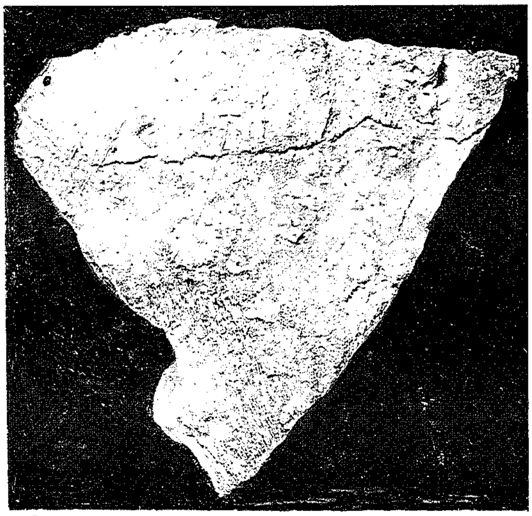
Spicules are relatively large I-, Y-, and X-shaped dendroclones, with moderately smooth shafts and moderately long cladomes. Shafts range up to 0.6 or 0.7 mm long and have smooth diameters that range 0.03–0.06 mm, with most 0.05–0.06 in the moderately stubby appearing spicules. Clads of the cladome range 0.10–0.16 mm long

EXPLANATION OF PLATE 6

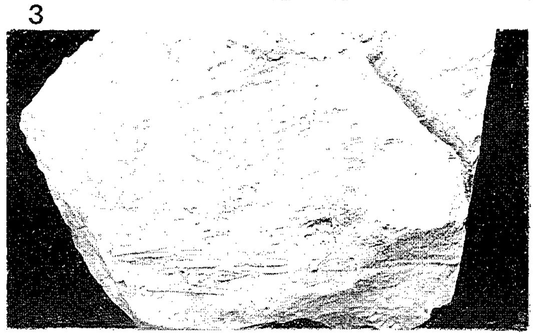
Rhopalocoelia, root tufts, *Patellispongia*, and *Anthaspidella* from the San Juan Formation Talacasto Gulch locality. Fig. 1.—*Rhopalocoelia clarkii* Raymond and Okulitch, 1940, side view of figured specimen shows the general subcylindrical form of the species and its relatively robust anthaspidellid skeletal net, best shown in the center; the rounded upper oscular margin, though partially matrix-covered, is complete but the base is broken, CRICYT T-1/Cut, X1. Fig. 2.—Root tuft, small spicules show best in lower right, San Juan Formation, Villicúm Range, CRICYT VI-4, X1. Fig. 3.—*Patellispongia robusta* n. sp., paratype, shows the regular moderately coarse anthaspidellid skeletal net on the gastral surface, which is partially obscured by attached echinoderm bases and matrix; the regularity of the net shows best in the lower and central part of the sponge, which is characteristic of the thin-walled species of the genus, USNM 463465, X0.5. Figs. 4, 5.—Root tuft of large monaxial spicules, probably oxeas, which have been inserted into silty calcareous matrix, Villicúm Range locality, CRICYT VI-54, *4*, X10, *5*, X1. Figs. 6, 7.—*Anthaspidella alveola* n. sp., holotype; *6*, dermal surface shows nonannulate, relatively smooth exterior with small pores interrupting a dense dermal layer in the upper right center, near the moderately complete rounded margin of the sponge; *7*, gastral surface with shallow excurrent openings (arrow) near the right margin; tangential lateral canals are faint and short, San Juan Formation, Talacasto Gulch locality, CRICYT T-SQ1, both X1. Figs. 8, 9.—*Patellispongia robusta* n. sp., paratype; *8*, dermal surface with slightly reflexed uppermost complete rim; prominent radial skeletal structure of coarse trabs and subparallel canal series produce the ribbed appearance; a thin dermal layer is well exposed in the upper right (arrow) where circular ostia to canals pierce the layer and connect to radial canals of the interior of the wall; *9*, gastral surface partially matrix-obscured, but with the radial structure moderately well exposed in the lower center and in the upper left, San Juan Formation, Talacasto Gulch locality, USNM 463466, both X1.


1

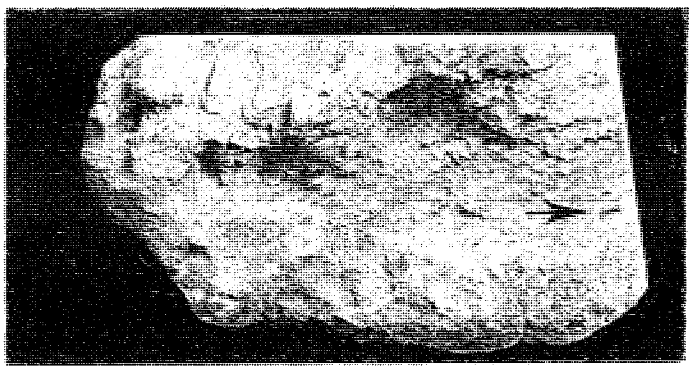

2

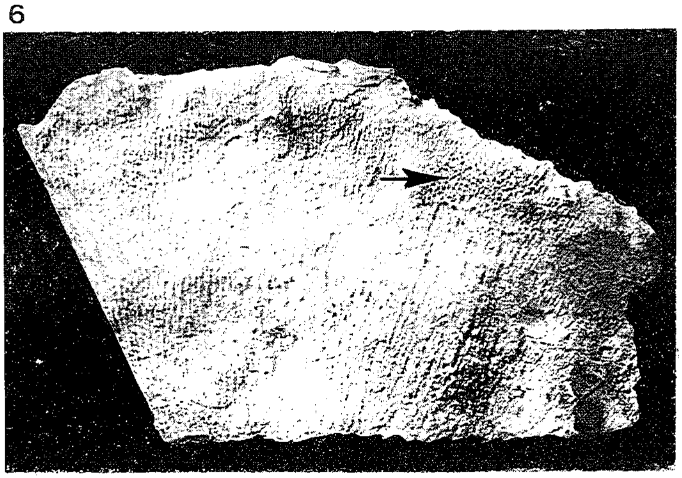

3

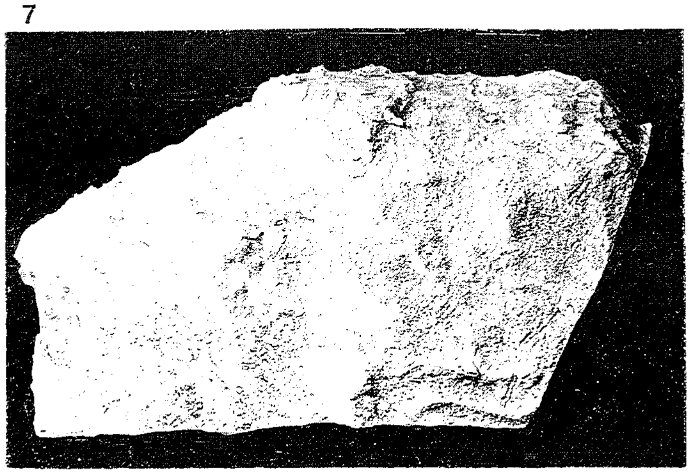

4


5


6


7


8


9

in characteristic Y-shaped spicules; most are approximately 0.14 mm long and 0.03–0.04 mm in diameter. Some clads range up to 0.08 mm in diameter, but these have been apparently enlarged by diagenesis. A few markedly elongate clads form prominent subvertical rays with complex digitate margins that articulate with spicules within the clads. Some of these upward expansions may be as long as 0.15 mm and have zygomes clearly defined and spaced 0.01–0.02 mm apart. Individual zygomes are approximately 0.01 mm long and in diameter and have moderately stubby, fingerlike terminations. These cladomes are commonly almost flat-appearing surfaces, when seen from the side, other than for the zygomes. In these spicule forms, the openings between clads tend to be triangular, but in some the openings are almost circular where the clads flare at articulating tips, rather than narrow down like a root system. A few spicules have two cladomelike terminations at each end of the shaft, and in some there may be three clad-type terminations where one of the clads bifurcates.

In horizontal sections skeletal nets appear open and moderately coarse, with Y- and I-shaped spicules as the most common. Y-shaped spicules range from those with short cladome upper arms to those where the three rays are almost of the same length, approximately 0.10–0.15 mm long. These kinds of broad, equal-rayed, Y-shaped dendroclones are most characteristic where major canals are bridged.

What appear to be long, smooth oxeas occur as coring spicules in the trabs in a few areas. In vertical sections they appear to be 0.04–0.05 mm in diameter and occur 1–3 in some sections. Lengths of these spicules or their termination shape are unknown because they are seen only in partial longitudinal sections in vertical sections. In transverse sections they appear as distinct circular elements but are not clearly separable from sections through the robust clads that all combine to produce a moderately open porous trab as seen in transverse sections. The discrete vertical elements occupy from one-half to two-thirds the volume of the cylindrical trab, but associated pore space is obvious as well.

Elongate skeletal pores, parallel to the trabs, are defined by the stacked "ladders." These pores may have triangular, quadrangular, or even pentagonal cross sections. In general, most are triangular and range 0.3–0.5 mm across, or on a polygonal side. These openings are defined by stacked series of dendroclones. Interruptions in those dendroclone series connect the long, upward-diverging skeletal pores. These same long skeletal pores connect vertically into the large horizontal canals. The small circular ostia in the dense dermal net are openings to the skeletal pores.

Discussion. Raymond and Okulitch (1940, p. 210–12) described two species of *Rhopalocoelia. Rhopalocoelia regularis* Raymond and Okulitch, 1940, is a relatively small form, with coarse canals in a size and structure significantly different from size and canal pattern seen in the Argentine material. *Rhopalocoelia clarkii,* the type species of the genus, however, appears to be of the same general dimensions as the material described here. Details of the skeletal net and the canal system, however, were not presented by Raymond and Okulitch, but measurements from their published figures suggest that the skeletal net of the New York material is essentially like that of the Argentine species. Dimensions and spacing of the trabs and their general textural relationships appear strikingly similar, at least within the ranges of the diagenetically altered and calcareous replaced skeleton. Because of this, we have tentatively included the Argentine material in *Rhopalocoelia clarkii* Raymond and Okulitch.

Material. Nine moderately well preserved specimens are in the collection from the San Juan Formation in Talacasto Gulch, in the Precordillera Central of San Juan Province. Several of the specimens were collected by William Sill and by Matilde Beresi in the late 1970s and early 1980s. Figured specimens: CRICYT TA-02, T-1/27, T-1/11, and TA-08, and an additional five reference specimens, USNM 463472–463476, are in the collections.

RHOPALOCOELIA RAMA n. sp.

pl. 2, figs. 5, 6; pl. 9, figs. 1, 2; pl. 11, fig. 3

Diagnosis. Branched to unbranched, fine-textured *Rhopalocoelia;* branches 14–18 mm in diameter, pierced with prominent spongocoel of essentially one-half branch diameter. Surface smooth, indented by dermal ostia, 0.3–0.5 mm in diameter, of horizontal regularly stacked canals that occur six to seven per 5 mm in vertical series and pierce thin walls 3–5 mm thick. Skeleton anthaspidellid with moderately straight trabs approximately 0.1 mm across. Spicules principally long-shafted, Y-shaped dendroclones 0.3–0.4 mm long and approximately 0.03 mm in diameter. Trabs not strongly pinnate, up to 12 dendroclones per mm in a vertical series where uninterrupted by canals.

Description. Two specimens of a branched to unbranched, fine-textured *Rhopalocoelia* occur in the collection. The branched holotype is approximately 70 mm tall, with two branches that diverge upward from an elliptical base 15 × 27 mm across. Even in the basal preserved part, however, the specimen is somewhat 8-shaped, indicating the incipient branching that appears to take place approximately 30 mm above the base. Above that are two more or less clearly divided subcylindrical stems; one 14 × 18 mm in diameter and one 16 × 18 mm in diameter are recognizable. They are subparallel and possibly remerge, at least in part in the upper cm, but the two branches apparently maintain separate spongocoels.

The simple spongocoel is 8-shaped and approximately 13.5 mm across in the base, with one subcircular part 8 mm in diameter and the other approximately 6 mm in diameter.

Dermal surfaces of the branches are smooth, except where indented by ostia that range 0.3–0.5 mm across, but nearly all are approximately 0.4 mm in diameter. They are circular and are spaced six to seven per 5 mm in moderately regular stacked vertical series. Ostia also occur six to seven per 5 mm, laterally, around the circumference of the sponge. Individual ostia are separated by 0.4–0.5 mm of skeletal material and connect to only moderately well defined canals of the interior in the transverse section that is available. They appear to be approximately 0.3 mm in diameter and are essentially the same dimensions as the triangular to rectangular skeletal pores that parallel the trabs.

Trabs are spaced approximately 0.3–0.4 mm apart, both concentrically and radially. They are 0.09–0.12 mm in diameter, with most approximately 0.10 mm across in the transverse section and in parts of the dermal skeleton where the trabs are subparallel to the outer surface. Trabs apparently meet the gastral surface at moderately low angles so that the trabs remain relatively straight, rather than abruptly curved. This suggests that the surface of pinnation may be only a short distance away from the dermal layer. This is probable because the walls are thin, generally only 3.0–3.5 mm thick, although on one end of the elliptical transverse section one segment of the wall is up to 5 mm thick.

There is no differentiated dermal nor gastral layer, but the relatively fine-textured, uniform, anthaspidellid-type skeleton extends from wall to wall. Individual dendroclones are dominantly I-shaped but occur with some long-shafted, Y-shaped dendroclones. Shafts are smooth and 0.3–0.4 mm long, with narrow diameters of 0.025–0.030 mm in the middle, but they widen toward both ends to 0.030–0.035 mm across. Cladomes are ill defined in the fine-textured skeleton. Individual clads, where at all evident, are approximately 0.1 m long, and, judging from spicule expansions, clads must diverge from axes of shafts at acute angles and must be relatively short. They appear to be approximately 0.02 mm in diameter, but in general the clads are not preserved as seen in the transverse section.

Spacing of dendroclones in the skeletal net is variable because of uniform interruption by the moderately closely spaced radial canals. Generally four or five dendroclones occur per half millimeter in a ladderlike series between ostia of canals, but the series is interrupted by ostia so that only about five or six dendroclones occur per mm in most vertical series because of those interruptions. Were there no such interruptions there may be 10–12 dendroclones per mm in single vertical series.

Discussion. The most distinctive features of the species are its branching habit, fine-textured skeletal net, and the relatively small horizontal canals of about skeletal pore dimension that lead from the exterior to the interior through the thin walls. Low angles of divergence of trabs from the surface of pinnation are also distinctive features.

At first glance one might wonder if the holotype were a thin-walled cylindrical form that had collapsed, rather than a branched form. Such is clearly not the case, for in transverse sections there is abrupt thickening of the wall between the two subcylindrical incipient spongocoels, and there is no sign of disruption of the skeletal net, such as would be apparent if the sponge were a collapsed cylindrical species.

Like many other sponges in the collection, boring algae produce irregular light-colored, spar-filled impressions through the skeleton and into the matrix filling the spongocoel. Some of these borings appear to be lined with darker organic material, but all show a moderately uniform size. They generally extend through matrix rather than interrupt the skeletal elements.

Material. Two specimens from the San Juan Formation at Talacasto Gulch in the Precordillera Central of San Juan Province. The branched holotype, CRICYT T-07, and the unbranched specimen, CRICYT T-09, are considered to represent the species. Both of these were included in earlier collections made by Matilde Beresi and William Sill.

Etymology. Rama, L., branched, in reference to the growth form of the holotype.

Genus HUDSONOSPONGIA Raymond and Okulitch, 1940

Diagnosis. Pyriform, obconical to depressed unbranched sponges with a shallow spongocoel; radial arrangement of skeleton and horizontal canal system clearly defined. Moderately large, vertical axial canals form cluster below base of spongocoel and have their origins in upflexed inner ends of horizontal canals. Upward- and outward-oriented canals not defined, but structure of skeleton clearly with upward and outward divergent trabs in characteristic anthaspidellid skeletal pattern; spicules dominantly long-shafted, Y-shaped dendroclones, but others may be developed as accessories.

Discussion. Raymond and Okulitch (1940, p. 203) provided only a moderately vague diagnosis of the genus. They compared the species known at that time to those within the genus *Zittelella* Ulrich and Everett, in Miller (1889), and noted that *Hudsonospongia* generally has a radial architecture somewhat less clearly defined than that of *Zittelella*. In addition, it is now known that *Zittelella* has a surface of pinnation near the outer or dermal surface so that much of its skeleton is built of trabs that rise essentially vertically from that surface of pinnation. In *Hudsonospongia* the surface of pinnation may be nearly axial or along margins of the shallow spongocoel. As a result, much of the skeleton is composed of upward and outward radiating trabs in a structure quite distinctly different from that seen in *Zittelella,* although it may have almost the same degree of radial symmetry. In *Zittelella* the canals are distinctly straight radial, and in *Hudsonospongia* there may be variations from moderately straight radial to upward arcuate and convergent with a moderately irregular trend, as noted by Rigby and Webby (1988, p. 34).

Species of *Hudsonospongia* have smooth dermal surfaces, rather than the sculptured surface common in *Nevadocoelia* Bassler, 1927 (Bassler 1941, p. 94–96). *Hudsonospongia* also lacks the annulate shape typical of *Archaeoscyphia* (Billings 1859). *Rhopalocoelia* Raymond and Okulitch, 1940, is elongate, cylindrical, or club-shaped with a prominent, deep spongocoel that penetrates to near the base of the sponge with a regular canal system of radiating canals.

Our present interpretation of differences between *Hudsonospongia* and *Aulocopium* Oswald, 1847, relates principally to differences in the canal structure. Although Raymond and Okulitch (1940) reported an upward and an outward radiating canal system, we suspect that these are the skeletal pores parallel to the dominant trab system, rather than a distinctive set of large open canals.

Aulocopium is characterized by a radiant that is near the base and a surface of pinnation that is approximately 2 mm, or a short distance, above the basal dermal layer, which also produces a difference in the skeletal structure. In that respect, *Aulocopium* is similar to *Zittelella,* but *Aulocopium* lacks the prominent radial structures of *Zittelella* and is more like *Hudsonospongia* in development of somewhat irregular, upward-arching, horizontal radial canals. However, in addition to that system, throughout the main body of the *Aulocopium* there is an upward and an outward series of divergent small canals that occur in interspaces between the larger radiating horizontal canals. Both genera have strong, coarse vertical axial canals that form a cluster which empties into the base of the spongocoel and both have skeletons composed of anthaspidellid trabs with skeletons made of Y- and X-shaped dendroclones. Analysis of these and related genera are continuing, following on lines of evidence discussed by van Kempen (1989).

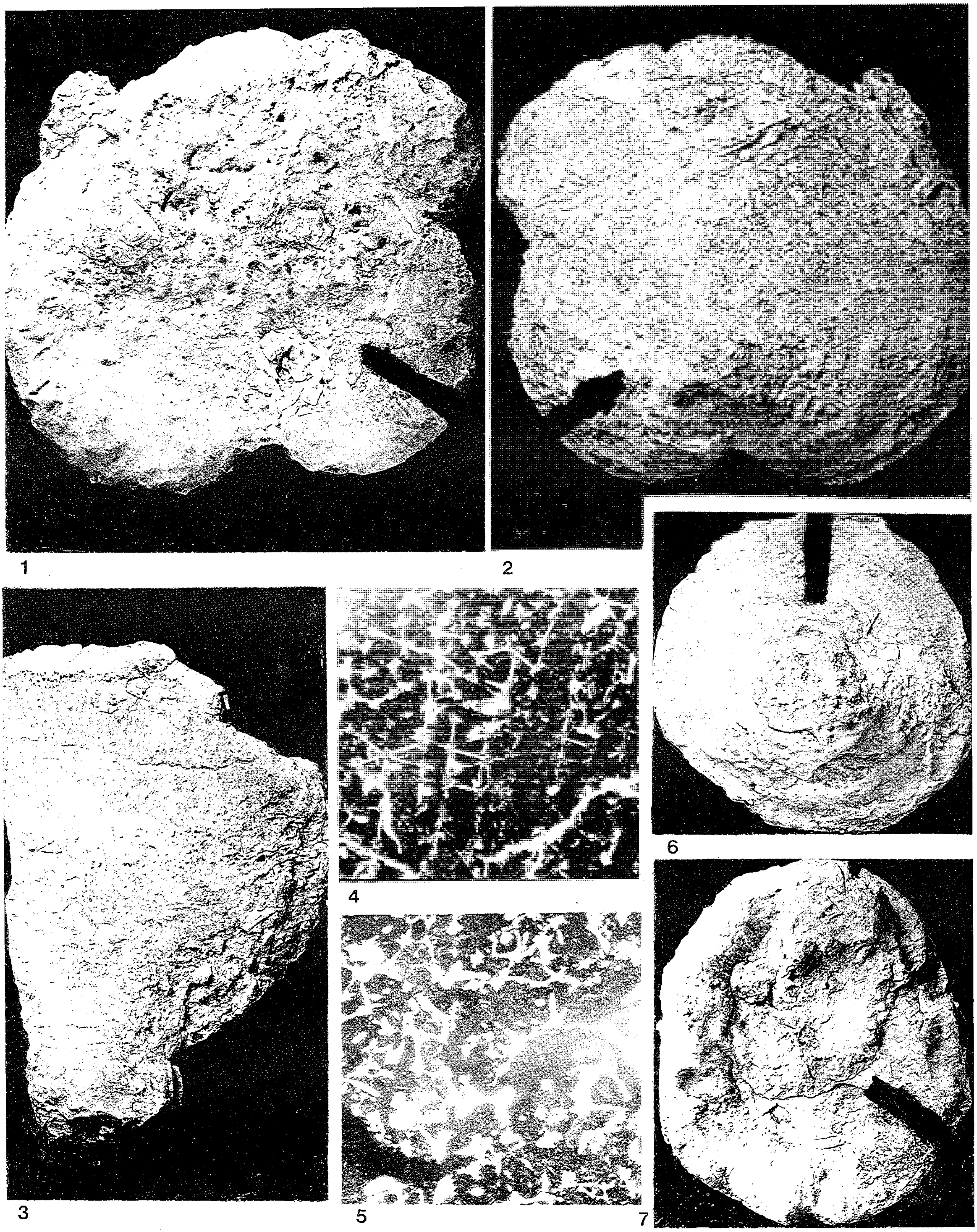
HUDSONOSPONGIA CYCLOSTOMA Raymond and Okulitch, 1940

pl. 2, figs. 1, 4; pl. 7, fig. 5; pl. 9, figs. 3–5

Synonymy. Hudsonospongia cyclostoma Raymond and Okulitch, 1940, p. 204–05, pl. 3, figs. 1–4; Shimer and Shrock, 1940, p. 53, pl. 15, figs. 10–12; de Lauben-

EXPLANATION OF PLATE 7

Specimens of *Patellispongia* and thin sections of *Archaeoscyphia* and *Hudsonospongia*. Figs. 1, 2, 3, 6, 7.—*Patellispongia robusta* n. sp. from the San Juan Formation, Talacasto Gulch locality, all are X0.5; *1, 2,* paratype CRICYT T-1/15; *1,* gastral surface, in large part matrix-covered, but radial canals show along the sponge margin in the lower left, in the thick wall; matrix fills the shallow spongocoel; the notch in the lower right is where the specimen was cut to prepare a thin section of the low cone; 2, dermal surface shows regular, radially arranged, skeleton with radially and concentrically aligned ostia of canals, that produce a weak annulation in the low conical form; 3, holotype, dermal view shows regular vertically expanding skeleton; most evidently defined by parallel ostia of radial canals, best seen in the upper left; a short stalk forms a subcylindrical base of the palmate sponge; the dermal surface is partially obscured by crinoidal-rich matrix along the right, CRICYT T-45; *6, 7,* paratype, CRICYT T-1/18, *6,* dermal view of the low conical sponge shows radial skeleton and aligned ostia of canals; the sponge appears to be weakly annulate because of the concentric arrangement of some ostia, the centralmost part of the sponge shows a cross section of a weak stalk; the notch at the top was made when thin sections were prepared; *7,* gastral view shows partially filled, shallow, spongocoel in the moderately thick-walled specimen; straight radial canals show in the lower part. Fig. 4.—Photomicrograph of thin section of *Archaeoscyphia minganensis* (Billings 1859); transverse section shows prominent uniform radial canals that are bridged in the center and left-center by rodlike prominent dendroclones that combine at their tips to produce the trabs, here cut in cross section; dendroclones show best in the upper center; dark matrix fills the canals and calcite-replaced spicules and trabs appear light gray; dermal direction is towards the top, CRICYT T-1/30, Talacasto Gulch, X10. Fig. 5.— Photomicrograph of a thin section of *Hudsonospongia cyclostoma* Raymond and Okulitch, 1940; the high-angle transverse section shows light colored skeletal elements surrounded by dark matrix; Y-shaped dendroclones in the left-center and right-center near the base show relative dimensions of the skeletal net, including the moderately irregular trabs and the irregular canals; light crystalline calcite fillings of algal borings show in the lower center, CRICYT VI-2, Villicúm Range, X20.


1
2
3
4
5
6
7

fels, 1955, p. E53; van Kempen and ten Kate, 1980 p. 437–53, figs. 2–6; Eggink, 1991, p. 31–32.

Hudsonospongia cf. *H. cyclostoma* Raymond and Okulitch, 1940, Rigby and Webby, 1988, p. 35–37, pl. 10, figs. 6–8, pl. 11, figs. 1–9; text fig. 10.

Hudsonospongia cyclostomata Raymond and Okulitch, Lange and Bartholomäus, 1991, p. 107–10, pl. 1, figs. 1–4, text fig. 12.

Diagnosis. Sponge pyriform, to 10 cm high, usually symmetrical, with small shallow spongocoel in upper end, greatest sponge diameter at or near upper end. Internal structure with numerous near-vertical axial canals, approximately 1.8 mm in diameter, convergent horizontal series of canals, 0.7–0.8 mm in diameter. Skeletal structure typically anthaspidellid with axis of pinnation near the axis of the sponge. Trabs 0.08–0.10 mm in diameter radiate upward and outward in regular fashion, spaced 8–10 per 5 mm; moderately large dendroclones to 0.5 mm long arranged in regular ladderlike series.

Description. A single specimen of the species is in the collection. It is a steeply obconical sponge with smooth edges and a moderately shallow spongocoel in its crest. The sponge is approximately 8 cm high. It expands upward from a moderately rounded base, 15 mm across, to a maximum diameter of approximately 48 mm, 1 to 2 cm below the upper surface. Above maximum diameter the sponge narrows to 35–40 mm at the moderately flat, upper oscular surface.

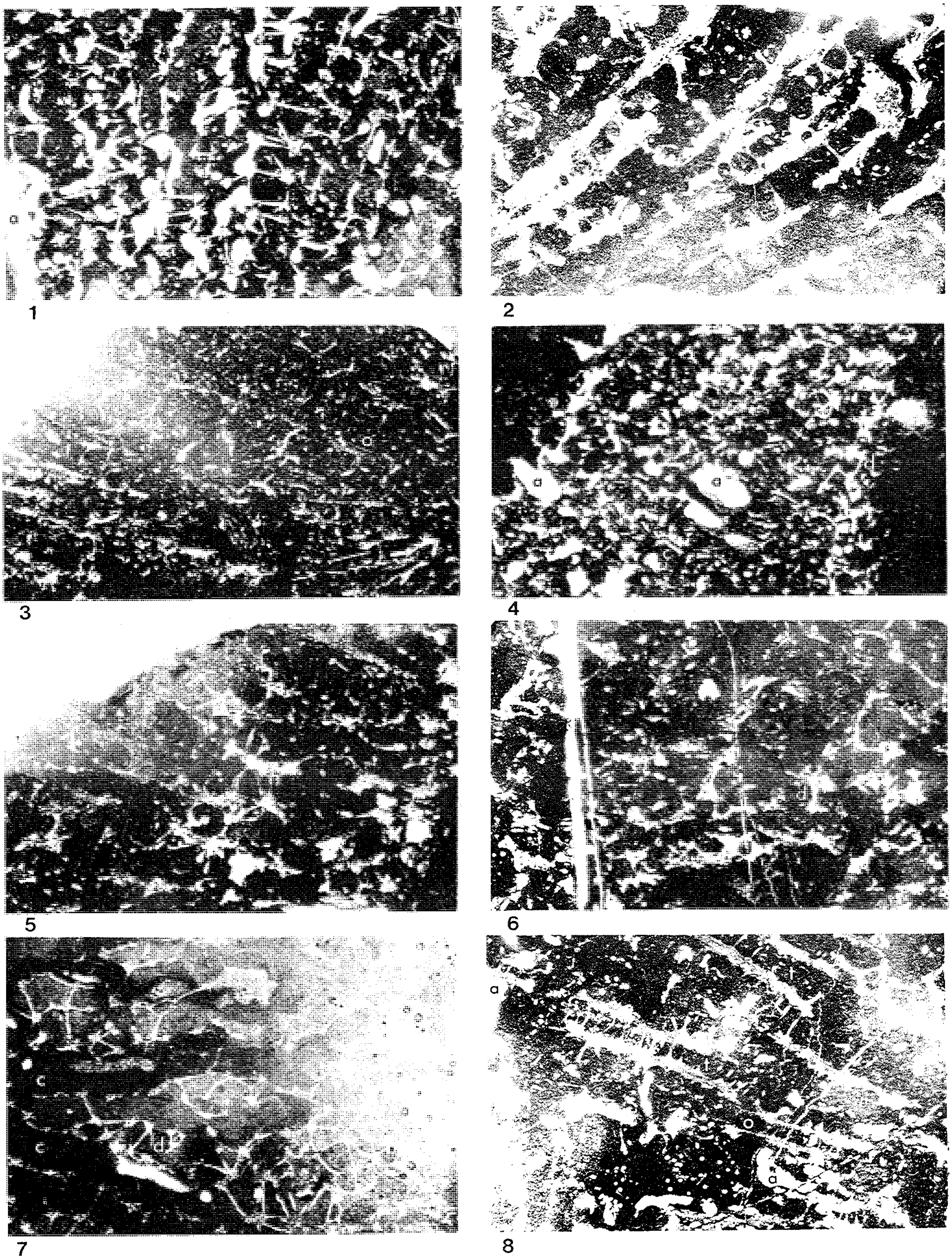
The upper surface has a shallow spongocoel, approximately 20 × 16 mm, in the bottom of which are ostia of the vertical axial canal cluster. The spongocoel is approximately 1.2 cm deep and has a rounded bottom and moderately steep, smooth, lateral slopes below the upper rounded crest of the wall.

Upper margins of walls are indented by irregularly and moderately straight radiating tangential canals. These are precursors of the arcuate horizontal canals of the wall interior.

Walls range 1.7–1.8 mm thick and are of moderately uniform thickness around the central oscular pit. Some of the walls may have been eroded, but along one margin where the walls appear thickest there is an outer dermal layer that defines the original complete wall of the sponge, and in that area the wall is 19–20 mm thick. The dermal surface is smooth, marked only by the indented

EXPLANATION OF PLATE 8

Photomicrographs of thin sections and cellulose peals of *Archaeoscyphia*, *Calycocoelia*, and *Rhopalocoelia*. All are from the San Juan Formation and all are X10. Figs. 1, 2.—*Archaeoscyphia minganensis* (Billings 1859); *1*, horizontal section, essentially at right angles to trabs, shows their radial arrangement and the long, runglike, dendroclones that combine at their tips to produce the trabs, here shown in irregular cross section; radial canals (*C*) show as interruptions in the network, and are essentially the width of spaces between trabs and the length of the dendroclones; light crystalline calcite fills algal borings that generally penetrated into matrix; *2*, vertical section through the wall with the spongocoel through the bottom and top of the sponge toward the right; the compound nature of the trabs shows best in the upper center and the somewhat grossly calcite-replaced network. Trabs are the sides of the ladderlike structure and the rungs are the individual dendroclones that compose the skeleton, CRICYT T-1/30. Figs. 3, 4.—*Archaeoscyphia nana* n. sp.; *3*, shows relatively delicate nature of the skeletal structure with the surface of pinnation near the lower margin and with trabs diverging upward and outward into the annulations; top of the sponge towards the left, dermal margin toward the top; small rodlike oxeas (below the small white *o*) core the relatively delicate trabs, well developed dendroclone shows in the lower right as a prominent Y-shaped spicule connecting two relatively ragged trabs (arrow), Talacasto Gulch, CRICYT T-15; *4*, subtransverse section shows the irregular general radial arrangement of the trabs separated by fine canals (*c*) that show best in the lower center; runglike dendroclones (*d*) are best preserved near the dermal margin on the right calcite-filled algal borings (*a*) are light gray, holotype, Huaco locality, CRICYT T-13. Figs. 5, 6.—*Calycocoelia perforata* n. sp., paratype; *5*, vertical section through the wall shows trabs diverging upward and outward from the plane of pinnation, near the base, toward the dermal margin at the top; Y-shaped dendroclones unite at their tips to form the moderately coarse trabs, top of sponge to left; *6*, approximately transverse section shows relatively coarse trabs cross-connected by dendroclones (*d*) and the entire skeleton interrupted by more or less circular canals (*c*), Villicúm locality, CRICYT V1–2. Figs. 7, 8.—*Rhopalocoelia clarkii* Raymond and Okulitch, 1940, figured specimen; *7*, horizontal or transverse section shows regular canals (*c*) that interrupt the skeletal net; trabs are cross connected by long dendroclones (*d*), a well-defined dermal layer (*D*) shows along the right margin; *8*, vertical section with the plane of pinnation near the base and with upper trabs (*t*) diverging toward the dermal surface; dendroclones to the right of the *t* in the center cross-connect two relatively coarse trabs; what may be oxeas, continue with moderately long rods below the *o* in the lower right center; dark matrix in the trab below the central *t* may represent matrix filling a tube left vacant by a dissolved oxea, Talacasto Gulch, CRICYT TA-02.


1
2
3
4
5
6
7
8
a
a

and moderately, regularly aligned ostia. Generally, the sponge lacks annulations or nodes, such as are characteristic of *Nevadocoelia* or *Archaeoscyphia*, for example, although there is some weak variation in expansion of the sponge upward.

Circular dermal ostia of the horizontal, arcuate canal series range 0.4–0.9 mm in diameter, with most approximately 0.7–0.8 mm across. They occur in vertically stacked series that are parallel to the trabs in a very regular spacing. Around the exterior there are eight trabs per 5 mm, measured horizontally, so that they are spaced approximately 0.7 mm apart, which is the average diameter of ostia of the canal system.

Internally, two series of canals are prominent. The coarsest are the large vertical axial canals of the central cluster that rise upward in sweeping curves from ends of the horizontal canals that connect to the dermal ostia. The axial canals range 1.5–1.8 mm in diameter, with most approximately 1.7–1.8 mm across in the bottom of the spongocoel. These tend to be subcircular or subprismatic, separated from adjacent canals only by a single trab series so they occur almost side by side. Most canals in the central part of the cluster have their origins from the upturned ends of the incurrent horizontal canals near the basal part of the sponge. Those in the outer part of the axial cluster have origins as the upturned ends of horizontal canals that are in younger or more upper parts of the sponge. In vertical section, the axial cluster is about eight canals across. The available horizontal section does not cut through the canal cluster. Faint impressions of about 16 axial canals occur in the outer ring of the cluster, which would suggest there may be as many as 30 axial canals in the cluster, but the number is uncertain and probably variable.

The other prominent canals are essentially horizontal and connect from ostia in the dermal layer into pores of the spongocoel or into lower tips of canals of the axial cluster. Horizontal radial canals range 1.0–1.3 mm in diameter, with most approximately 1.1–1.2 mm across. They tend to be moderately uniform in diameter from the dermal area into the spongocoel. They may be isolated, relatively straight canals, or some may converge inward, and two canals may form a single canal at about midwall and extend on to the spongocoel. They are not lined but appear only as interruptions in the regular skeletal net. In vertical section these canals are essentially subhorizontal through much of the wall but flex up sharply at their inner edges to grade into the vertical axial canals or to open in gastral ostia on the spongocoel walls. They are moderately straight, essentially normal to the outer smooth surface, rather than arcuate upward like in some related sponges.

There is no evidence of a major vertical canal series in the wall, but only the upward and outward divergent, moderately open, coarse-textured skeletal pores between the trabs. These skeletal pores commonly range from 0.12 mm up to moderately large openings 0.28 mm across, but a few large openings up to 0.48 mm across also occur. These latter openings probably occur where the upward-expanding skeletal system does not yet have a trab inserted to keep the skeletal texture uniform.

The skeletal net is characteristically anthaspidellid, in which dominantly I-shaped and long-shafted, Y-shaped spicules combine at their cladome-brachyome tips to produce the trabs, the dominant element of the skeleton. They range 0.08–0.10 mm in diameter, with moderate uniformity. The trabs show moderately variable diameters along individual segments, and several appear moderately porous. In the outer part of the sponge wall, trabs are spaced eight per 5 mm, measured horizontally. In some of the more closely spaced parts of the skeletal net, 9 or 10 trabs may occur per 5 mm, particularly in the zone of expansion, but elsewhere in the middle and outer part of the wall six to seven trabs occur per 5 mm moderately uniformly throughout the skeleton.

A surface of pinnation is essentially parallel to the gastral layer, only one or two trabs in from that surface. The skeleton generally expands outward and upward at the rate of expansion of the basic sponge so that trabs on the exterior are essentially parallel to the dermal surface in a regular upward expanding pattern. Trabs do not flex sharply outward like those in *Archaeoscyphia* or *Calycocoelia*.

The skeleton is made dominantly of long-shafted, Y-shaped dendroclones. These spicules have shaft lengths of 0.12–0.48 mm, but most appear to be approximately 0.25–0.30 mm long. These shafts have diameters of 0.04–0.08 mm, with narrowest diameters generally in the vicinity of the brachyome and then expanding toward the cladome.

Clads are 0.08–0.16 mm long and have diameters of 0.04–0.06 mm, much like that of the shafts. In vertical sections clads commonly diverge at right angles in most spicules, but with significant range so that some diverge at acute angles and others at up to 120°. Openings between the clads may be circular or triangular and 0.08–0.10 mm across in some of the coarse spicules, or significantly smaller than that in some small dendroclones. Tips of articulation are lost in the calcareous preservation, but moderately large zygomes occur as part of articulating tips in many clads. Separate zygomes are occasionally preserved. They may be up to 0.02 mm in diameter and generally 0.05–0.10 mm long. They appear almost root-like as they articulate with adjacent surfaces. Generally speaking, however, tips of dendroclones are not that well preserved. Moderately coarsely branching cladomes thus produce a fairly open, porous trab, when all of the branching structures are combined, so that in transverse section the trabs appear porous where best preserved.

Dendroclones in the single ladderlike series range from four or five to only one or two per mm. Where uninterrupted and where there is no branching of the trabs, three or four dendroclones occur per mm in a normal series. The spicules produce skeletal pores that may be horizontally elliptical or moderately subquadrate and that range 0.2–0.7 mm high. Taller pores tend to be more subquadrate, and shorter pores tend to be distinctly elliptical.

A few rare, equal-rayed, Y-shaped spicules are present in transverse sections. These spicules generally have rays up to 0.3–0.4 mm long but have other dimensions essentially like those of longer-shafted dendroclones that make up the vast majority of spicules in the skeleton.

A few moderately rare, smooth oxeas core the trabs, generally one per cross section. They range up to approximately 0.03 mm in diameter and are of unknown length because we do not see the full preserved length of the spicules.

A dermal layer is moderately well defined around part of the specimen where it has been protected by an encrusting fossil and by matrix. That layer is approximately 0.5 mm thick and is moderately dense. Natures of spicules are obscured. The outer edges of the trabs are enlarged to 0.4 mm in diameter, and perhaps some of the tangential dendroclones may be expanded as well. Details of the structure are obscure, but the layer is clearly evident in transverse section. A few dendroclones are visible in the dermal layer. Their shafts are 0.04 mm in diameter and 0.08 mm long, and their clads are 0.08 mm long as well, and 0.04 mm in diameter. They produce relatively robust structures.

Discussion. In the original description of *Hudsonospongia cyclostoma* Raymond and Okulitch (1940, p. 204), the authors noted that the internal structure shows a number of nearly vertical canals in the axial region and other smaller ones that radiate upward and outward from these to the surface. The nature of those upward and outward radiating canals is in question. Raymond and Okulitch may have seen only the moderately coarse skeletal pores that are parallel to the trabs and interpreted these as canals. They did not describe the much more prominent horizontal canals that pierce the walls of the sponge. Because our specimen lacks major canals parallel to the upward and outward radiating trabs, we suggest that Raymond and Okulitch interpreted the skeletal pores that are parallel to the trabs as a canal series.

Such an interpretation raises some question about the interpretation of *Hudsonospongia* by Rigby and Webby (1988, p. 34–37) in which they clearly show a coarse series of canals that rise upward and outward, essentially normal to the radiating subhorizontal canal series. This canal pattern would now suggest that what they termed *Hudsonospongia* cf. *H. cyclostoma* should probably be included within *Aulocopium. Aulocopium* has three prominent sets of canals: the axial cluster of vertical canals; the moderately coarse, incurrent radiating subhorizontal system; and the series of upward and outward diverging canals that are more or less parallel to the trabs. In addition to those three distinct canal series, there are the triangular to polygonal skeletal pores that parallel the trabs.

Canal differences appear to provide an easy means for differentiating *Hudsonospongia* from *Aulocopium*, and in our description of the Argentine collection we have utilized those differences in canal structure to separate those genera, but these genera are still under investigation as part of a major analysis of North American Ordovician sponges.

Material. The figured and only specimen, CRICYT VI-2, from the Don Braulio Gulch locality in the Villicúm Range, San Juan Formation, in the Precordillera Oriental.

HUDSONOSPONGIA TALACASTENSIS n. sp.

pl. 3, figs. 2, 9, 10; pl. 9, figs. 6–8

Diagnosis. Broadly obconical to pyriform with smooth dermal surface and shallow spongocoel at the summit; sponges mainly low, broadly expanded, and turbinate, perhaps to 6 cm tall and 7–8 cm in diameter; spongocoel approximately 15–20 mm across and deep. Horizontal canals through walls distinctly arcuate upward, upflexed inner ends lead to coarse vertical canals of central axial cluster. Axial canals approximately 2 mm across, and horizontal canals generally 1.6–1.8 mm in diameter. Skeleton characteristically anthaspidellid, but fine textured, with trabs mostly approximately 0.1 mm in diameter and generally spaced 0.2 mm apart in dermal area and up to 0.5 mm apart in canalled interior. Dendroclones dominantly Y-shaped with long shafts 0.12–0.20 mm long and 0.04 mm in diameter, spaced six dendroclones per mm in single ladderlike series. Single coring oxeas may occur in some trab cross sections.

Description. Broadly obconical, toplike, or beetlike sponges with a smooth dermal surface are included here. These sponges expand abruptly upward from a rounded base to a maximum width at about two-thirds the height, then round abruptly to the narrow oscular margin, which is perforated by a simple, moderately shallow spongocoel.

Two specimens are in the collection. The holotype is approximately 5.5 mm high and expands upward from a rounded, almost stalklike base 2.7 cm across to a maximum diameter of 8 cm, approximately 2 cm below the summit. Above this it narrows gently to 6.9 cm across at the upper edge of the rounded wall and then abruptly, but moderately smoothly, narrows to the oscular margin. The spongocoel is approximately 1.6 cm deep and has a diameter at the osculum of approximately 1.6 cm.

The paratype is somewhat less expanded, is approximately 5 cm tall, and expands upward from a rounded base, 2.4 mm across, to a maximum diameter of approximately 6.3 cm. It does not round appreciably in the upper third of the sponge but has a broad saucer-shaped depression on the summit into which the shallow spongocoel is excavated. That saucerlike depression is approximately 11 mm deep below the rounded upper margins in the turbinate holotype. A shallow spongocoel approximately 15 mm deep is ill defined in the upper part of the paratype. The spongocoel margin, as in the holotype, is outlined by fairly coarse gastral ostia and has a rounded base above the axial cluster of canals. The spongocoel is approximately 1.6 mm across, with walls 1.8–2.6 cm thick.

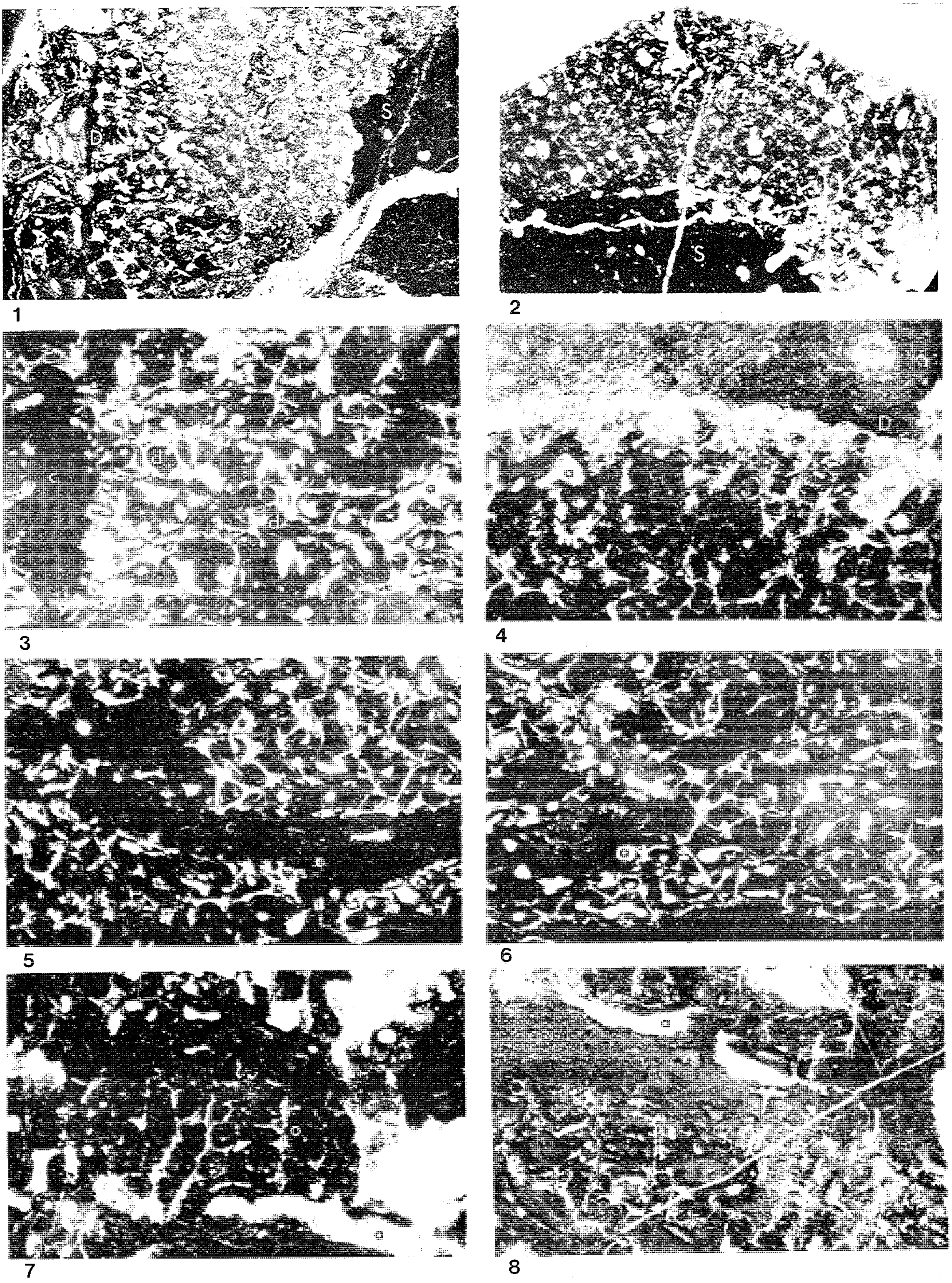
The outer or dermal surface of the species is smooth, except for the impressed circular ostia that occur in moderately regularly vertically stacked series. Two distinct series of canals are represented. The first and coarser of these canals are included in an axial cluster. These moderately large canals rise vertically from near the base and from upturned ends of the second series—the radial, upward-arcuate, horizontal canals. In the larger specimen the vertical axial canals range 2.0–2.3 mm across but are ill defined in the only available, but somewhat diagonal section. In the smaller specimen the vertical coarse canals range 1.9–2.8 mm in diameter, with most approximately 1.9–2.1 mm across. As in other species of the genus, and other genera within the family, these axial canals are side by side, outlined by parallel trabs. Only a single trab series separates each of the canals. The canals are generally subprismatic, because of their complex spacing, and occur five to six across in the axial cluster, which would suggest perhaps that 10 canals occur within the cluster.

The principally horizontal canals are distinctly upward arcuate and enter the dermal part of the wall essentially normal to the dermal surface or inclined slightly upward. They become horizontal in the inner part of the wall and then flex sharply upward to merge with canals of the axial complex. These canals may arch through 30°–40° as they change from the angles at which they entered through the dermal surface to where they open into the spongocoel. The lower canals in the sponge connect internally with the axial series, but upper canals empty as large openings on walls of the pitlike spongocoel.

Horizontal canals in the species range 1.4–1.8 mm high, with most in the upper diameter range. In the larger specimen they range 1.0–1.8 mm across, with those 1.6–1.8 mm in diameter most common. These canals lead in from dermal ostia that may be slightly restricted, but the canals tend to be subcylindrical throughout their

EXPLANATION OF PLATE 9

Photomicrographs of thin sections and acetate peals of *Rhopalocoelia* and *Hudsonospongia*. All are from the San Juan Formation and all are X10. Figs. 1, 2.—*Rhopalocoelia rama* n. sp., holotype, both are transverse sections; *1*, section through the wall shows relatively small, closely spaced trabs as light gray, starlike, crystalline calcite clusters, locally cross-connected by rods that are axes of short dendroclones; the spongocoel (*S*) is on the right and the dermal layer (*D*) is on the left; the sponge is encased in bioclastic debris; *2*, transverse section showing the general nature of the regular skeletal net, with trabs cross-connected in uniform triangular or quadrangular patterns by rodlike dendroclones; irregular algal borings (*a*) are filled with light crystalline calcite; the absence of a differentiated gastral layer between the skeletal wall and the spongocoel (*S*) and the lack of a dermal layer on the exterior are characteristic, Talacasto Gulch, CRICYT T-07. Figs. 3, 4, 5.—*Hudsonospongia cyclostoma* Raymond and Okulitch, 1940, figured specimen; *3*, vertical section shows parallel trabs as compound structures made of dendroclones, which are well exposed near the white *d* and canal (*c*) and algal borings (*a*); *4*, transverse section of the outer part of the wall shows the dermal layer, a light gray coarsely recrystallized layer below the *D;* algal borings (*a*) cut into the matrix that fills the canals (*c*) between the star-shaped trabs, part of the attached root tuft shows in the upper center; *5*, transverse section showing characteristic coarse dendroclones and trabs in the open texture; dendroclones forming the trabs show particularly well above the *c* in the canal filling in the center; a broad Y-shaped dendroclone is well exposed to the lower right of the *c*, Villicúm Range, CRICYT VI-5. Figs. 6, 7, 8.—Paratype; *6*, transverse section in which dark uninterrupted matrix fills canals between elements of the skeletal net, made of moderately coarse dendroclones that combine to form star-shaped trabs, which are here cut at high angles; algal borings (*a*) penetrate matrix in the canals; *7*, vertical section shows the runglike, Y-shaped dendroclones to the left of the white *o* that combine to produce the trabs; dark matrix fills the central part of the trab in the right center, such an opening may represent a straight tubular opening produced by early solution of a coring oxea; *8*, vertical section shows the trab-based skeleton interrupted by a matrix-filled horizontal canal (*c*), which has been bored by algae (*a*); several trab segments have a dark axis around which rays of dendroclones converged to produce the hollow trab. These, like the trab in 7, are thought to have been cored by oxeas that were differentially dissolved, Talacasto Gulch locality, CRICYT T-1/32.


S
D
1
S
2
D
3
4
5
6
7
8

length and then either open as ostia approximately 1.8–2.0 mm high on the gastral surface or flex sharply upward to join the wide axial canals that are about 2 mm across.

There are no significant large canals that rise upward parallel to the trabs, nor are any arranged approximately normal to the arcuate horizontal canals, as in *Aulocopium*, for example. Dermal ostia are not evident in the matrix-covered exterior of the sponge, but in sections they appear to be of essentially the same dimensions as the horizontal canals of the interior.

The skeleton is characteristically anthaspidellid, with prominent trabs and dendroclones arranged in ladderlike series. There is no prominent surface of pinnation, but the skeleton appears to radiate upward from a radiant that was probably present below the broken base of the specimens that we have.

Dermalmost trabs appear to be essentially parallel to the lower, moderately straight surface of the sponge and remain so up to the approximate level of the maximum diameter. Above that trabs emerge at the dermal surface, because they maintain essentially straight, linear trends. They intersect the upper surface essentially normal to that surface. Trabs are also essentially subparallel to walls of the spongocoel. The entire skeletal net shows a uniform upward and outward expansion but does not curve away from a surface of pinnation.

Trabs in the dermal layer of the holotype are 0.08–0.10 mm in diameter and generally range 0.08–0.12 mm in diameter in the thin section. They are, thus, moderately small for the family. They show some irregularity when traced along individual trabs, but most are moderately uniform for some distance. They are generally spaced 0.2 mm apart so that approximately three trabs occur per millimeter, measured around the dermal surface. In the interior, in radial section, they are spaced 0.36–0.53 mm apart, with that variation a measure of the amount of upward expansion in the skeletal net. In general, new trabs appear to be inserted rather than branched in the single section available.

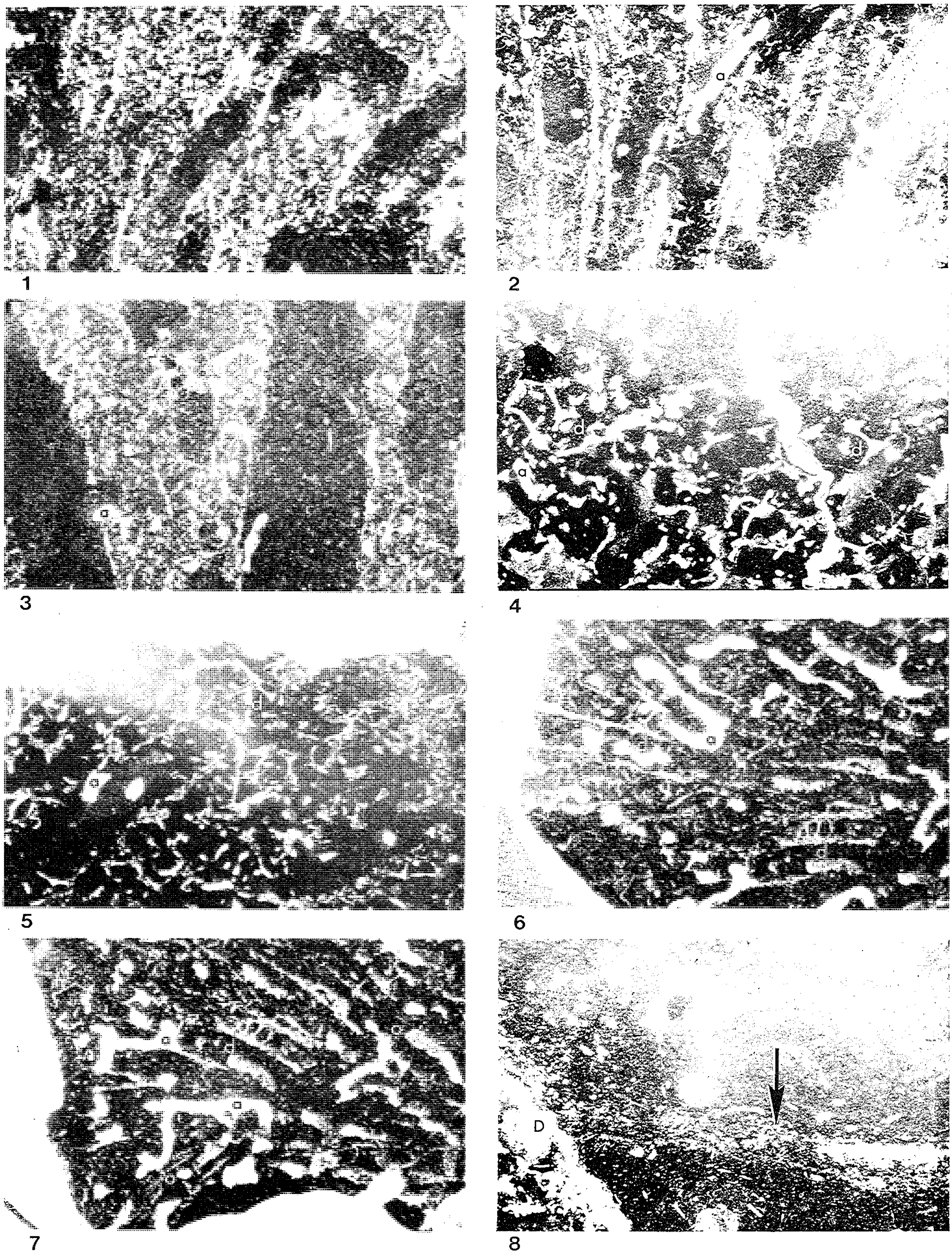
Dendroclones of the skeleton appear to be dominantly Y-shaped forms with long shafts. In the dermal layer these shafts are 0.12–0.20 mm long and have diameters of 0.04 mm. Clads may be up to 0.15–0.18 mm long, but are relatively coarse, 0.10 mm in diameter, as seen on the dermal surface. On the dermal surface six dendroclones occur per mm along a single series. They outline quadrate to rounded skeletal pores that may be 0.20 × 0.28 mm.

In the thin section, spicule shafts range 0.16–0.32 mm long and have diameters of approximately 0.04 mm, as in the dermal surface. Clads range 0.08–0.20 mm long and have diameters that range 0.03–0.06 mm, with most approximately 0.04 mm across. Variations of lengths of spicules within the interior of the wall are apparently related to the radial expansion of the net and distance variations before new trabs are inserted to equalize the texture of the skeleton.

The trabs appear to be relatively simple structures, with perhaps a single coring oxea in some sections. In most trabs, however, oxeas are not apparent. In one area, one oxea fragment, 0.05 mm in diameter, was cut in a thin section. In adjacent trabs, matrix fills straight-walled cen-

EXPLANATION OF PLATE 10

Photomicrographs of *Aulocopium, Anthaspidella, Patellispongia* and a hexactinellid root tuft. All are from the San Juan Formation and all are X10. Figs. 1, 2, 3.—*Aulocopium sanjuanensis* n. sp.; *1, 2,* holotype, both are nearly longitudinal sections and show the characteristic relatively fuzzy appearance of the skeletal structure, in which trabs are composed of ray tips of relatively short small dendroclones; the numerous small spicules produce an almost "hairy" appearance to the skeletal structure, which is among the finest textured of the anthaspidellids; trabs appear almost frayed and fibrous in the distinctive fabric around the canals (*c*); matrix bored with algae (*a*); the surface of pinnation is near the left margin in *1,* but in the left center of *2,* Talacasto Gulch, CRICYT T-1/22; *3,* paratype shows general fuzzy nature of the fine-textured skeletal tracts between canals (*c*); specimen was bored by algae (*a*), Villicúm, CRICYT VI-13. Figs. 4, 5.—*Anthaspidella annulata* n. sp., holotype, both show the relatively coarse texture of the skeletal net made of dendroclones (*d*) that have well-defined brachyome and cladome terminations, where they combine to produce the starlike cross sections of trabs, which are cut at high angles; algae (*a*) have bored the matrix that filled the canals; Talacasto Gulch, CRICYT T-49. Figs. 6, 7.—*Patellispongia robusta* n. sp., paratype, both sections are essentially vertical, parallel to the trabs, and show clearly defined relatively fine-textured dendroclones (*d*) with prominent Y-shaped brachyome terminations that combine with other spicules to produce the rodlike trabs; isolated coring oxeas occur above the *o* in the lower left and in the upper right in *7;* surface of pinnation is approximately horizontal and through the center of both *6* and *7,* Talacasto Gulch, USNM 463466. Fig. 8.—Root tuft attached to the dermal layer of a *Hudsonospongia cyclostoma* Raymond and Okulitch, 1940, tuft extends into matrix in the lower part (arrow); individual spicules are oxeas, which are here cut at high angles and most appear as small circular areas of light crystalline calcite; dermal surface of *Hudsonospongia* shown with letter *D;* Villicúm locality, CRICYT VI-2.


1
2
a
3
4
a
d
5
6
7
8
D

tral tubes that probably represent oxeas which were dissolved prior to calcification. These are commonly only 0.03 mm in diameter, but some are traceable for nearly 2 mm in the structure. Similar matrix-filled tubes are moderately common throughout the skeleton.

In some areas where spicules are well preserved, the rootlike zygomes of the dendroclones show well as branches from the clads. These zygomes are approximately 0.02–0.03 mm in diameter and may be of the same length. In addition to the small skeletal pores developed between the diverging clads, these zygomes may also isolate small circular openings that are now matrix-filled. This tends to produce a fairly porous texture to the trabs.

Long rhizoclones occur but are rare. A characteristic rhizoclone is 0.6 mm long, with four zygomes that arch upward from their flared attachments to the shaft of an associated dendroclone. The main parts of these zygomes are 0.06 mm in diameter at their maximum and may be up to 0.04 mm in diameter through most of their lengths. Zygomes appear almost appendagelike. They may be approximately 0.1 mm long and are commonly 0.04–0.06 mm in diameter in the upper part, but narrow to approximately 0.02 mm before they flare in their handlike zygome attachments.

Discussion. In the general canal arrangement, this species is similar to *Hudsonospongia cyclostoma* Raymond and Okulitch, 1940, except in this San Juan species the horizontal canals are distinctly arcuate upward, instead of almost straight and normal to the outer surface. In addition, the skeletal net is considerably finer textured than in the moderately coarse species of *Hudsonospongia,* and that species tends to be moderately tall and conical, whereas this species tends to be low, moderately expanded, and turbinate in its growth form.

Material. Two specimens of the species are in the collection; the holotype, CRICYT T-1/32, and the paratype, CRICYT T-1/10, are both from the San Juan Formation at Talacasto Gulch, in the Precordillera Central, San Juan Province.

Genus AULOCOPIUM Oswald, 1847

Diagnosis. Steeply obconical to hemispherical or mushroom-shaped sponges with smooth exteriors and a shallow to moderately deep spongocoel on upper surface. Axial cluster of moderately coarse vertical canals that lead upward from horizontal radial canals, which may be straight to irregularly curved. Prominent upward-and-outward divergent subvertical canals in spaces between the vertical stacks of radial series. Skeleton anthaspidellid with prominent trabs diverging from surface of pinnation essentially at midwall. Skeleton mainly of Y-shaped dendroclones, although other spicules including rhizoclones and X- and H-shaped dendroclones may occur in the skeleton.

Discussion. Comparisons of *Aulocopium* with *Hudsonospongia* have been presented under discussion of the latter genus. The principal difference relates to presence of vertical, upward-and-outward radiating canals in *Aulocopium* and their presumed absence in *Hudsonospongia.* Similarly, *Rhopalocoelia* lacks the steep upward divergent series but has the horizontal radial series and the coarse axial cluster prominent in *Aulocopium.* In addition, *Aulocopium* tends to be a broad turbinate form, in contrast to the tubular, cylindrical to steeply obconical shapes of *Rhopalocoelia, Archaeoscyphia,* or *Calycocoelia.*

Aulocopium does not have the prominent, regularly radiating, almost septal-like structure developed in *Zittelella,* although the general pattern of the skeleton in the two may be similar. Both have a surface of pinnation in the lower and outer part of the skeleton, near the dermal surface, and have trabs that rise essentially vertically in the interior of the sponge.

Type species. Aulocopium aurantium Oswald, 1847.

AULOCOPIUM SANJUANENSIS n. sp.

pl. 3, figs. 7, 8; pl. 4, figs. 1–3; pl. 10, figs. 1, 2

Diagnosis. Unbranched, steeply obconical to turbinate or mushroom-shaped sponges to 7–8 cm high and wide, with smooth exteriors and a shallow spongocoel; maximum diameters may be in lower or upper part of the variably shaped sponge, above a rounded base. Spongocoel 2.0–2.5 cm across and 2 cm deep, into which rises an axial cluster of coarse vertical canals, each approximately 2.5 mm in diameter or wide, as prismatic, closely spaced openings. Arched lateral canals essentially horizontal; inner ends curve up into and grade into vertical canals of axial clusters; horizontal canals approximately 1 mm in diameter. Upward-and-outward divergent canals of third series, generally 1 mm across, and long continuous subvertical canals in interspaces between vertically stacked horizontal series. Surface of pinnation essentially at midwall, with trabs subvertical in gastral part of the skeleton curve to 15°–20° from the surface of pinnation; trabs in dermal part of the wall curve outward approximately 30° from surface of pinnation. Trabs approximately 0.1 mm in diameter, separated 0.24–0.30 mm to form skeletal pores parallel to the trabs. Most spicules long-shafted, Y-shaped dendroclones to 0.5 mm long and 0.6 mm in diameter; some dendroclones irregularly oriented with shafts subvertical or at irregular angles.

Description. Single, steeply obconical to turbinate or mushroom-shaped sponges with moderately smooth exteriors expand upward either very rapidly or become almost subcylindrical in the upper part, with a shallow spongocoel on the upper surface. Exteriors lack nodes or prominent annulations and are smooth, except for prominent, vertically stacked ostia.

The holotype (CRICYT T-1/22) fragment is 6.8 cm high and appears almost barrel-shaped. It widens upward from a broken base, approximately 35 mm across, to a maximum diameter of 58 mm near midheight. Above that the sponge narrows to the moderately flat, upper oscular margin, with an upper diameter of approximately 35 mm. The upper spongocoel is approximately 22 mm across and approximately 30 mm deep, with smooth walls pierced only by the large ostia of the vertically stacked horizontal canals. Sponge walls narrow upward to only a few millimeters wide at the oscular rim, but at approximate midheight they may be up to 25 mm thick near the base of the spongocoel.

A more mushroom-shaped paratype, CRICYT T-4/43, is only 3.7 cm high and has a prominent rounded base. The sponge expands upward very abruptly to a maximum diameter of approximately 6.8 cm, about 15 mm below the rounded upper summit. From that maximum width the sponge narrows with a smooth curving profile to the oscular margin, where the sponge walls are relatively narrow around the spongocoel. The spongocoel is approximately 2.4 × 2.0 cm across. It is a shallow depression in the upper surface. The spongocoel pit is approximately 1.6 cm deep and is marked along its slopes by ostia of horizontal tangential canals characteristic of the interior of the sponge.

All of the shallow spongocoel openings have smooth lateral surfaces and rounded bases into which rise prominent excurrent axial canals. These are the coarsest canals in the skeletal structure. For example, in CRICYT T-4/43 the vertical cluster includes canals 1.7–2.4 mm in diameter, with most 1.9–2.0 mm across. They are prismatic, closely spaced in the cluster, and separated only by single trabs. The cluster has essentially the same width as the spongocoel opening. There may be up to 28 canals in the cluster, packed in three or four concentric rings of canals. Those in the center are distinctly vertical. Those along the outer edges are curved because of their transition from horizontal arcuate parts to vertical positions at edges of the axial cluster. In the holotype, axial canals are somewhat smaller, from 1.3–2.1 mm across, but most of these are also in the coarser part of that range.

The second major series of canals includes the subhorizontal upward-arcuate openings. These canals have dermal ostia 0.7–1.3 mm in diameter, with most approximately 1 mm across. Subhorizontal canals in the holotype may arch downward, but those in CRICYT T-4/43 and CRICYT VI-D13 arch upward to terminate as part of the vertical axial complex. In the holotype these horizontal canals range 0.4–0.9 mm in diameter, with most approximately 0.7 mm across, in the middle part of the wall. These prominent canals may interrupt the skeletal structure. In the other specimens these canals arch upward slightly at midwall as they parallel former oscular edges of the wall. These are the vertically stacked canals that open as prominent gastral ostia on the inner surface.

A third canal series in the moderately complex "plumbing" includes those that diverge upward and outward, moderately parallel to the trabs and nearly at right angles to the arcuate horizontal series. These divergent canals range 0.7–1.1 mm in diameter, with most approximately 1.0 mm across. They have a gently upward and outward arched appearance and occur in interspaces between the vertically stacked horizontal series. These smaller divergent canals may be almost side by side, or they may be separated 1 or 2 mm within the single radial series.

Thus, the species is characterized by three prominent canal series: an axial cluster of coarse canals that are approximately 2 mm in diameter; horizontal to upward arcuate incurrent canals that are approximately 1 mm high; and the upward- and outward-diverging series of canals that are approximately 1 mm across.

The skeleton is typically anthaspidellid, with prominent upward- and outward-diverging trabs formed by united tips of small, fairly irregular dendroclones. A surface of pinnation, essentially at midwall, is moderately well defined in the holotype. Trabs on the inner or gastral part of the wall tend to be subvertical and diverge at angles of perhaps 15°–20° from the surface of pinnation. They become nearly straight and extend subvertically from the surface of pinnation. Those trabs below and more dermal to the surface of pinnation curve upward and outward to diverge up to approximately 30° from the surface of pinnation. Their angles of divergence increase toward the dermal margin.

Trabs range 0.06–0.10 mm in diameter and are moderately small when compared with some of the coarser genera in the collection. Internally, nine trabs occur per 5 mm, radially, and are generally 0.24–0.30 mm apart.

Most spicules tend to be long-shafted, Y-shaped dendroclones. In CRICYT VI-D13 they range 0.12–0.54 mm long, with most approximately 0.2–0.3 long. This results in skeletal pores that range 0.16–0.50 mm across. That variation is a result of the upward and outward divergence of the trab system. Most of those skeletal pores are approximately 0.24–0.30 mm across. Clads of the dendroclones range 0.08–0.20 mm long and 0.03–0.06 mm in diameter.

The trabs in paratype CRICYT VI-D13, in particular, appear almost frayed and fibrous, with numerous small dendroclones with short rays that diverge from the moderately irregular trabs. In general, dendroclones are spaced five to six per mm in single series, but in some areas may range up to 10 per mm in unusually closely packed parts of the skeleton.

The fairly fuzzy-appearing nature of the skeleton is distinctive of the species. Another distinctive feature is the apparent irregular orientation of many of the dendroclones. Many shafts appear subvertical or at irregular angles, producing an almost stippled appearance when seen in vertical sections. The trabs appear moderately dense. No unequivocal evidence of coring oxeas is preserved in the thin sections available.

Discussion. The species apparently shows significant variation in shape from almost obloid biscuitlike forms to barrel-shaped specimens. However, in the sections available, the fine-textured, irregular nature of the skeletal net, the coarse canals, and the canal system suggest that the variant specimens should be included in a single species.

Available material. Three specimens are in the collection of the species. The holotype, CRICYT T-1/22, and paratype, CRYCYT T-4/43, are from the San Juan Formation at Talacasto Gulch in the Precordillera Central. Paratype CRICYT VI-D13 is from the San Juan Formation at Villicúm in the Precordillera Oriental, San Juan Province.

PROTACHILLEUM Zittel, 1877

Emended diagnosis. Mushroom-shaped sponge with broad short stalk and overhanging platterlike upper part, summit may be centrally arched, but spongocoel lacking; basal part smooth to weakly annulate. Dermal ostia prominent in stalklike base, canals rise inward to produce major porous zone in lower part of stalk and rise sharply upward to produce isolated, separated vertical canals scattered throughout the central part of sponge, but not as an axial cluster. Skeleton anthaspidellid with trabs that radiate from radiant near base. Lower trabs essentially horizontal, and upper trabs radiate upward and outward. Surface of pinnation developed in thin, overhanging, platterlike part, where trabs diverge downward to dermal surface and upward to gastral surface. Spicules principally Y- and X-shaped dendroclones. Skeleton fine textured.

Discussion. Protachilleum was not well defined by Zittel (1877a). The genus and species were described as a sponge with a mushroom-shaped body that is stalked and with an arched upper surface that lacks a central cavity. The skeleton was described as consisting of large coalescing sexiradiates with thickened crossing nodes. That description is sufficiently vague for almost any of the flat, broad, anthaspidellids to fit here.

The paper where Zittel (1877a) described *Protachilleum kayseri* was the first paper on fossil sponges from the Ordovician from South America, so the species takes on unusual historical significance. The genus was reported by de Laubenfels (1955, p. E53) as occurring in the Silurian of Argentina. This age is incorrect, for the locality is in the Ordovician San Juan Formation at Huaco Gulch in the Precordillera Oriental of San Juan, in the northern part of the province. The material described here is from the same locality.

Type species. Protachilleum kayseri Zittel, 1877.

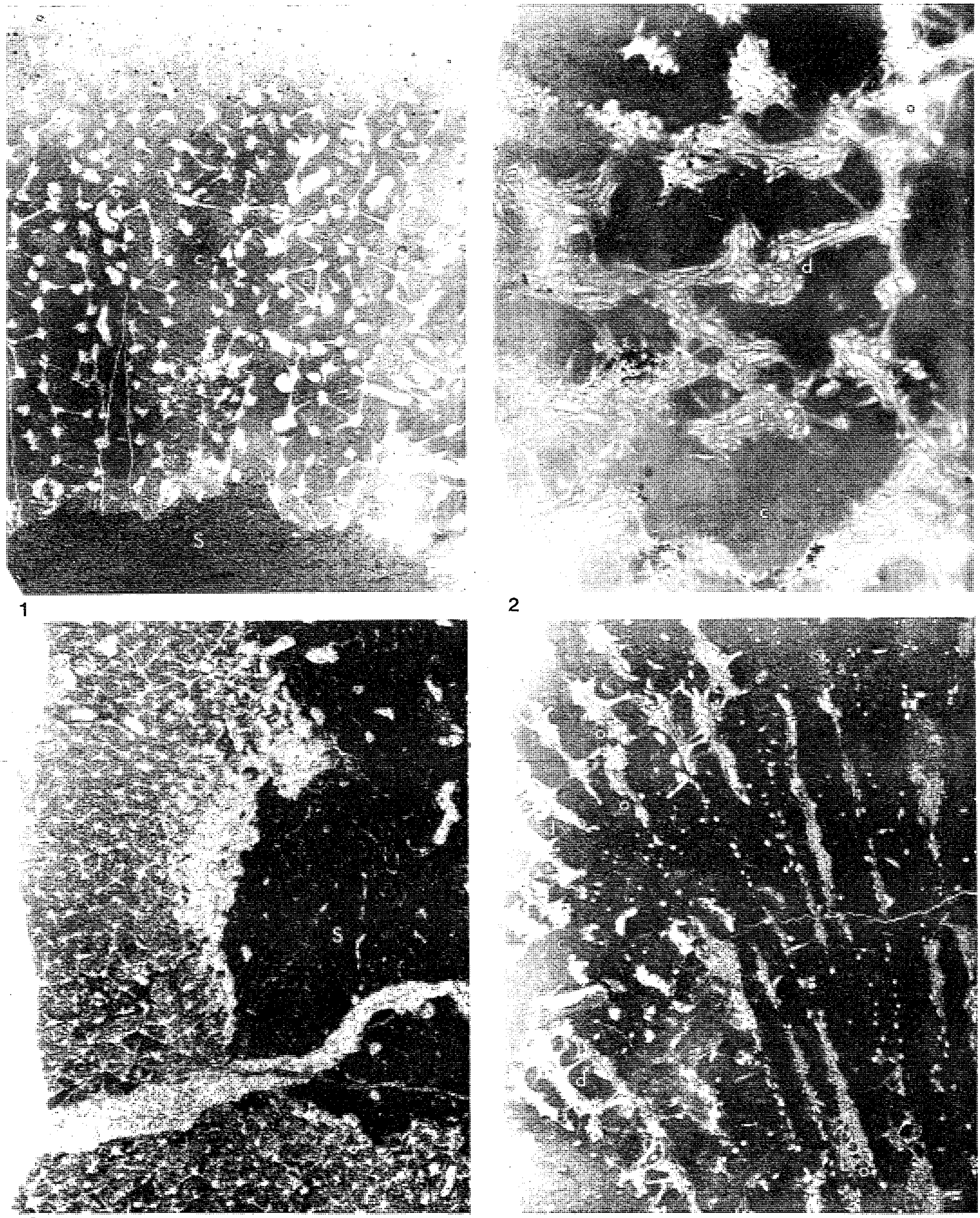
PROTACHILLEUM KAYSERI Zittel, 1877

pl. 3, figs. 3–6

Synonymy. Protachilleum kayseri Zittel, 1877a, series 2, v. 1, p. 22, pl. 5, fig. 10; Zittel, 1877b, p. 35, 45; Zittel,

EXPLANATION OF PLATE 11

Photomicrographs of *Rhopalocoelia, Talacastonia,* and *Patellispongia*. All are from the San Juan Formation and all are X20. Fig. 1.—*Rhopalocoelia clarkii* Raymond and Okulitch, 1940; horizontal section shows most of the wall from the spongocoel (*S*) margin to near the dermal surface, at the top; dark matrix fills the canals (*c*) that are essentially horizontal and radial in the sponge, between rows of trabs here cut at high angles; dendroclones (*d*) bridge from trab to trab and ray tips of the dendroclones produce the beamlike major elements of the skeleton, figured specimen, Villicúm Range, CRICYT VI-2. Fig. 2.—*Talacastonia chela* n. sp., holotype, transverse section shows relatively coarse canals (*c*) defined by the broad compound trabs (*t*); dendroclones like that above the *d* in the right center have arcuate ray-tips almost as grasping structures around circular section of light gray oxeas (*o*), which are generally single coring elements but occasionally three may occur, as in the upper right (black *o*), Talacasto Gulch, CRICYT T-53. Fig. 3.—*Rhopalocoelia rama* n. sp., holotype, transverse section shows a dark matrix-filled spongocoel (*S*), in part filled with sparry calcite that may represent a geopetal structure, in the left center, and with light gray irregular algal borings; the dendroclone nature of the skeletal structure shows well in the upper left, where rodlike dendroclones converge to produce the star-shaped or irregular light gray coarse trabs; horizontal canals (*c*) are relatively small in this fine-textured species, Talacasto Gulch, CRICYT T-09. Fig. 4.—*Patellispongia robusta* n. sp., paratype, vertical section shows prominent, relatively coarse, trabs with coring oxeas (above and to right of white *o*) in upper center and lower right; dendroclones show particularly well near the left margin (above and left of white *d*); canals (*c*) are upward arched and interrupt trabs as they extend from the dermal surface on the left, toward the gastral surface beyond the plane of pinnation near the right margin, Talacasto Gulch, USNM 463466.


1 2 3 4

1878–80, p. 172 (translation); de Laubenfels, 1955, p. E53; Beresi, 1981, p. 405.

Diagnosis. Small, flat-based, stalked, mushroom-shaped sponges with overhanging lateral margins, sponges usually only a few centimeters wide, but wider than high; spongocoel lacking; dermal ostia in stalk 0.8–1.0 mm in diameter, moderately well aligned; canals from ostia arch upward into porous zone from which rise isolated canals, 0.8 mm in diameter, spaced 1–3 mm apart; axial cluster not developed. Essentially horizontal canals developed at midwall in overhanging area and joined by smaller openings, 0.4 m across, which trend at high angles across trabs. Skeleton typically anthaspidellid, with radiant near base; trabs small for family, most approximately 0.15–0.16 mm in diameter, spaced 0.15–0.30 mm apart to define skeletal pores parallel to trabs. Skeleton of Y- and X-shaped dendroclones; shafts of Y-shaped forms mostly approximately 0.4 mm long and 0.03–0.04 mm in diameter.

Description. Broad, flat-based, mushroom-shaped sponges with a broad stalk and platterlike overhanging edges are included here. The upper summit lacks a spongocoel, and the dermal surface is smooth, except for aligned ostia, although it may be gently annulate in lower part of the sponge.

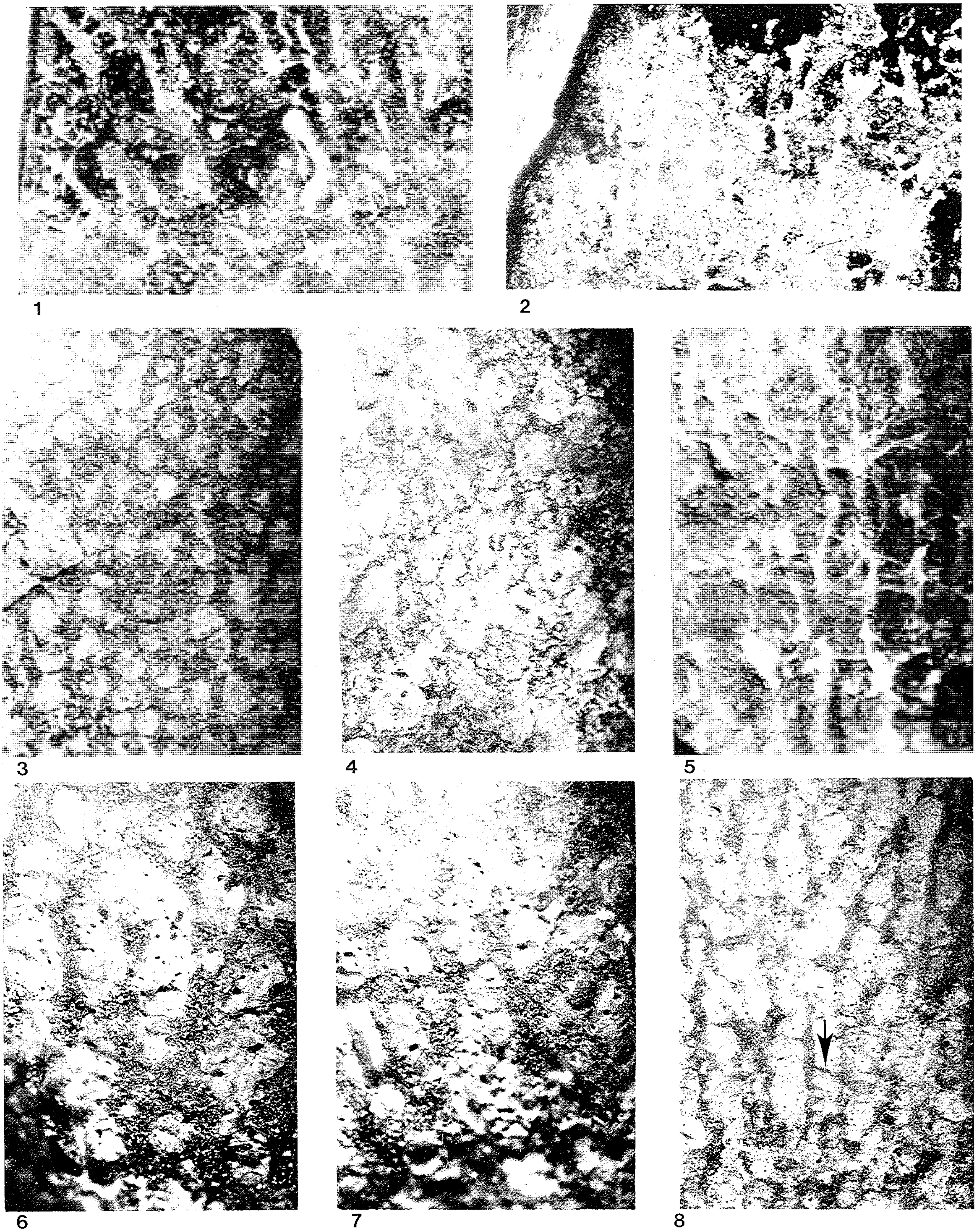
The large specimen, CRICYT H-42, is approximately 20 mm high and has a maximum diameter of approximately 48 mm. The sponge expands sharply outward above a stalk to produce a relatively narrow overhang in almost a cake-platter-like structure, with outer edges sagging or drooping somewhat. The stalk is a subcylindrical structure and, in the largest specimen, has a flat, virtually complete base 3 cm across and about 1 cm high. Weak annulations on the stalk are about 5 mm apart and appear as faint ridges, 1.0–1.5 mm across, that rise approximately 0.5–1.0 mm out from the stalk, or the stalk may be essentially smooth. The relatively narrow overhang extends 10–15 mm on either side beyond the upper part of the stalk. Those overhangs have a proximal thickness of approximately 10–11 mm. They narrow to almost a rectangular margin approximately 6 mm thick at the outer edge. The upper surface is pitted on the specimens that are available, but a central spongocoel or upper depression is lacking.

The smaller specimen, CRICYT H-43, has a stalk about 1.2 mm high and 1.7 mm across at the base. It, too, is subcylindrical but expands slightly upward to a diameter of 20–22 mm before the sponge flares abruptly outward to the maximum diameter of approximately 30 mm, with an upper thin part of the wall approximately 0.6 mm thick. In only one small area, however, is there an overhang developed.

A few dermal ostia occur on the base in the smaller sponge. These range 0.8–1.0 mm in diameter, are circular, and occur moderately well aligned in a horizontal ring 2–3 mm above the base. Canals from these ostia apparently arch inward and upward to produce a major porous zone. Such a zone is exposed in the lower part of the stalk of the larger specimen about 5 mm above the central part of the base. These upward-convergent, moderately wide-

EXPLANATION OF PLATE 12

Photomicrographs of acetate peels and weathered natural surfaces of Ordovician sponges from the San Juan Formation of the Argentina Precordillera, all figures are X10. Fig. 1.—*Anthaspidella alveola* n. sp., holotype, acetate peel showing the general anthaspidellid nature of the skeleton with prominent, relatively robust trabs and cross connecting dendroclones, best shown in the upper and lower left where they appear runglike between the upward and outward diverging moderately coarse trabs. Crystalline calcite-filled algal borings (*a*) penetrate the matrix in the right center, Talacasto Gulch, CRICYT T-SQ1. Fig. 2.—*Rhopalocoelia clarkii* Raymond and Okulitch, 1940; thin section of the distal part of the wall shows moderately coarse trabs and robust cross-connecting dendroclones, with canals filled with medium and dark gray matrix, Talacasto Gulch, CRICYT T-1/Cut. Figs. 3, 8.—*Patellispongia robusta* n. sp.; *3*, weathered dermal surface of paratype shows densely spiculed, thin dermal layer with ostia separated by broad tracts; ostia in moderately irregular pattern; slightly reflexed distal margin of the sponge toward the right; *8*, weathered surface shows regular trab-based skeleton and occasional runglike cross connecting dendroclones, some with distinct Y-shaped cladome terminations (arrow), Talacasto Gulch, USNM 463466. Fig. 4.—*Anthaspidella inornata* n. sp., holotype, weathered dermal surface shows irregular thin, complexly spiculed, dermal layer with ostia filled by light gray matrix; spicule nature of the dermal net is uncertain; small dark circular areas within ostia are crystalline calcite fillings of algal borings, Talacasto Gulch, CRICYT T-48. Fig. 5.—*Psarodictyum magna* n. sp., holotype, weathered exterior of dermal surface shows moderately coarse trabs and long thin-rayed dendroclones as runglike structures between the trabs; dark matrix fills aligned ostia of the canal system that is parallel to the trabs, Villicúm Range, CRICYT VI-44. Figs. 6, 7.—*Talacastonia chela* n. sp., holotype, coarse compound trabs are roughly vertically aligned, but have a somewhat irregular course and are cross-connected by thick compound lateral trabs or coarse dendroclones, in one of the coarsest skeletons of any sponge in the collection, Talacasto Gulch, CRICYT T-53.


1
2
3
4
5
6
7
8

spread canals are generally 0.5–0.6 mm in diameter. They do not develop an axial cluster but appear to diverge upward and outward in the upper part of the sponge, parallel to radiating trabs in the region above the stalk. Both specimens show the canals to be upward convergent in the outer one-third, but then apparently bend upward to become the vertical canals spaced 1–3 mm apart as isolated, apparently excurrent openings in the inner parts of the sponge.

A series of smaller openings, approximately 0.3–0.4 mm across, cut at high angles across the trabs in the overhang areas. These canals connect to other canals that more or less parallel the trabs and extend at essentially midthickness of the overhang in toward the central region of the sponge.

The skeleton is typically anthaspidellid, with a radiant near the base of the sponge. Trabs radiate essentially horizontally from the radiant near the base of the sponge, but elsewhere rise upward and outward as relatively straight elements in most of the rest of the sponge. A possible surface of pinnation is developed approximately 1 mm above the flat base of the sponge, but divergence from horizontal trabs to those lower ones is so slight that a surface remains ill defined. In the thin overhanging shelf, however, a surface of pinnation is developed essentially in the middle of that structure. Trabs diverge from that surface of pinnation downward and outward to meet the base of the overhang at 30°–40°. Trabs above the surface of pinnation continue radiating outward and upward to meet the upper surface at about the same angle.

Trabs are small for the family and range 0.12–0.18 mm in diameter, with most approximately 0.15–0.16 mm across. As in other genera, trabs are slightly irregular in diameter, dependent upon where dendroclones converge. Trabs are relatively straight, continuous, and are interrupted only where ostia and the moderately large canals cross their trends. Trabs are spaced four to six per mm in the upper part of the skeleton where they are best preserved in the section available to us. They are separated 0.15–0.30 mm and define the skeletal pores that parallel the trabs systems. New trabs apparently result from both branching and insertion.

The skeleton is made of Y- and X-shaped dendroclones. The long-shafted, Y-shaped spicules have shafts 0.3–0.5 mm long, with most approximately 0.4 mm long. They range 0.02–0.04 mm in diameter, with most approximately 0.03–0.04 mm across. As in other species, some of the large spicules appear to have diameters enlarged by diagenesis, but variation may represent dimensions of the sponges here. Clads range 0.10–0.14 mm long with considerable variation, and they range 0.02–0.03 mm in diameter near where the two clads diverge from the tips of the shafts. They generally decrease in diameter toward the trabs, where flaring tips are developed. Details of articulation are lost in the coarse calcareous replacement. X-shaped dendroclones appear relatively rare. These have short shafts and relatively long clads that bridge the skeletal pores. Dendroclones are spaced so that four to six occur per mm in a general series, and the trabs are spaced 14–15 per 5 mm, measured in the upper part of the sponge where the textures are the coarsest.

Discussion. This species is one of the most fine-textured sponges among the anthaspidellids from the Ordovician of Argentina. The fine skeleton, the flat-based stalk, and overhanging mushroomlike appearance separates the species from nearly all of the associated genera, except perhaps small species of *Patellispongia* or *Psarodictyum.* In those forms, however, the prominent radial system of trabs on the dermal layer and the coarse texture of the skeleton contrast sharply to the small skeletal dimensions in the species described here. These small sponges might appear as fragments of *Archaeoscyphia,* but the surface of pinnation is essentially vertical in the latter genus, rather than essentially horizontal as in the overhanging expansions characteristic of *Protachilleum kayseri.*

Material. The species is represented in the collection by two figured specimens (CRICYT H-42 and CRICYT H-43) from the Huaco section of the San Juan Formation, in the Precordillera Oriental in the northern part San Juan Province. This is the type locality for the material described by Zittel (1877a), and it is also the only place from which the species has been reported thus far.

Genus PSARODICTYUM Raymond and Okulitch, 1940

Discussion. Psarodictyum was proposed by Raymond and Okulitch (1940), based on fossils from northeastern United States. Their description is so brief, however, that virtually every funnel-like or discoidal form within the family could be included within the genus. Bassler (1927, p. 393; 1941, p. 97) proposed the term *Patellispongia* for similarly shaped, unilaminar fragments of what are probably discoidal saucer-shaped or perhaps palmate or fan-shaped sponges. The two genera are strikingly similar in growth form. Rigby and Webby (1988, p. 37–41) described species of both genera from the Ordovician of Australia and noted the similarity of the two. They tentatively concluded (1988, p. 39) to include those forms with a thick dermal layer in the genus *Patellispongia* and to include those forms that lack such a layer within the genus *Psarodictyum,* dependent on some ultimate serious review of the two North American sponges. For the present we will continue the separation of the genera as utilized by them.

Type species. Psarodictyum magnificum Raymond and Okulitch, 1940.

PSARODICTYUM MAGNA n. sp.

pl. 4, fig. 4; pl. 12, fig. 5

Diagnosis. Curved palmate sponges expand upward from basal stem; basal wall 5–6 mm thick to 16 mm thick at the upper edge; lacks annulations, dermal surface marked only by coarse trabs and indented ostia to 2 mm in diameter that occur in prominent vertical series. Lacks clustered canals on gastral surface and lacks a dermal layer. Most canals approximately 1 mm in diameter through most of wall; ostia and canals seven to eight per 10 cm parallel to trabs, in series spaced five to six per 5 mm horizontally. Skeleton anthaspidellid, trabs straight with most approximately 0.2 mm in diameter. Dendroclones principally Y-shaped with smooth shafts, mostly approximately 0.7 mm long and 0.1 mm in diameter, spaced two to four per mm in ladderlike series. Clads coarse and prominent. Coring oxeas may occur five to six per cross section in trabs.

Description. Arcuate palmate sponges that expand upward from a basal stem are included here. The holotype (CRICYT VI-44) has a somewhat broken attachment area, 1.5 cm across, in the stalklike base of the upward expanding fan that is 4 cm across at the base. The sponge expands to a maximum width of 8.5 cm, although at least one of the edges appears to be broken and the sponge may have been somewhat larger than that. It is approximately 10 cm high and apparently reached maximum width at 6.5 cm above the base, where the diverging skeletal structure suggests a complete one-half width approximately 4.5 cm across. Above this, the sponge rounds to a more or less complete rounded upper edge.

The relatively thin basal part of the wall is 5–6 mm thick. It thickens upward to approximately 10 mm thick at midheight and then to 13–16 mm at the upper preserved margin. The exterior lacks prominent annulations, is relatively smooth, and is marked only by relatively coarse trabs and indented impressed ostia. The sponge appears to lack both dermal and gastral armoring layers, for endosomal spiculation appears to extend to the preserved surface. At least two series of canals are evident in the sponge. One appears to be essentially normal to the surface and has circular ostia on the exterior that range 1.4–2.0 mm in diameter, with most approximately 1.6 mm across. These canals penetrate completely through the sponge wall, based on traces of canals on the upper broken surface. The canals narrow somewhat from the moderately large ostia and appear to be 0.8–1.0 mm in diameter through most of the wall.

Much of the gastral surface is presently still buried by matrix. Arrangement of ostia on the gastral surface remains unknown.

In addition to the coarse circular ostia, which are rare on the exterior, there are somewhat more common circular ostia of canals 0.8–1.0 mm in diameter. These are also not common, however, and most of the porous nature of the skeleton is expressed by canals that appear to have elliptical openings on the dermal surface. These are obviously canals that are ascending and meet the dermal surface at a moderate angle and, hence, have an elliptical appearance where they terminate at the surface. These latter elliptical openings tend to be bounded by prominent, moderately coarse trabs. Canals generally range 0.6–0.9 mm across and 0.9–1.1 mm long, with the long direction parallel to the trabs. Ostia are all more or less evenly elliptical, although a few may be somewhat elongate quadrate, where defined by closely spaced dendroclones. These are the most abundant and prominent canals in the skeleton and occur seven to eight per 10 cm, measured parallel to the trabs in a single series. There may be five to six series per 5 mm, measured at right angles to the trabs, which would result in approximately 80 elliptical ostia per 10 cm^2.

The skeleton is characteristically anthaspidellid, with prominent trabs and ladderlike series of dendroclones arranged in an uniform, upward-radiate pattern. The trabs tend to be straight and subparallel to the dermal surface. Trabs range 0.1–0.3 mm in diameter, but most appear to be approximately 0.2 mm across. Trabs are spaced 0.6–0.9 mm apart, with most in the lower range of approximately a 0.6-mm separation.

Dendroclones appear to principally Y-shaped dendroclones with long smooth shafts that range 0.5–0.9 mm long, with most approximately 0.7 mm long. These shafts have ranges of diameters in their narrowest part of 0.09 to approximately 0.12 mm, but most appear to have diameters of approximately 0.10 mm. The two bifurcating clads on the cladome end appear to range 0.15–0.20 mm long and 0.05–0.08 in diameter, with most approximately 0.10 mm across. As clads diverge from ends of shafts to form the trabs with their articulate complex tips, they may broaden abruptly vertically. Individual clads may form part of a cladome up to 1 mm high as they arch and form tips with main axes subparallel to the trab axis. An alternation of brachyome and cladome ends of the spicules is present in some areas in single series.

Dendroclones are spaced two to four per mm in the single ladderlike series. They define elliptical to rounded subquadrate openings between "rungs" in the ladderlike structure. These pores are generally 0.3–0.4 mm high, but in a few cases may range up to 0.7 mm high in coarse interruptions in a regular skeletal net. They range 0.3–1.0 mm wide, with most approximately 0.7 mm wide in the uniform skeletal net. Most of the dendroclones are moderately uniformly spaced, but in some areas the shafts are almost side by side, only 0.05–0.20 apart.

Some trabs have dark matrix filling their axial regions, as on the upper left center of the specimen as figured. A few trabs show coring oxeas. In one trab, for example, three oxeas show around the periphery, which would suggest that there may be five or six oxeas in a cross section. Full lengths of the oxeas are not preserved, but they do have a clearly defined diameter of 0.03–0.04 mm. They are side by side, closely spaced, and in this area make up much of the diameter of the trab.

Discussion. The Argentine species may be somewhat different from a related species described from the Ordovician of New South Wales, where coring oxeas are a prominent part of the skeletal makeup of the Australian species. Microstructure with only a few oxeas, where present, would suggest the species is included within *Psarodictyum,* based on comparisons with the few oxeas present in the species *Psarodictyum crassum* Rigby and Webby, 1988, as compared with the associated *Patellispongia australis* Rigby and Webby, 1988, in which there are many oxeas in the trabs.

The species *Psarodictyum magnificum* Raymond and Okulitch, 1940, and *Psarodictyum planum* Raymond and Okulitch, 1940, are low, broadly conical forms somewhat like the palmate fragment in the collections described here. Both of those eastern American species were noted by Raymond and Okulitch (1940) as having thin walls, but they gave no measurements. In general, the relatively small form here would have a moderately thick wall compared to other discoidal or funnel-like sponges. The Australian species has a wall up to 23 mm thick, which is significantly thicker than the maximum of approximately 16 mm seen in the species from San Juan.

The surface of pinnation in the Australian species is essentially at midwall, so trabs appear to emerge at the dermal surface essentially at right angles to that surface, whereas in the San Juan species trabs are essentially subparallel to the outer surface or meet the outer surface at very low angles. This would suggest that the surface of pinnation in this species must be close to the dermal surface.

Material. Only the holotype, CRICYT VI-44, occurs in the collection. It is from the San Juan Formation, in Don Braulio Gulch, Villicúm Range, in the Precordillera Oriental. The specimen was collected by Matilde Beresi.

Etymology. Magnus, L., large or great, referring to the coarse nature of the skeleton.

Genus PATELLISPONGIA Bassler, 1927

Emended diagnosis. Sponges unilaminar, broad, saucer-shaped to palmate, with short stem. Dermal surface smooth with dense differentiated dermal layer pierced by minute, closely spaced pores arranged in rows parallel to trabs of the skeleton. Gastral surface smooth, marked by similar more or less radial series of ostia and coarse trabs; gastral surface lacks discrete separated clusters of excurrent canals.

Type species. Patellispongia oculata Bassler, 1927.

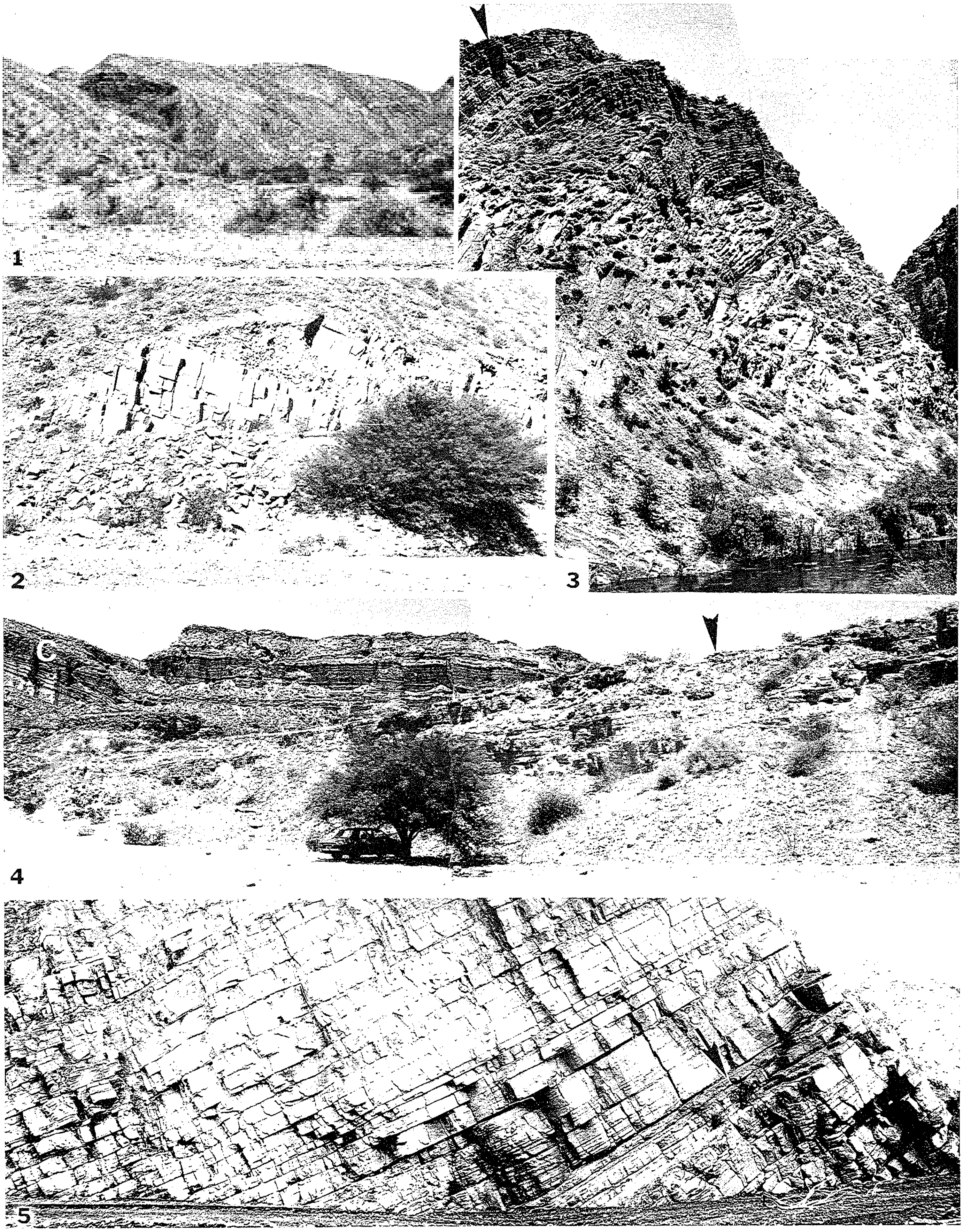
PATELLISPONGIA ROBUSTA n. sp

pl. 4, fig. 5; pl. 5, figs. 1, 4 , 6; pl. 6, figs. 3, 8, 9; pl. 7, fig. 1–3, 6, 7; pl. 10, figs. 6, 7; pl. 11, fig. 4; pl. 12, figs. 3, 8

Diagnosis. Large, saucerlike to palmate or upward and outward expanding funnel-like sponges, may be stalked with walls to 22 mm thick; dermal surface smooth with thin dense dermal layer, lacks annulation; upper gastral surface smooth or may have broad depressions to 1.4 cm in diameter, but lacks clusters of excurrent canals. Dermal ostia in two series: smaller approximately 0.3–0.5 mm in diameter, as openings through the dermal layer, and the larger approximately 0.8–1.3 mm in diameter. Trabs range 0.10–0.25 mm in diameter and spaced 10–12 per 5 mm radially, but up to 16 per 5 mm measured at right angles to trabs in distal part of dermal surface. Spicules principally long-shafted, Y-shaped dendroclones with shafts mostly 0.4–0.5 mm long and 0.06 mm in

EXPLANATION OF PLATE 13

Fig. 1.—View toward the north of the Huaco anticline, which exposes the San Juan Formation in the core; unconformably overlying Carboniferous rocks are exposed near the right margin; the Canyon of Agua Hedionda Creek is the gorge in the left center. Fig. 2.—Quarry exposures of San Juan Formation in Talacasto Gulch. Fig. 3.—San Juan Formation exposures along Agua Hedionda Creek; arrow in upper left marks the top of the sequence near the sponge locality. Fig. 4.—Exposures of the San Juan Formation, in the foreground, at the Huaco locality at Buenaventura Luna; unconformable overlying Carboniferous rocks (*C*) form the exposures in the background along the left; the arrow marks the top of the San Juan beds. Fig. 5.—View toward the north of exposures of the middle part of the San Juan Formation along Talacasto Gulch; arrow indicates sponge-bearing beds; thick bed by the arrow is about 1 m thick.


1
2
3
C
4
5

diameter. Oxeas occur as coring spicules but are not common.

Description. Large, saucerlike to palmate or funnel-like and upward-expanding sponges with flattened, broad, funnel-like general appearance, asymmetric in radial growth pattern. These large saucerlike sponges range up to 22 cm across, or high, to nearly complete upper or outer rims and have walls up to 22 mm thick. The holotype expands upward from a basal, conical, stalklike area approximately 5 cm in diameter and 2.5 cm high as a fairly steep expansion. Above and out from that stalklike area, the dermal surface of the saucer-shaped holotype extends as a relatively even and smooth surface.

Paratypes have distinct stalks. One palmate paratype is approximately 19 cm tall from the base of the stalk to the top of the preserved, nearly complete edge. The entire palmate sponge would have been 18–20 cm wide at maximum width. The short elliptical stalk is approximately 4 cm tall and 14 × 30 mm wide at the torn, broken base. The wall is folded over to nearly completely enclose a spongocoel, with a gap of only 3 or 4 mm from the complete enclosure. Walls of the stalk are approximately 16 mm thick at the edge, but thin to less than 10 mm thick near the rounded incomplete closure. The transition from the stalked basal part to the palmate part is 6 cm wide and 3.0–3.5 cm thick. The stalk narrows somewhat toward the base of the fan, which is approximately 7 cm wide above the infolded part around the basal "spongocoel." That opening is approximately 20 mm in diameter below where the upper palmate part of the sponge begins to flare. Near the base, the sponge wall is 15 mm thick, but thickens up to approximately 19 mm thick in the middle and upper part. It narrows somewhat in the upper 2 or 3 cm to only 12–13 mm thick, particularly in the slightly reflexed uppermost part of the margin.

The sponge lacks dermal annulations other than very weak broad ridges developed in the distal part of the surface, where the low ringlike elements, 4–5 mm wide, are accentuated by concentric rings of ostia. The entire low funnel-like sponge, from the broken tip of the conical attachment point to the upper margins, is approximately 4.5 cm high. The upper surface has a prominent broad depression above the conical stalk central area.

The dermal surface, interior to the dermal layer, is pitted by numerous ostia that are generally arranged in radiating series in moderately well defined lines out from the central attachment cone. In some areas uniform concentric lines of ostia produce a pseudo-annulate appearance because they are indented.

Large, circular to weakly elliptical dermal ostia of interior canals range 0.8–1.6 mm in diameter, with most approximately 1.0–1.4 mm across. They are more scattered than similar-sized openings on the gastral surface and occur four to six per cm^2. They are 1–3 mm apart, separated by dense fine skeleton. Smaller ostia, 0.3–0.7 mm in diameter, are less evident and occur in tracts between the larger openings. Most of these smaller ostia are approximately 0.5 mm in diameter and are distinct circular interruptions of the skeleton. The general pore structure on the dermal layer is, thus, significantly finer textured than that of the gastral layer.

These coarse ostia are spaced four to five per 5 mm, measured concentrically parallel to the outer margin. In the inner part they occur six to eight per 10 mm, measured radially along a single series. In the distal part of the dermal layer, the openings become somewhat elliptical and are spaced only five to six per cm in a radial series. Their shape suggests that perhaps the canals emerge at the dermal surface at moderate angles, in contrast to those that are nearly at right angles to the surface in the more juvenile part of the sponge. On the dermal surface, the coarse ostia are in radial series, but tiny skeletal pores, about 0.1 mm in diameter, occur in the intervening areas between the radiating canal series. Tangential surficial canals are not developed on the dermal surface.

The gastral surface is marked by more or less regular radial series of moderately coarse trabs and gastral ostia. The latter are circular to radially elliptical and, in general, form three series. The largest ostia are 1.1–1.8 mm in diameter, with most of the series approximately 1.4 mm across. Where they are elliptical, they may range up to 2.8 mm high radially. These coarse ostia occur 12–18 per cm^2 over the entire upper surface. An intermediate and smaller series ranges 0.7–1.1 mm in diameter, with most approximately 0.8 mm across. Almost all of these are circular, and they are spaced 15–18 per cm^2. Pores of a third small series are 0.2–0.3 mm in diameter. They are circular and occur between the trabs and between the larger openings, perhaps as a small incurrent series.

The larger canals are arranged two to three per 5 mm in a radial series and are the coarse canals that apparently pierce the entire wall. In the endosomal part of the net, these same canals are spaced seven to eight per cm in a single radial series in the middle and outer part of the sponge, and approximately five per cm in radial series in the more irregular and proximal inner half of the fan. They become more distinctly aligned in the outer part and somewhat more irregular in the inner part of the palmate blade.

The skeleton is typically anthaspidellid, composed of prominent trabs and less distinctly preserved small dendroclones. The surface of pinnation of the skeleton is 2–4 mm in from dermal surfaces and 10–11 mm from the gastral surfaces. Trabs swing abruptly upward to approximately 45° to merge at the distal edge of the sponge, essentially normal to the sponge surface. They meet the upper or gastral surface at approximately 45°. Trabs in the lower or dermal part of the skeleton are essentially subparallel to the dermal surface.

Trabs in the dermal and gastral layers are 0.10–0.22 mm in diameter and are spaced 0.6–0.7 mm apart. Where best preserved, approximately 16 trabs occur per 5 mm, measured at right angles to the trab trend. Trabs in the interior range 0.10–0.25 mm, with most in midrange, approximately 0.10 mm across. They show a moderate range in diameter irregularity along individual trabs. Trabs are spaced approximately 10–12 per 5 mm in the radial sections through the walls and are separated 0.3–0.6 mm apart, with most approximately 0.5 mm apart.

Most of the spicules are long-shafted, normal, I- and Y-shaped dicranoclones with shafts that range 0.3–0.8 mm long, with most 0.4–0.5 mm long. These same shafts have diameters that range 0.02–0.08 mm, with most 0.04–0.06 mm across. Those larger than about 0.06 mm appear to have been thickened during diagenesis. Clads of the long Y-shaped spicules range 0.04–0.13 mm long and 0.02–0.60 mm in diameter. Near their common junction with ends of the shafts, they range 0.02–0.4 mm in diameter, with most approximately 0.03 mm across. Tips of cladomes and brachyomes are lost in the coarse calcareous preservation.

A few equal-rayed, Y-shaped spicules occur. One representative example has rays 0.2–0.3 mm long and 0.02–0.03 mm in diameter. Tips of those rays flare abruptly, but details are lost as they articulate with other elements to help form the trabs.

Oxeas occur as coring spicules, usually one per cross section. They are usually approximately 0.02 mm in diameter, and segments to 1 mm long were seen in sections. In one vertical section, a dark matrix-filled impression approximately 0.02 mm in diameter marks what may have been an oxea that was dissolved during diagenesis from the center of a trab near the dermal surface.

Elliptical openings between dendroclones in ladder-like series range 0.25 × 0.40 to 0.40 × 0.50 mm high and across. Most appear to be approximately 0.4 mm across and 0.5 mm high parallel to the trabs. They tend to be moderately rectangular with rounded corners. Some such pores are nearly circular and are generally 0.4 mm in diameter, although they range 0.3–0.5 mm. Generally, two to three dendroclones occur per mm in the ladderlike series, producing a moderately open-textured, fairly coarse skeleton.

Algal borings are evident throughout the sponge, as in many of the other sponges from Talacasto.

Discussion. This species is considerably finer-textured than *Psarodictyum magna* n. sp. In that species trabs range 0.2–0.3 mm in diameter, and individual dendroclones are considerably longer, ranging up to approximately 1 mm long as they bridge the moderately widely spaced canals. *Patellispongia robusta* lacks the prominent annulations characteristic of the discoidal or palmate thin *Anthaspidella annulata* n. sp. In addition, the skeletons here are considerably coarser textured in terms of spicule makeup and porosity within the sponge.

Patellispongia robusta n. sp. has essentially the same wall thickness as *Patellispongia oculata* Bassler, 1927, but has ostia significantly larger and more widely spaced than in that Nevada Ordovician species. Of the other species described by Bassler, *Patellispongia clintoni* has ostia on slight elevations on the upper surface that are spaced 4–5 mm apart in a pattern quite different than seen here in *Patellispongia robusta*. *Patellispongia minutipora* Bassler, 1927, has a wall only 4 mm thick and small pores that average only 0.5 mm in diameter. In general it appears to have a canal system considerably finer textured than that in the San Juan species. On the other hand, *Patellispongia magnipora* Bassler, 1941, has canals 2.0–2.5 mm in diameter in a unilaminar sheet only 3–8 mm thick. It also has approximately 14 pores or ostia per cm, measured longitudinally in the dermal layer, with each of those pores only approximately 0.6 mm in diameter. *Patellispongia magnipora* had the largest ostia observed in the genus by Bassler (1941, p. 98). Although some of the differences in the dermal layer may be related to preservation, the Ordovician species from Nevada appear to have a moderately thick, clearly defined layer through which the isolated ostia pierce, rather than the only moderately well defined dermal layer seen here in *Patellispongia robusta*.

Patellispongia australis Rigby and Webby, 1988, has walls 7–8 mm thick, but ostia on the gastral surface are only approximately 0.2 mm across, rather than the coarse ostia that are mostly approximately 1.0–1.4 mm across in *Patellispongia robusta*. In addition, prominent tangential, radial, lateral canals occur beneath the dermal layer on the lower surface of *Patellispongia australis*, and ostia that pierce the dermal layer in that species are 0.6–0.8 mm in diameter but occur on the crest of small volcano-like cones. Dermal ostia in the San Juan species are approximately 1.4 mm across and are considerably coarser textured, and the San Juan species also lacks the prominent tangential, radial canals seen in the Australian and Nevada species.

Material. Two complete sponges, the holotype, CRICYT T-1/15, and paratype, CRICYT T-1/18, plus less complete paratypes, USNM 463463–463466, are all from the San Juan Formation from Talacasto Gulch in the Precordillera Central of San Juan Province.

Etymology. Robustus, L., strong, referring to the thick strong walls of the sponge.

Genus ANTHASPIDELLA Ulrich and Everett, 1890

Emended diagnosis. Flat to saucer- or funnel-shaped sponges with a short stalk; gastral surface with numerous oscula, each with several tangential canals that converge into a small osculum, the depression of which is occupied by a few, rather large, thin-walled, vertical canals. Dermal surface of sponge with round ostia arranged in more or less radiating rows and defined by radial anthaspidellid trab-based skeleton, which is composed in large part of dendroclones in ladderlike series.

Discussion. Anthaspidella is one of three genera of common saucer- or open funnel-like sponges included within the Anthaspidellidae. *Anthaspidella* is characterized by numerous clusters of convergent tangential canals that produce numerous oscules on the gastral surface in a moderately complex canal system. These types of tangential canals and clusters do not occur on gastral surfaces in either *Psarodictyum* or *Patellispongia.* On dermal surfaces, however, all three genera may appear similar, but *Patellispongia* commonly has a well-defined, differentiated, dermal layer that helps to separate it from both *Anthaspidella* and *Psarodictyum.*

In specimens where that dermal layer is ill defined, *Patellispongia* may appear distinctively similar to *Psarodictyum,* which has been interpreted as lacking a differentiated dermal layer. Bassler (1927, p. 393) erected *Patellispongia* as a new genus and later (1941, p. 97) expanded the original description to point out that the thick dermal layer on the thin unilaminar sponges is a diagnostic feature. In other respects, however, *Patellispongia* and *Anthaspidella* have basically the same skeletal structure.

Review of the North American type specimens of the genera is necessary before the genera can be consistently and easily differentiated. They may be more closely related than presently considered. For now, we will follow the precedence established by Rigby and Webby (1988, p. 39) and will consider the two genera as distinct, and both of them as distinct from *Anthaspidella.*

In the well-preserved silicified material from Australia, *Patellispongia australis* Rigby and Webby, 1988, has trabs that contain many coring monaxons, and, in fact, these spicules may make up most of the trab diameters. The monaxons apparently include both oxeas and styles in that species. Coring oxeas also occur in *Psarodictyum crassum* Rigby and Webby, 1988, which has trabs that include three to four monaxons per cross section as well. Both of these species have monaxons more common than the Argentine representatives of both genera.

Type species. Anthaspidella mammulata Ulrich and Everett, 1890.

ANTHASPIDELLA INORNATA n. sp.

pl. 5, figs. 2, 3; pl. 12, fig. 4

Diagnosis. Small, upward expanding, frondlike sponge with walls 10–14 mm thick. Dermal surface smooth, except for ostia of two series: one principally 0.4 mm across and the other principally 0.7 mm across, spaced approximately four per 5 mm radially. Gastral surface with faint tangential radial canals from cluster, 7–8 mm wide, composed of canals approximately 1 mm in diameter. Ostia of canals that pierce wall approximately 1 mm diameter, where circular, and 1 × 2 mm, where elliptical, spaced approximately three per 5 mm, measured radially and horizontally parallel to margin. Skeletal structure anthaspidellid, with trabs mainly 0.08–0.10 mm in diameter, spaced only 0.15–0.20 mm apart. Y-shaped dendroclones main spicules.

Description. A single, ear-shaped basal part of a small upward-expanding frondlike sponge is the holotype. Most of its upper and lateral margins are complete, but the sponge has been broken at the base. It is 6.5 cm wide, with an incomplete broken height of approximately 4 cm. It appears to flare upward and outward in the upper half from an incipient steeply obconical lower part to an upper, more nearly horizontal flared upper part, as though this were the basal part of a broadly expanding discoidal sponge, rather than a steeply conical form. Walls at the broken base are approximately 10 mm thick, but thickness increases to about 14 mm thick in the general region where the change in direction of growth takes place. The wall thins again to approximately 10 mm thick in the upper complete rim.

The dermal surface is smooth, except for impressions of crudely aligned ostia. These ostia are generally circular and range from small openings 0.4–0.5 mm in diameter up to large openings 0.8–0.9 mm across. Most of the ostia appear to fall into two groups; one is mainly 0.4 mm across and the other mainly 0.7 mm across. These occur intermixed in the skeletal net. The large ostia occur in crudely upward-aligned series, approximately four per 5 mm, and three of those series occur per 5 mm, as measured horizontally parallel to the upper preserved rim. That alignment and spacing is most evident in the upper, flared part of the sponge. The smaller, more nearly basal part shows less regularity.

A few faint impressions of tangential radial canals occur on the gastral surface. The most prominent of these extends from near the flexure point of the flare upward to near the distal margin for a distance of approximately 25 mm. The canal is widest near the base of the trace, where it appears indented approximately one-half its diameter, and that diameter is moderately irregular. It ranges from about 1.3–1.5 mm wide near the base, narrows at mid-trace to approximately 1 mm, and then continues to narrow toward the top, where it is only 0.5 mm wide before the trace is lost at the periphery of the sponge. A second even more faint impression of a tangential canal occurs in the left part of the interior, and it, too, is approximately 1.0–1.7 mm in diameter. Its upper end, however, is lost in matrix, and the lower end is faint, becoming more distinct at about the point of wall flexure.

The gastral surface is marked additionally by indented, now largely matrix-filled ostia of excurrent canals that range 0.4–1.1 mm in diameter. A moderately prominent cluster of these canals, most of which are approximately 1 mm in diameter, occurs in the lower left of the sponge in almost a spongocoel-like basal pit impression. There appears to be an inner ring of 4–5 canals surrounded by a ring of 10–11 canals. These are separated generally only 0.3–0.5 mm and form a cluster 7–8 mm wide. Impressions of the surficial tangential canals become evident 4–5 mm from the margin of this cluster.

Ostia in the outer or upper part of the sponge are essentially the same size as those in the cluster interior but are distinctly aligned radially. They are somewhat elliptical at the surface, which indicates their emergence at angles to the general surface. Elliptical ostia are approximately 1 mm wide and up to 2 mm long, radially, in that small part of the sponge surface where they are most prevalent. They are spaced such that approximately three radial series of ostia occur per 5 mm, measured horizontally parallel to the upper margin. Ostia occur two to three per 5 mm measured radially in a single series. Thus, ostia on the gastral surface may be spaced four to six per 25 mm^2. On the dermal surface they may range seven to nine per 25 mm^2.

Trabs diverge from a surface of pinnation in the interior of the wall and meet the gastral surface, in particular, at moderately high angles. The skeletal structure is only locally, moderately distinct. In the upper part of the dermal surface, trabs parallel the curved upper surface and range 0.07–0.12 mm, but most are approximately 0.08–0.10 mm in diameter. On the dermal surface, approximately six trabs occur per millimeter, so their spacing is very close, approximately 0.15–0.20 mm apart.

Roughly circular skeletal pores occur between poorly defined dendroclones on the exterior; six to seven dendroclones or circular skeletal pores occur per millimeter, measured radially along a single trab series.

Discussion. Anthaspidella inornata n. sp. is characterized by isolated small clusters of essentially vertically oriented excurrent canals and associated tangential radial surficial canals. The latter are moderately rare but do radiate from the one distinct cluster preserved in the specimen. This contrasts to the relatively coarse skeleton in most of the species described by Ulrich and Everett (1890), in which there are numerous clusters, each marked by convergent canal complexes that are tangential on the upper surface.

Of the species described by Ulrich and Everett (1890), perhaps the most similar is *Anthaspidella florifera* Ulrich and Everett, 1890, in terms of the numbers of canal clusters and their size and spacing, but *Anthaspidella florifera* has many prominent tangential canals, at least as figured (Ulrich and Everett 1890, pl. 1, fig. 2). Bassler (1941) also described species of *Anthaspidella* that he differentiated on the basis of the sizes and comparative spaces of oscules and radiating canals, but these two species have numerous oscular openings and convergent canals well marked on the gastral surface. They contrast sharply to the only moderate tangential canals developed in *Anthaspidella inornata.*

Material. The holotype, CRICYT T-48, is from the San Juan Formation in Talacasto Gulch, in the Precordillera Central in San Juan Province.

Etymology. Inornatus, L., unadorned, in reference to the limited tangential canals and oscular clusters on the gastral surface of the sponge.

ANTHASPIDELLA ANNULATA n. sp.

pl. 5, fig. 7; pl. 10, figs. 4, 5

Diagnosis. Palmate to open discoidal sponge with prominently annulate dermal surface, but moderately smooth upper gastral surface; annulations 8–11 mm apart and up to 6–7 mm high. Spacing of clusters on gastral surface unknown. Skeleton anthaspidellid with surface of pinnation 2–3 mm below smooth gastral surface; trabs curve upward and downward sharply, are small, 0.06–0.12 mm in diameter in the interior and up to 0.18 mm in diameter on the dermal surface; trabs spaced 0.4–0.5 mm apart. Spicules dominantly Y-shaped dendroclones, but long-shafted, X-shaped spicules also occur, shafts generally 0.25–0.30 mm long; four to five dendroclones occur per millimeter in uninterrupted ladderlike series within the skeleton. Coring oxeas rare.

Description. A single triangular-shaped fragment of a palmate to broadly open discoidal sponge occurs in the collection. It has broken margins and expands upward from a basal width of approximately 3 cm to a maximum upper preserved width of about 13 cm. The height or radial length of the specimen is approximately 7.5 cm.

The upper or gastral surface is buried in dense matrix, but the annulate dermal surface shows well. Annulate ridges tend to be moderately sharp crested and laterally continuous, although in at least one instance there is lateral bifurcation of one of the sharp-crested ridges into two or three more irregularly nodose and discontinuous ridges near the basal part of the fragment. Lower annulations are moderately irregularly 6–8 mm apart, but upper annulations are relatively consistently 9–11 mm apart, crest to crest. The sharp-crested ridges are generally 2–3 mm across, with a sharp triangular to irregularly rounded surface at the top of sweeping curved slopes that rise from the broad rounded interridge annulations. These depressions tend to be 5–6 mm wide with almost circular profiles at their bases. The ridge slopes become moderately straight at midheight as they rise to the sharp crest. Crests of the ridges are moderately smooth, laterally, in the upper part but are weakly nodose in the lower part of the sponge, where the annulate ridges are less distinct. These nodes are not aligned in any radial pattern but are merely irregularities on summits of the horizontal ridges.

In cross section the gastral surface appears moderately smooth so that heights of annulations on the dermal surface show as thickenings in the wall, which in general appears to be 9–10 mm thick, but annulate ridges make the overall thickness of the sponge approximately 16 mm thick. The upper or gastral surface is moderately ill defined, so the total thickness is somewhat obscured.

As in several other species in the collection, diagenesis has modified dimensions of elements of the skeletal net with apparent increase in diameters, particularly in the trabs. In addition, algae have produced moderately coarse irregular borings, now filled with sparry calcite, that are 0.10–0.15 mm in diameter. These tend to be irregularly branching with irregular courses. They appear as dark fillings of the perforations on the weathered exterior. The prominent surface of pinnation is approximately 2–3 mm in from the smooth gastral surface. The trabs curve moderately sharply, both dermally and gastrally. They meet the smooth gastral surface at approximately 45° to the surface of pinnation. Trabs in the dermal part of the wall curve so they are essentially parallel to the lower ridge surfaces of annulations, but meet the upper surfaces of the ridges at high angles to almost normal to the upper surface. They curve generally 50°–70° from the surface of pinnation and continue to curve into the ridges.

Trabs are small; they generally range 0.06–0.12 mm in diameter. Some of the coarser ones have been enlarged by diagenesis. Trabs appear to both branch and to be inserted to maintain essentially uniform skeletal dimensions outside the zone of pinnation.

Trabs on lower sides of the annulate ridges are somewhat fibrous appearing and larger than trabs of the interior of the endosomal part of the skeleton. In the ridge area they range 0.15–0.18 mm in diameter, and the structure looks delicate. Trabs are spaced approximately 0.4–0.5 mm apart, radially, once outside the zone of abrupt expansion parallel to the surface of pinnation. In that middle one-third part of the sponge wall, spicules may be shorter and the trabs more closely spaced.

Spicules appear to be dominantly Y-shaped dendroclones, but some moderately long-shafted, I- or H-shaped spicules also occur. Y-shaped dendroclones have smooth long shafts, generally 0.25–0.30 mm long, but may range up to 0.4 mm long in the outer part of the skeleton. Dendroclone shafts range 0.02–0.05 mm in diameter, with nearly all approximately 0.04 mm in diameter. Cladomes are clearly defined on some spicules. The clads generally range 0.06–0.08 mm long, but some are up to 0.15 mm long. They are 0.02–0.04 mm in diameter, with most approximately 0.04 mm across. They diverge from each other at 60°–90°.

I- or H-shaped dendroclones occur but are moderately rare. They have shafts up to 0.10 mm long that are usually 0.04–0.05 mm in diameter. Clads diverge from both ends of shafts at 60°–90°. These clads are commonly 0.10–0.15 mm long and range 0.02–0.04 mm in diameter, with most approximately 0.04 mm across in the zone of divergence. Zygomes on tips of the spicules are lost in the moderately coarse calcareous replacement of the skeletal structure.

A few segments of oxeas occur in thin section. These spicules range up to 0.05 mm in diameter, but most of the small segments are 0.03 mm in diameter. These generally occur as single impressions coring the moderately small trabs. Length is unknown because most are seen only in diagonal cross sections.

Within a single spicule series, four to five spicules occur per mm in the uninterrupted part of the skeleton. Elliptical skeletal pores in the ladderlike structure are 0.15–0.20 mm high and 0.25–0.30 mm wide. Only two to three spicules occur per mm where large lateral pores to canals interrupt the spicule series. These pores may range 0.5–0.7 mm high and 0.4–0.5 mm wide and are moderately rectangular interruptions. These are pores that open from the triangular skeletal pores, which parallel the trabs, into the major horizontal or piercing canals. None of those canals are clearly intercepted in the single available radial thin section, but some openings, 0.6–0.8 mm across, do interrupt the trabs in a moderately uniform occurrence, and the canals are not distinctly developed.

There is no dermal nor gastral differentiation of skeletal structure, with the exception of a somewhat coarsened outer trab or two in lower parts of the dermal surface on the annulations.

Discussion. This species has a skeletal net that is composed of the most fine-textured elements seen in the funnel-shaped or broad, open, frond-shaped species in the collection. It differs from the coarse-textured *Patellispongia robusta* n. sp. in this important respect. It is also distinguished by the prominent annulate growth form of the dermal surface. The species apparently lacks a thick dermal layer, and hence is probably not a *Patellispongia,* but is included here within *Anthaspidella.* Wall thicknesses fall within the range of *Patellispongia oculata* Bassler, 1927, but *Patellispongia oculata* has a smooth outer surface with a dermal layer and lacks the annulations so characteristic and prominent in this Argentine species.

Psarodictyum magna n. sp. has a relatively smooth dermal surface marked only by ostia of moderately large canals in the fairly coarse skeletal net. *Psarodictyum magna* also has a fairly thick wall made of skeletal elements that range considerably coarser than the relatively fine-textured trabs and dendroclones preserved in this species.

Poorly preserved oscula (?) are expressed as pits on the upper surface. If these depressions are really oscular pits, they range approximately 7–10 mm across and are separated by 1–2 cm where they occur around edges of the sponge.

Material. The holotype and only known specimen, CRICYT T-49, is from the San Juan Formation, in Talacasto Gulch in the Precordillera Central of San Juan Province, Argentina.

Etymology. Annulatus, L., ringed, in reference to strong regular ridges on the dermal surface of the species.

ANTHASPIDELLA ALVEOLA n. sp.

pl. 6, figs. 6, 7; pl. 12, fig. 1

Diagnosis. Moderately flat, broad, saucer-shaped sponges with walls to 16 mm thick. Gastral surface with shallow pits of excurrent canal clusters 5–6 mm in diameter, most canals approximately 1 mm across; lateral tangential canals to cluster faint and short. Dermal surface with weak annulations in proximal part, distal part smooth; marked by aligned major ostia, may be circular and approximately 1 mm across or elliptical and up to 1.6 mm high; all in distinct linear series spaced two to three per 5 mm, laterally, at right angles to trabs. Trabs approximately 0.2 mm in diameter, laterally spaced 10–11 per 5 mm with surface of pinnation at midwall, from which trabs diverge to gastral and dermal surfaces at approximately 30°. Spicules long, Y-shaped, dendroclones with shafts approximately 0.4 mm long and 0.05 mm in diameter, produce skeletal pores 0.3–0.5 mm across. Lacks differentiated dermal layer.

Description. A single specimen of a moderately flat, broad, saucer-shaped sponge is in the collection. It includes the proximal part and some of the distal part of what appears to have been a palmate form. It is 7.4 cm across, essentially at right angles to the direction of growth, and 4.1 cm high as a moderately rectangular specimen. The sponge wall ranges 14–16 m thick, and in one area appears to be moderately complete with a rounded to somewhat bullet-shaped profile.

The upper or gastral surface is weathered but shows moderate pits of clusters of excurrent canals typical of the genus. These clusters range 5–6 mm in diameter and are spaced approximately 10 mm apart. They are floored by prismatic to circular prismatic canals that range in diameter from 0.8–1.5 mm, with most approximately 1 mm across. There are seven to eight of the closely spaced canals per cluster, and the pits in which they occur in characteristic expression are 1–2 mm deep. The normal lateral canals that converge into the canal clusters in other species of the genus are faint and short here. The vertical canals of the cluster are traceable up to 3 mm deep into the sponge wall before they lose their identity. Other ostia on the gastral surface are not well defined.

The radial pattern of the trabs is apparent in their linearly arranged terminations on the gastral surface. Trabs diverge upward and downward from the surface of pinnation, which is essentially in the middle of the wall, and meet both the gastral and dermal surfaces at approximately 30°. Structures on the dermal surface, however, are considerably more regular.

The dermal surface is sculptured by very weak annulations in the proximal part of the sponge. These ridges are spaced 4–5 mm apart, ridge-to-ridge, and they are 2–3 mm wide and 1.0–1.5 mm high. Five or six annulations are prominent. They are laterally discontinuous in the first 3–4 cm of the sponge, but above that the dermal surface becomes moderately smooth.

The dermal surface is interrupted only by ostia of the major incurrent canals. These ostia are circular to slightly elliptical openings that range 0.7–1.1 mm in diameter, with most approximately 0.9–1.0 mm across. The largest elliptical ostia are approximately 1.1 mm across and up to 1.5–1.6 mm high, and their canals apparently enter the sponge wall at moderate angles, essentially normal to the trabs. They occur in definite linear series, and two or three ostia occur per 5 mm within a series, parallel to the radiating trabs. They are commonly separated up to 1 mm by skeletal material. There is no consistent ringlike arrangement of their spacing, even in the lower part of the sponge where the annulations are most prominent.

Trabs appear as distinctly uniform, rodlike structures approximately 0.2 mm in diameter. Interior trabs range 0.12–0.24 mm in diameter, with most approximately 0.18–0.20 mm across, as on the exterior. On the dermal surface trabs are spaced such that 10–11 occur per 5 mm, measured at right angles to the trend of the trabs.

Dominant spicules are long, Y-shaped dendroclones with shafts 0.3–0.5 mm long and with most approximately 0.4 mm long. Shafts range 0.04–0.06 mm across, and most of them are approximately 0.05 mm in diameter. The clads are moderately obscure in the coarse calcareous preservation but range 0.15–0.30 mm long in those that could be measured. Most cladomes are preserved as triangular masses of crystallized calcite, but where preserved, clads range 0.03–0.05 mm across. They taper from the maximum diameter at the point of divergence to those narrow dimensions before their structural detail is lost in the coarse preservation. Clads diverge from 90° to as much as 120°, and some clads are markedly elongate in their terminations.

Trabs are spaced 10–11 per 5 mm, in radial section, measured in the outer part of the sponge walls, and are spaced to produce skeletal pores 0.3–0.5 mm across. In single series two to three dendroclones occur per mm in the normal skeleton, although there may be some areas where canals interrupt that regularity or a few areas, particularly where the trabs first diverge from the surface of pinnation, where there may be as many as five to six dendroclones per mm in a single series.

Discussion. The skeletal structure is more fine textured, the walls thinner, and the canals smaller than in the other anthaspidellid species from San Juan described here.

Ulrich and Everett (1890) described several species of *Anthaspidella* from the Ordovician of Illinois. *Anthaspidella mammulata* Ulrich and Everett, 1890, is the type species and has ostia clusters of essentially the same size and separation as in the *Anthaspidella aveola* described here. In the Illinois species, however, the oscula are in small mounds rather than in depressions, like those seen in the species here. *Anthaspidella parvistellata* Ulrich and Everett, 1890, also has small clusters, but they are considerably closer together than recognized in the San Juan *Anthaspidella. Anthaspidella florifera* Ulrich and Everett, 1890, has prominent tangential canals associated with moderately large and fairly widely spaced oscular clusters. Gastral sculpture and dimensions of the various clusters in the Illinois species is considerably larger than in the species described here.

Anthaspidella firma Ulrich and Everett, 1890, has a central area that appears similar to the San Juan sponge with short tangential canals around moderately widely spaced small clusters. In the Illinois species, however, the tangential canals along the upper parts of the sponge, around the nearly complete margin, are prominent and radially linear. These types of canals are not preserved on the fragment available. In addition, *Anthaspidella firma* appears to be a moderately steeply conical form, rather than a broad saucer-shaped species, as preserved in our collections. Most other species of *Anthaspidella* have small, closely spaced oscules that have prominent tangential canals around them on the gastral surface and are immediately differentiated from the species described here.

Anthaspidellid species described by Bassler (1941) also have prominent tangential canals around the oscular clusters. The San Juan and Nevada species are similar in terms of wall thickness, general growth form, and other dimensions, but differences in canal patterns immediately separate them from *Anthaspidella alveola*.

Material. The holotype and only known specimen of the species, CRICYT T-SQ1, is from the San Juan Formation in Talacasto Gulch, Precordillera Central in San Juan Province.

Etymology. Alveolus, L., m. dim., cavity, pit, or channel; reference to the small shallow pits on the gastral surface.

TALACASTONIA n. genus

Diagnosis. Cylindrical to conico-cylindrical tubular sponges with coarse-textured, dendroclone-based skeleton, but with complex trabs cored by oxeas in which talonlike cladomes grasp oxeas and dendroclone tips, and with other irregular vertical elements in the skeleton as well. Canals essentially horizontal through wall and moderately coarse.

Discussion. The species on which the new genus *Talcastonia* is based is represented in the collection by only a small, subcylindrical fragment. Whether this fragment represents the mature form of a small conico-cylindrical sponge or perhaps the stem of a goblet-shaped sponge is unknown. It is recognized as a separate taxon, however, because of the peculiar spicule structure within the coarse trabs. We know of no other anthaspidellid genus with which this Argentine sponge might be confused, if details of spiculation are preserved. The trabs are much more complex than those of any other genus with which the sponge is associated in the San Juan collections.

Gleesonia Rigby and Webby, 1988, is a coarse-textured anthaspidellid with moderately complex beams composed of several trabs united into a webbed structure. These might appear somewhat similar to the trabs in *Talacastonia,* except there is no evidence of webbed connecting structures between the trabs in *Talacastonia,* but rather it has almost echinating, irregular, moderately coarse dendroclones. Zygomes of cladomes in *Gleesonia porosa* Rigby and Webby, 1988, are fingerlike or digitate and articulate almost zygome to zygome with adjacent tips, producing very open porous trabs. They do not have the talonlike "grasping" articulations of dendroclones so evident in thin sections of *Talacastonia.*

Vandonia Rigby and Webby, 1988, has very coarse trabs but has a regular reticulate structure produced by unusually large dendroclones that are uniformly spaced to produce an almost laminate-appearing regular skeleton. Such a regular structure is not evident in *Talacastonia. Vandonia* does have webs of cladome origin that may connect trabs, but they do not produce compound open beams in a consistent fashion, like those developed in *Gleesonia. Vandonia* has a considerably more regular skeletal net that is composed of spicules which are much coarser than even the coarsest spicules seen in *Talacastonia.* Dendroclones in *Vandonia* are unusual, for they have cladomes that may extend great distances, vertically, along trab axes to produce a complex structure.

The skeletal nets of *Gleesonia, Vandonia,* and perhaps *Talacastonia* are sufficiently different from the normal dendroclone- and trab-based simple structures seen in other genera within the Anthaspidellidae that perhaps these three distinctive genera should be separated into other families, based on the spicule composition of the trabs and their structural relationships.

Type species. Talacastonia chela n. sp.

Etymology. Talacasto, the locality where the sponge was first discovered.

TALACASTONIA CHELA n. sp.

pl. 5, figs. 8, 9; pl. 11, fig. 2; pl. 12; figs. 6, 7

Diagnosis. Cylindrical to conico-cylindrical, tubular sponges with prominent central spongocoel approximately one-half diameter in sponges up to 2.5 cm across. Coarse dermal ostia circular to elliptical, up to 2 mm in diameter, in crude vertical rows, three per 5 mm, smaller dermal ostia 0.04–0.07 mm in diameter; canals may include irregular vertical midwall canals, but these ill defined. Very coarse compact trabs 0.6–0.8 mm in diameter with irregular spinose-appearing edges composed of moderately large dendroclones to 0.8 mm long; cladomes with common talonlike terminations attached to coarse coring ostias in multielement trabs. Oxeas may range to five per cross section and 0.16 mm in diameter.

Description. The single fragmental tubular holotype of the species is in the collection. It is broken and only approximately 3 cm high and ranges in diameter to 2.3–2.4 cm. The continuous spongocoel appears to be a tubular, slightly elliptical opening 6.5 × 9.0 mm across. Sponge walls range 3–9 mm thick, as seen in transverse section.

Dermal ostia are generally circular and range 0.7–2.0 mm, with most approximately 1 mm in diameter. Ostia on the dermal surface are in crude vertically aligned rows, but those rows are far less regular than those in *Calycocoelia* or in *Archaeoscyphia*, for example. Dermal openings are spaced vertically such that three occur per 5 mm. They may be separated by up to three dendroclones or a cluster of the coarse complex branching trabs. There are approximately four of the series per 5 mm, as measured horizontally around the circumference of the sponge. This tends to produce a very coarse porous skeleton. The surface is smooth, without annulations or prominent nodes, but the fairly coarse ostia indent the surface between the coarse trablike structures of the skeleton.

Ostia of the exterior connect to relatively straight horizontal canals that appear to lead directly through the wall from the dermal area into the spongocoel. Ostia of those canals in the spongocoel wall may be up to 1.5 mm in diameter.

In addition, large openings occur in midwall and near the gastral surface of the wall. These suggest development of irregular vertical canals that are up to 2 mm in diameter, with most approximately 1.5 mm across. They have irregular outlines, depending upon their definition by bordering relatively massive trabs and dendroclones. The openings may be subtriangular or subpentagonal in cross sections.

The very coarse, multielement trabs are one of the distinctive features of the genus. These are relatively large structures for the family. Trabs in the very coarse skeleton range 0.6–0.8 mm in diameter, with most approximately 0.6 mm across. They have irregular, almost spinose-appearing edges—not the clean, well-defined rounded edges like those seen in other genera in the collection.

In the exposed dermal area, the trabs are of essentially the same cross section. They appear to anastomose or meander somewhat, rather than to appear like the upright, almost cylindrical trabs in other genera of the assemblage. Trabs may curve around the large canals to accommodate those circular openings.

Two series of ostia occur in the exterior. The larger circular to elliptical ostia, 1.8–2.2 mm across, are openings of the horizontal radial canals. The smaller openings range 0.4–0.7 mm in diameter and are also circular. The latter open into the skeletal pores between the trabs and may have functioned as incurrent openings, in contrast to the large canals that may be excurrent in the general structure.

Principal spicules in the skeleton are moderately large, relatively coarse dendroclones. They have shafts that range 0.36–0.80 mm long. The latter bridge between the coarse complex trabs as distinct single elements. Shafts range 0.04–0.08 mm in diameter, with most near the coarse upper end of that range. In many spicules the cladome is well defined as almost a "clutching" termination, like curved fingers around a circular bottle. These tips curve and apparently attach to the coring oxeas. They may do so only on one end, but commonly grasp oxeas on two ends as they bridge in ladderlike series from trab to trab. The clads may be up to 0.2 mm long and have diameters of approximately 0.04 mm. The clads diverge from each other at 60° to approximately 95°, as seen in the horizontal section. They may form long vertical elements that are part of the circular cluster of discrete spicule tips around the coring oxeas so evident in the transverse section.

Coring oxeas occur from one or two per cross section up to four or five per cross section. They range 0.12–0.16 mm in diameter. They appear in horizontal section as distinctly circular, bright spar-replaced elements enclosed in cladomes in many instances. Lengths of oxeas are impossible to tell because they have been seen only in horizontal cross sections.

Terminations of individual cladomes must be very complex, with perhaps very long vertical extensions. These have been cut in horizontal cross sections and appear as the small circular elements in transverse sections of the trabs. In addition to grasping, almost handlike tips, some of the spicules must have vertically elongate clads, much like those in *Gleesonia porosa* Rigby and Webby, 1988, from the Molongulli Formation of Australia.

In some areas cross sections of the cladome complex become irregular, almost as though rhizoclonelike spicules were involved in the trab complex, but these are almost impossible to isolate in the calcareous preservation.

Because of the relatively complex and large size of the trabs, and because dendroclones appear to converge onto that trab from a variety of directions, the entire skeletal net appears spinose. Unlike the trabs in *Gleesonia*, however, where there is a high percentage of pore space, trabs here have little dark-colored matrix within the coarse skeletal tract. There is enough matrix, however, to show that where pores were available, the fine micritic, muddy matrix filled those pores.

Skeletal pores within the ladderlike series are subquadrate to rounded and up to 0.5 × 0.8 mm in the dermal layer. In the thin section they range from rounded to triangular and up to 1.0 mm across. In some of the widely spaced skeletal sections up to 1.2 mm across, they form rectangular openings between the uniformly spaced trabs.

Discussion. The coarse trabs and the complex nature of the trabs are perhaps the most diagnostic features, on a microscopic scale, of the subcylindrical tubular sponges. This, plus the relatively irregular, almost ragged or spinose appearance of the skeletal elements in thin section should differentiate the genus and species from any of the other species and genera with which it is associated in the Argentina collections.

Although *Gleesonia* Rigby and Webby, 1988, is used as a model to explain the moderately complex makeup of individual trabs, *Gleesonia* has a regular upward and outward expanding skeletal net, often consisting of weblike dendroclones, in a structure that separates it from the San Juan material described here.

Material. The holotype and only specimen, CRICYT T-53, was collected from the San Juan Formation in Talacasto Gulch, in the Precordillera Central, by William Sill.

Etymology. Chela, L., claw, in reference to the clawlike end of dendroclones in the trabs.

Class HEXACTINELLIDA Schmidt, 1870
Order, Family, Genus Uncertain
Root Tufts

pl. 5, fig. 5; pl. 6, figs. 2, 4, 5; pl. 10, fig. 8

Two samples of extensive root tufts are included in the collection from Villicúm (figure 1, Locality 3). Very large monaxon-appearing spicules, ranging up to 1.7 mm in diameter, occur on one of the hand sample fragments; those slightly smaller, approximately 0.9–1.0 mm in diameter, are common, and some of these spicules extend the full 45-mm length of the hand sample without appreciable taper. This suggests that the large root-tuft spicules are considerably longer than that, but their full dimensions are not known.

Most spicules in that particular hand sample range 0.15–0.20 mm across; these are scattered through the matrix and are abundant. The smallest spicules have diameters of approximately 0.1 mm. These are widely spaced in the matrix and could be only the tips of the somewhat larger spicules, but they, too, represent essentially nontapering segments.

Tuft spicules in this sample probably make up less than 15% of the total volume of the rock. They appear inserted at irregular levels through the matrix, are generally moderately well aligned, but occur at irregular levels within the hand sample.

In the other available tuft, spicules are more consistently of one size. The coarsest spicules are 0.4 mm in diameter and are relatively rare compared to most of the spicules that are 0.10–0.12 mm in diameter. The latter are closely spaced, almost side by side, with a sweeping general appearance like a lock of hair. They, too, are long, perhaps 3–4 cm, but on none can we see the full length with any accuracy. Whether the spicules are monactines or diactines or perhaps pentacts could not be determined. No certain hexactine-based spicules were observed on a weathered surface or in acetate peels.

A small section of hexactinellid root tuft appears attached to the dermal layer of the specimen of *Hudsonospongia cyclostoma* Raymond and Okulitch, 1940 (CRICYT VI-2). The root tuft is a small segment, approximately 1 mm wide in thin section, and extends for approximately 5 mm along the surface of the sponge. The tuft extends an additional approximately 15 mm out from the surface through the matrix. It is made of a cluster of tiny oxeas, or some other small diactine form, that makes a tresslike structure of closely spaced spicules. Spicules range up to approximately 0.4 mm in diameter, as the largest seen in section, but most appear to be approximately 0.02 mm across or smaller. These could be just tips of larger more elongate spicules.

Most of the spicules show as circular cross sections, for the section was cut at angles to the tuft. In the lower or proximal part, next to the dermal layer of *Hudsonospongia*, some spicules appear to be aligned moderately parallel to the section.

There is no evidence of hexactines, but like other tufts in the collection, it is presumed that these are related to hexactinellids. Other more isolated sponge spicules also occur in the matrix associated with the *Hudsonospongia*. Some have circular cross sections to 0.11 mm and suggest large spicules like those associated in the two more extensive tufts. At least three specimens in the collection represent tufts of hexactinellids.

The tuft attached to the *Hudsonospongia* is associated with a small anthaspidellid-type sponge, which has also attached to the same specimen. The trabs and dendroclones are apparent, but even generic identification of the sponge must remain uncertain because so little of it is evident. It may only be the attachment point of a much larger sponge.

Discussion. Root tufts such as these are commonly associated with hexactinellids and, in many sequences, are the only evidences of hexactinellids. Spicules in sponge bodies tend to disassociate if they are not fused, and such dictyonine structure is relatively rare among Paleozoic hexactinellids. Because root-tuft spicules are inserted into the substrate or trap muds and are buried by the substrate, they are commonly preserved essentially intact, even though the body spicules are lost.

Fine-textured matrix associated with the root tuft composed of small spicules has been broken by a series of parallel, closely spaced joints. These fractures were subsequently healed by crystallization of secondary calcium carbonate. Where the fractures cross through the root tuft at high angles, they produce a pseudohexactine reticulate structure. In this particular sample they produced a pseudodictyosponge-appearing network, but the nature of the fractures is revealed by their three-dimensional extension through matrix. The internal crystalline filling and nature of the fracture system becomes readily apparent in thin sections or cellulose acetate peels, where the microstructure of the fracture filling contrasts sharply to that of the recrystallized root-tuft spicules. The reticulate nature was initially interpreted as a possible hexactine sponge until the fracture origin of the crossing structures became apparent. Two crossing sets of microfractures produced a similar microreticulate pattern, which was initially confused as a hexactinellid sponge, in Cambrian rocks of Zonda Gulch in the Precordillera. The resulting fractures produced a complex boxwork of calcium carbonate fillings in the fine-fractured matrix.

The tufts may be the *Leptomitus* Walcott noted by Carrera (1985, p. 5).

Material. Two hand samples, CRICYT VI-54 and VI-4, and another small tuft attached to *Hudsonospongia cyclostoma* Raymond and Okulitch, 1940, on CRICYT VI-2; all from Don Braulio Gulch in the Villicúm Range, Precordillera Oriental, San Juan Province, Argentina.

Class CALCAREA Bowerbank, 1884
Order HETERACTINIDA de Laubenfels, 1955
Family ASTRAEOSPONGIIDAE Miller, 1889
Genus Indeterminant

pl. 2, fig. 2

A single octactine spicule occurs in matrix on the gastral side of a large fragment of *Patellispongia robusta* n. sp. (USNM 463464). The spicule consists of six tangential rays in a plane with a fragment of a proximal or distal ray at right angles to the plane. The six tangential rays are radially and uniformly arranged approximately 60° apart. Rays tend to be subcylindrical in their inner parts but then taper moderately quickly to broken tips. There is not a complete ray preserved on the spicule.

The longest rays are approximately 0.6 mm long; they have basal ray diameters of 0.12 mm and taper to approximately 0.10 mm across at the outer broken ends. The proximal or distal ray is approximately 0.12 mm in diameter and represents only the basal approximately 0.05 mm of the ray.

A second small octactine occurs in matrix filling a pore in a paratype of *Calycocoelia perforata* (CRICYT VI-2). The spicule has a prominent central disk 0.2 mm in diameter from which radiate six equal-spaced rays in a common plane. Only proximal parts of the rays are preserved. These are 0.08 mm in basal diameter at their junctions with the disk. Most rays appear to have almost subcylindrical proximal parts, but one fragment of a ray, 0.3 mm long, tapers from a diameter of 0.08 mm at the base to 0.06 mm in diameter where the ray tip is lost in matrix. Only a faint ringlike impression of a proximal or distal ray is preserved on the somewhat weathered surface of the central disk. That ring is approximately 0.10 mm in diameter, and it contains a slight node on the weathered surface. Because of that node and the faint ring, however, the spicule is considered to be an octactine rather than a sexiradiate, but both are common spicules in Ordovician heteractinid sponges.

Discussion. Even though the spicules are isolated, they do document the occurrence of heteractinid sponges, probably related to *Astraeospongium,* in the Ordovician section of the Precordillera of San Juan Province in Argentina. However, the spicules are a generalized type and are not even generically identifiable.

Material. The spicule attached to a paratype of *Patellispongia robusta* n. sp. (USNM 463464) is from the Talacasto Gulch locality, and the spicule in pore-filling matrix on the dermal surface of a paratype of *Calycocoelia perforata* (CRICYT VI-2) is from the locality in Don Braulio Gulch in the Villicúm Range. Both spicules are from the San Juan Formation in the Precordillera, San Juan Province.

REFERENCES CITED

Aceñolaza, F. G., and Baldis, B., 1987, The Ordovician System of South America: International Union of Geological Sciences Publication 22, 68p.

Aceñolaza, F. G., Durand, F. R., and Díaz Taddei, R., 1977, Nautiloideos Ordovícicos de la Precordillera Argentina, Fauna de Huaco, provincia de San Juan: Actas Geológica Lilloana, Tucumán, v. 12, no. 8, p. 219–44.

Alberstadt, L. P., Walker, K. R., and Zurawski, R. P., 1974, Patch reefs in the Carters Limestone (Middle Ordovician) in Tennessee, and vertical zonation in Ordovician reefs: Geological Society of America Bulletin, v. 85, p. 1171–82.

Baldis, B., and Beresi, M., 1981, Biofacies de culminación del ciclo deposicional calcáreo del Arenigiano del oeste de Argentina: Actas do II Congreso Latinoamericano de Paleontología, Porto Alegre, Brasil, p. 11–19.

Baldis, B., Beresi, M., Bordonaro, O., and Vaca, A., 1984, Argentine Precordillera as a key to Andean structure: Episodes, v. 7, no. 3, p. 14–19.

Baldis, B., and Blasco, G., 1975, Primeros trilobites ashgillianos del Ordovícico sudamericano: I Congreso Argentino Paleontología y Bioestratigrafía, v. 1, p. 33–48.

Baldis, B., Bordonaro, O., Armella, C., Beresi, M., Cabaleri, N., Peralta, S., and Bastía, H., 1989, La Cuenca Paleozoica inferior de la Precordillera Argentina: Correlación Geológica, Universidad Nacional de Tucumán, no. 6, p. 101–2.

Baldis, B., Bordonaro, O., Beresi, M., and Uliarte, E., 1981, Zona de dispersión estromatolítica en la secuencia calcáreo-dolomítica del Paleozoico inferior de San Juan: Actas VIII Congreso Geológico de Argentino, v. 2, p. 419–34.

Bassler, R. S., 1927, A new Early Ordovician sponge fauna: Washington Academy of Science Journal, v. 17, p. 390–94.

———, 1941, The Nevada Early Ordovician (Pogonip) sponge fauna: U.S. National Museum Proceedings, v. 91, no. 3126, p. 91–102.

Benedetto, J. L., 1987, Braquiópodos clitambitáceos de la Formación San Juan (Ordovícico temprano), Precordillera Argentina: Ameghiniana, Revista de la Asociación Paleontológica Argentina, Buenos Aires, v. 24, no. 1–2, p. 95–108.

Benedetto, J. L., and Herrera, Z. A., 1986, Braquiópodos del Suborden Strophomenida de la Formación San Juan (Ordovícico temprano), Precordillera Argentina: Actas IV Congreso Argentino de Paleontología y Bioestratigrafía, Mendoza, v. 1, p. 89–97.

———, 1987a, El género *Platystrophia* King (Brachiopoda) en la Formación San Juan de la Precordillera Argentina: Ameghiniana, Revista de la Asociación Paleontológica Argentina, Buenos Aires, v. 24, no. 1–2, p. 51–59.

———, 1987b, *Sanjuanella*, un nuevo género de la Subfamilia Ahtiellinae (Brachiópoda, Plectambonitácea) del Ordovícico de la Precordillera Argentina: Actas IV Congreso Latinoamericano de Paleontología, Bolivia, v. 1, p. 97–109.

Beresi, M. S., 1981, Fauna y ambiente en los sedimentos carbonáticos arenigianos de Talacasto, San Juan, Argentina: Actas VIII Congreso Geológico Argentino, San Luis, Argentina, v. 2, p. 399–417.

———, 1986a, Paleoecología y biofacies de la Formación San Juan, al sur del paralelo de 30° sur, Precordillera de San Juan, Argentina: Unpublished doctoral thesis, Universidad Nacional de San Juan, Departmento de Geología, 450p.

———, 1986b, Capas con *Archaeoscyphia* (Porifera) en los sedimentos carbonaticos arenigianos de Talacasto, Precordillera de San Juan: Actas Primeras Jornadas sobre Geología de Precordillera, San Juan, v. 1, p. 99–102.

———, 1986c, Presencia de algas calcáreas en los sedimentos carbonáticos arenigianos de Talacasto, Precordillera de San Juan: Actas Primeras Jornadas sobre Geología de Precordillera, San Juan, v. 1, p. 94–97.

———, 1987a, Ensayo paleoecológico sobre la diversidad faunistica en la plataforma San Juan (Ordovícico inferior), en el perfil de Jáchal, San Juan, Argentina: Actas IV Congreso Latinoamericano de Paleontología, Bolivia, v. 1, p. 27–34.

———, 1987b, Biofacies y paleoambiente de la Formación San Juan (Arenigiano) en el área de Huaco, Precordillera Argentina: Actas IV Congreso Latinoamericano de Paleontología, Bolivia, v. 1, p. 635–43.

———, 1988, Sincronismo, diacronismo y cronología de las depositación calcárea Ordovícica en la Precordillera Argentina, en base a biozonas de conodontes: Actas V Congreso Geológico Chileno, v. 2, p. C27–C36.

———, 1990, Las esponjas como indicadores paleoecológicos de la Formación San Juan, Precordillera: Actas V Congreso Argentino de Paleontología y Biostratigrafía, Tucumán, v. 1, p. 19–24.

———, 1991a, Caracterización de la formación San Juan (Ordovícico inferior calcáreo) de la Precordillera de San Juan, Argentina: Actas VI Congreso Geológico Chileno, p. 302–6.

———, 1991b, Las algas calcáreas: aporte a la formación del sedimento carbonático del Ordovícico inferior de la Precordillera del oeste de Argentina: Actas VI Congreso Geológico Chileno, p. 781–85.

Beresi, M. S., and Bordonaro, Ol. L., 1984, La Formación San Juan en la Quebrada de Las Lajas, Sierra Chica de Zonda, Provincia de San Juan: Actas Noveno Congreso Geológico Argentino, S. C. Bariloche, v. 1, p. 95–107.

Berry, W. B. N., 1979, Graptolite biogeography: A biogeography of some Lower Paleozoic plankton: In Gray, J., and Boucout, A. J. (eds.), Historical biogeography, plate tectonics, and the changing environment: Oregon State University Press, Corvallis, p. 105–15.

Berry, W. B. N., and Wilde, P., 1990, Graptolite biogeography: Implications for paleogeography and paleooceanography: In McKerrow, W. S., and Scotese, C. R. (eds.), Palaeozoic Palaeogeography and Biogeography: Geological Society (London) Memoir 12, p. 129–37.

Billings, E., 1859, Fossils of the calciferous sandrock, including some of the deposit of White Limestone at Mingan, supposed to belong to the formation: Canadian Naturalist and Geologist, Natural History Society of Montreal, Proceedings, v. 4, art. 27, p. 345–46.

———, 1861, New species of Lower Silurian fossils: Geological Survey of Canada Pamphlet, v. 21, 24p.

———, 1865, On some new or little-known species of Lower Silurian fossils from Potsdam Group (Primordial Zone): In Palaeozoic fossils, containing descriptions and figures of new or little-known species of organic remains from the Silurian rocks: Geological Survey of Canada, v. 1, 429p.

Bolton, T. E., 1960, Catalogue of type invertebrate fossils of the Geological Survey of Canada: Geological Survey of Canada, v. 1, 215p.

Bordonaro, O. L., 1986, Bioestratigrafía del Cámbrico inferior de San Juan, Argentina: Actas VI Congreso de Argentino Paleontología y Bioestratigrafía, v. 1, p. 19–27.

Borello, A. V., 1961, El género *Westonóceras* entre los cefalópodos ordovícicos de la Precordillera de San Juan: Notas Museo de La Plata, La Plata, Buenos Aires, Geología, v. 20, p. 72.

Boucart, J., and Le Villain, G., 1931, La faune des Calcaires des Sidi Mouca D'Aglou: Service Mineralogie et Carte Géologique, Notes et Mémoires, 44p.

Bowerbank, J. S., 1864, A monograph of the British Spongiadae, v. III, Royal Society of London, 367p.

Carrera, M., 1985, Descripción de algunos poríferos de la formación San Juan (Ordovícico, Precordillera de San Juan): Reunión de Comunicaciones Paleontológicas, Asociación Paleontológicas Argentina, San Juan, p. 51–52.

Chamberlain, T. C., and Salisbury, R. D., 1907, Geology (3 vols.), v. 2, Earth History (2nd ed.), Henry Holt and Company, New York, 692p.

Church, S. B., 1974, Lower Ordovician patch reefs in western Utah: Brigham Young University Geology Studies, v. 21, pt. 3, p. 41–62.

Contreras, V., and Peralta, S. H., 1990, El genero *Cheirocrinus* Eichwald (Pelmatozoa, Cystoidea) en el Ordovícico de la Precordillera de San Juan, Argentina: Actas XI Congreso Geológico de Argentino, San Juan, v. 2, p. 211–13.

Cuerda, A. J., 1969, Sobre las graptofaunas del Silúrico de San Juan, Argentina: Ameghiniana, Revista de la Asociación Paleontológica Argentina, v. 6, no. 3, p. 223–35.

———, 1985, Graptolitos del techo de la Formación San Juan, Co. La Chilca, Precordillera de San Juan: Actas Primeras Jornadas sobre Geología de Precordillera, San Juan, v. 1, p. 18–19.

———, 1986, Graptolitos de techo de la Formación San Juan, Precordillera de San Juan: Actas IV Congreso Argentino de Paleontología y Bioestratigrafía, Mendoza, Argentina, p. 49–57.

Cuerda, A. J., Cingolani, C., Varela, R., and Schauer, O. C., 1985, El Ordovícico de la sierra del Tontal, Precordillera de San Juan: Actas IV Congreso Geológico Chileno, p. 190–92.

———, 1989, Ordovician graptolite biostratigraphy in the Pre-Andean region of San Juan, Mendoza, Argentina: XXVIII International Geologic Congress, v. 1, p. 347–48.

Cullison, J. S., 1944, The stratigraphy of some Lower Ordovician formations of the Ozark uplift: Bulletin of the Missouri School of Mines and Metallurgy, technical series, v. 15, no. 2, 112p.

Dana, J. D., 1895, Manual of geology treating of the principles of science with special reference to American geological history, 4th ed.: American Book Company, New York, 1087p.

Dawson, J. W., 1875, Life's dawn on earth; being the history of the oldest known fossil remains: London, 239p.

Deng, Z. Q., 1982, Palaeozoic and Mesozoic sponges from southwest China (in Chinese with English summary): Transactions of Academia Sinica: Stratigraphy and Paleontology, pt. 2, p. 245–54.

Desrochers, A., 1988, Stratigraphie de l'Ordovicien de la region de l'archipel de Mingan, Ministère de l'Energie et des resources du Quebec, Rapport Geologique MM 87–01, 70p.

Desrochers, A., and James, N. P., 1989, Middle Ordovician (Chazyan) bioherms and biostromes of the Mingan Islands, Quebec: In Geldsetzer, H. H. J., James, N. P., and Tebbutt, G. E. (eds.), Reefs, Canada and adjacent areas: Canadian Society of Petroleum Geologists Memoir 13, p. 183–91.

Di Prinzio, B., and Hünicken, M. A., 1990, Conodont fauna and biostratigraphy of the San Juan Formation (Ordovician) of Quebrada de Huaco, Jáchal, San Juan Province, Argentina: First Latin American Conodont Symposium: Abstracts of Meetings, Córdoba, p. 94–96.

Eggink, R. G., 1991, Drie anthaspidelliden van Sibculo: Grondboor en Hamer, v. 45, no. 2, p. 31–32.

Finks, R. M., 1960, Late Paleozoic sponge faunas of the Texas region: The siliceous sponges: American Museum of Natural History Bulletin 120, art. 1, 160p.

Finks, R. M., and Toomey, D. F., 1968, The paleoecology of Chazyan (lower Middle Ordovician) "reefs" or "mounds": New York State Geological Association, Guidebook to Field Excursions, p. 93–120.

———, 1972, Paleoecology of Chazy reef-mounds: Vermont Intercollegiate Geological Conference, Field Trip Guidebook, p. 443–68.

Freitas, T. A. de, 1989, Silurian *Archaeoscyphia* from the Canadian Arctic: A case for simplified generic taxonomy in the anthaspidellid lithistids (Porifera): Canadian Journal of Earth Sciences, v. 26, p. 1861–79.

Gnolli, M., and Seräpagli, E., 1980, A sponge spicule assemblage from Lower Ordovician of Precordillera Argentina: Revista Italiana di Paleontologia, v. 86, no. 2, p. 267–72.

Harrington, H. J., and Leanza, A. F., 1957, Ordovician trilobites of Argentina: University of Kansas, Special Publication 1, 159p.

Herrera, Z. A., and Benedetto, J. L., 1989, Braquiópodos del suborden Orthidina de la Formación San Juan (Ordovícico temprano en el área de Huaco) Precordillera Argentina: Ameghiniana, Revista de la Asociación Paleontológica Argentina, v. 26, no. 1–2, p. 3–22.

Hinde, G. J., 1884, Catalogue of fossil sponges of the British Museum (Natural History): London, 248p.

———, 1888, Note on the spicules described by Billings in connection with the structure of *Archaeocyathus minganensis:* Geological Magazine, series 3, v. 5, p. 226–28.

———, 1889, On *Archaeocyathus* Billings, and on other genera, allied to or associated with it, from the Cambrian strata of North America, Spain, Sardinia, and Scotland: Geological Society of London, Quarterly Journal, v. 45, p. 125–48.

Hitchcock, E., 1861, Report on the geology of Vermont; descriptive, theoretical, economical, and scenographica: Claremont, New Hampshire, 952p.

Hünicken, M. A., 1982, La zona de *Oepikodus evae* (conodonte, Arenigiano inferior) en la Formación San Juan, quebrada de Talacasto, Dpto. Ullum., Argentina: Actas V Congreso Latinamericano de Geología, Buenos Aires, p. 797–802.

———, 1985, Lower Ordovician conodonts: Biostratigraphy in Argentina: Boletín de la Academia Nacional de Ciencias, Córdoba, v. 56, no. 3–4, p. 309–22.

Hünicken, M. A., and Sarmiento, G. N., 1985, *Oepikodus evae* (conodonta, Arenigiano inferior) en la Formación San Juan, Arroyo Salado, Villicúm, San Juan, Argentina: Actas Primeras Jornadas sobre Geología de Precordillera, San Juan, p. 20.

Hünicken, M. A., Sarmiento, G. N., and Lozano, B. G., 1990, Some conodonts from the *Prioniodus elegans* zone (Lower Arenigian) of the San Juan Formation, Guandacol River, La Rioja Province, Argentina: First Latin American Conodont Symposium, pt. 2, Córdoba, p. 91–92.

James, N. P., and Klappa, C. F., 1989, Lithistid sponge bioherms, early Middle Ordovician, western Newfoundland: In Geldsetzer, H. H. J., James, N. P., and Tebbutt, G. E. (eds.), Reefs, Canada and adjacent areas: Canadian Society of Petroleum Geologists Memoir 13, p. 196–200.

Kayser, E., 1925, Contribuciones a la Paleontología de la República Argentina: Sobre fósiles primordiales e infrasilurianos: Actas de la Academia Nacional de Ciencias, Córdoba, v. 8, no. 3–4, p. 297–333.

Keller, M., Buggish, W., and Bercowski, F., 1989, Facies and sedimentology of Upper Cambrian shallowing-upward cycles in the La Flecha Formation (Argentine Precordillera): Zentralblatt für Geologie und Paläontologie, v. 1, no. 5/6, p. 999–1011.

Kempen, T. M. G., van, 1989, On a new anthaspidellid sponge from the Baltic Early Palaeozoic: Mitteilungen Geologische-Paläontologische Institute, University of Hamburg, v. 68, p. 131–57.

Kempen, T. M. G., van, and Kate, W. G. H. Z., ten, 1980, The skeletons of two Ordovician anthaspidellid sponges; a semi-numerical approach: Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, series B, v. 83, no. 4, p. 437–53.

Klappa, C. F., and James, N. P., 1980, Small lithistid sponge bioherms, early Middle Ordovician Table Head Group, western Newfoundland: Bulletin of Canadian Petroleum Geology, v. 28, p. 425–51.

Kobayashi, T., 1937, The Cambro-Ordovician shelly faunas of South America: Journal of Faculty of Science, University of Tokyo, v. 2, no. 5, p. 369–522.

Lange, M., and Bartholomäus, W. A., 1991, *Hudsonospongia cyctoslomata*, ein ordovizischer Schwanm aus dem sylter Kaolinsand: Geshiebekunde Aktuell, Hamburg, v. 7, no. 3, p. 107–10.

Laubenfels, M. W., de, 1955, Porifera: In Moore, R. C. (ed.), Treatise on Invertebrate Paleontology, Part E: Geological Society of America and Kansas Press, Lawrence, Kansas, p. E21–E112.

Lemos, V. B., 1981, Conodontes ordovicianos da Formaçao San Juan, Precordillera, Departmento Jáchal, San Juan, Rep. Argentina: Actas II Congreso Latinamericano de Paleontología, Porto Alegre, v. 1, p. 31–43.

Lesley, J. P., 1889–90, A dictionary of the fossils of Pennsylvania and neighboring states named in the reports and catalogues of the Survey: Pennsylvania Geological Survey Report, Part 4, 3 vols., 1283p.

Lozano, B., and Hünicken, M., 1990, Conodonts and biostratigraphy of the San Juan Formation (Arenig-Llanvirn) in the Talacasto Creek San Juan Province, Argentina: In First Latin American Conodont Symposium, Cordoba, Argentina, p. 94–96.

Miller, S. A., 1877, The American Palaeozoic fossils: A catalogue of the genera and species, with names of authors, dates, places of publication, groups of rocks in which found, and the etymology and significance of the words, and an introduction devoted to the stratigraphical geology of the Paleozoic rocks: Cincinnati, Ohio, 245p.

———, 1889, Class Porifera: In North American Geology and Paleontology: Cincinnati (published by the author), p. 152–67.

Nicholson, H. A., 1872, A manual of Palaeontology, with a general introduction on the principles of Palaeontology: Edinburgh and London, 885p.

Okulitch, V. J., 1935, Cyathospongia—A new class of Porifera to include Archaeocyathinae: Royal Society of Canada Transactions, series 3, v. 29, p. 75–106.

Oswald, F., 1847, Uber die Petrifacten von Sadewitz: Uebersicht Arbeit und Veränderungen Schlesischer Gessellschaft für Vaterlandische Cultur im Jahre 1846, Breslau, p. 56–65.

Pitcher, M. G., 1964, Evolution of Chazyan (Ordovician) reefs of eastern United States and Canada: Bulletin of Canadian Petroleum Geology, v. 12, p. 632–91.

Rauff, H., 1894, Palaeospongiologie: Palaeontographica, v. 41, 233–345.

———, 1895, Palaeospongiologie: Palaeontographica, v. 43, p. 223–72.

Raymond, P. E., and Okulitch, V. J., 1940, Some Chazyan sponges: Harvard College Museum of Comparative Zoology Bulletin, v. 86, no. 5, p. 197–214.

Reid, R. E. H., 1963, Preliminary notice of a classification of the Demospongia: Irish Naturalist Journal, v. 14, no. 5, p. 90–94.

Rigby, J. K., 1966, Evolution of Lower and Middle Ordovician sponge reefs in western Utah (abstract): Geological Society of America, Special Paper 87, p. 137.

———, 1971, Sponges and reef and related facies through time: North American Paleontology Convention, 1969, Part J, p. 1374–88.

———, 1973, A new anthaspidellid from the Silurian of Lake Timiskaming: Journal of Paleontology, v. 47, p. 801–4.

———, 1983, Fossil demosponges: In Broadhead, T. W. (ed.), Sponges and spongiomorphs: Notes for a short course: University of Tennessee Department of Geological Sciences, Studies in Geology 7, p. 12–39.

Rigby, J. K., and Chatterton, B. D. E., 1989, Middle Silurian Ludlovian and Wenlockian sponges from Baille-Hamilton and Cornwallis Islands, Arctic Canada: Geological Survey of Canada Bulletin 391, 69p.

Rigby, J. K., and Dixon, O. A., 1979, Sponge fauna of the Upper Silurian Read Bay Formation, Somerset Island, District of Franklin, Arctic Canada: Journal of Paleontology, v. 53, p. 587–627.

Rigby, J. K., and Nitecki, M. H., 1973, New *Archaeoscyphia* (Porifera) from the Ordovician of Anticosti Island, Quebec: Fieldiana (Geology), v. 33, no. 1, 10p.

Rigby, J. K., and Webby, B. D., 1988, Late Ordovician sponges from the Malongulli Formation of central New South Wales, Australia: Palaeontographica Americana, no. 56, 147p.

Roemer, C. F., 1876, 1880, Lethaea geognostica, oder Beschreibung und Abbildung der für Gebirgs-Formationen Bezeichnendsten Versteinerungen, I. Theil, Lethaea palaeozoica: E. Schweizerbart'sche Verlag, Stuttgart, v. 1, Atlas, 62p.; v. 2, 688p.

Sánchez, T. M., 1985, El género *Modiolopsis* en el Ashgilliano de la sierra de Villicúm y la comunidad de *Hirnantia-Modiolopsis*: Reunión de Comunicaciones Paleontológicas, Asociación Paleontológica Argentina, San Juan, v. 1, p. 58–59.

Sarmiento, G. N., 1985, La biozona *Amorphognathus variabilis–Eoplacognatus pseudoplanus* (Conodonta), Llanvirniano inferior, en el flanco oriental de la Sierra de Villicúm: Actas Primeras Jornadas sobre Geología de Precordillera, San Juan, Argentina, v. 1, p. 119–23.

Schmidt, O., 1870, Grundzüge einer Spongien-fauna des atlantischen Gebietes: Leipzig, 88p.

Schuchert, C., and Dunbar, C. O., 1934, Stratigraphy of western Newfoundland: Geological Society of America, Memoir 1, 123p.

Schuchert, C., and Twenhofel, W. H., 1910, Ordovicic-Siluric section of the Mingan and Anticosti Islands, Gulf of St. Lawrence: Geological Society of America Bulletin, v. 21, p. 677–716.

Scotese, C. R., and Barrett, S. F., 1990, Gondwana's movement over the South Pole during the Palaeozoic: Evidence from lithological indicators of climate: Palaeozoic Palaeogeography and Biogeography, Geological Society (London) Memoir 12, p. 75–85.

Scotese, C. R., and McKerrow, W. S., 1990, Revised world maps and introduction: Palaeozoic Palaeogeography and Biogeography, Geological Society (London) Memoir 12, p. 11–21.

Serăpagli, E., 1973, Carbonati di tipo Bahamitico nell Ordoviciano inferiore della Precordillera Argentina e relative observazzione paleoclimatologiche: Atti Societe National di Modena, Modena, Italia, v. 104, p. 239–454.

———, 1974, Lower Ordovician conodonts from Precordilleran Argentina (Province of San Juan): Bolletino della Societá Paleontologica Italiana, v. 13, no. 1–2), p. 17–98.

Shimer, H. W., and Shrock, R. R., 1944, Index fossils of North America: John Wiley and Sons, Inc., New York, 837p.

Sollas, W. J., 1875, Sponges: In Encyclopedia Britannica, 9th ed., p. 451.

Toomey, D. F., and Nitecki, M. H., 1979, Organic buildups in the Lower Ordovician (Canadian) of Texas and Oklahoma: Geology (new series), v. 2, 181p.

Twenhofel, W. H., 1938, Geology and paleontology of the Mingan Islands, Quebec: Geological Society of America Special Paper 11, 132p.

Ulrich, E. O., and Everett, O., 1890, Description of Lower Silurian sponges: Bulletin of the Geological Survey of Illinois, v. 8, no. 2, p. 253–82.

Vaccari, N. E., Waisfield, B., and Carrera, M., 1986, Nuevos trilobites de la Formación San Juan (Ordovícico temprano) Precordillera de San Juan, La Rioja, Argentina: Actas IV Congreso Argentino de Paleontología y Bioestratigrafía, Mendoza, v. 1, p. 89–97.

Walcott, C. D., 1886, Second contribution to the studies on the Cambrian faunas of North America: U.S. Geological Survey, Bulletin 30, 369p.

———, 1887, Note on the genus *Archaeocyathus* of Billings: American Journal of Science, series 3, v. 34, p. 145–46.

Walker, K. R., and Ferrigno, K. F., 1973, Major Middle Ordovician reef tract in eastern Tennessee: American Journal of Science, v. 273-A, p. 294–325.

Webby, B. D., and Rigby, J. K., 1985, Ordovician sphinctozoan sponges from central New South Wales: Alcheringa, v. 9, p. 209–20.

Williams, A., 1976, Introduction to the general aspects of correlation: In Williams, A., and others (eds.), Correlation of Ordovician rocks in the British Isles: Geological Society of London, Special Report 3, p. 1–74.

Wilson, A. E., 1948, Miscellaneous classes of fossils, Ottawa Formation, Ottawa–St. Lawrence Valley, Geological Survey of Canada, Bulletin 11, 116p.

Wyatt, D. J., 1979, Carbonate mud mounds from the Lower Ordovician Wah Wah Limestone of the Ibex area, western Millard County,

western Utah: Brigham Young University Geology Studies, v. 26, pt. 2, p. 104–14.
Zittel, K. A., 1877a, *Protachilleum kayseri:* In Ueber primordiale und Untersilurische Fossilien aus der Argentine Republik, E. Kayser: In Beiträge Geologie und Paläontologie der Argentine Republik, v. 2, no. 1, p. 22–23.
———, 1877b, Studien über fossile Spongien: I. Hexactinelliidae: Abhandlungen der Königlich Bayerischen Akademie Wissenschaften Mathematische–Physikalischen Klasse, v. 13, p. 1–63.
———, 1878, Studien über fossile Spongien, Zweiter Abteilung, Lithistidae; Dritte Abteilung: Monactinellidae, Tetractinellidae und Calcispongiae: Abhandlungen der Königlich Bayerischen Akademie Wissenschaften Mathematische–Physikalischen Klasse, v. 2, 138p.
———, 1880, Handbüch der Palaeontologie, v. 1: Protozoa, Coelenterata, Echinodermata, und Molluscoidea: Druck und Verlag von R. Oldenbourg, München and Leipzig, 765p.