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Lower Ordovician Sponges from the Manitou Formation in Central Colorado

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ABSTRACT

A limited fauna of largely anthaspidellid demosponges occurs in an approximately 3-meter-thick interval in the Ptarmigan Chert Member of the Lower Ordovician Manitou Formation in exposures along the Colorado Front Range northwest of Garden of the Gods and Manitou Springs. Cylindrical annulate *Archaeoscyphia* and plate-like *Patellispongia* are the most abundant genera of sponges in the Manitou Formation. *Patellispongia oculata* Bassler, 1927, is the most common sponge, but *Archaeoscyphia pulchra* Bassler, 1927, and *Archaeoscyphia* sp. B are also common. *Calycocoelia protera* Rigby, Linford and LeMone, 1999, is less common, and *Zittelella*(?) *varians* (Billings, 1861) and *Ozarkocoelia*(?) sp. are rare forms. An isolated sexiradiate spicule attests to the presence of the astraeospongiid heteractinid calcareous sponges, and is questionably included in *Astraeoconus calcarius* Rietschel, 1968.

This fauna, described for the first time, comprises the most diverse assemblage of Ordovician sponges known in Colorado. The sponges occur primarily in carbonate grainstone, and locally in bioturbated mudstone, around small, dominantly isolated stromatolite and thrombolite heads. None of the sponges are in growth position. Orthoceroid nautiloids and a number of gastropods co-occur with the sponge fossils.

Thin (<75 cm thick) stromatolitic units are interbedded with thicker units of chert-bearing, bioturbated lime mudstone and siltstone. Locally, stromatolitic units created short, wide mounds within which sponge-bearing grainstone was deposited between heads and within channels. The association of sponge fossils with stromatolites is common in the Lower Ordovician, e.g., the type section of the Ibexian in Utah and in equivalent beds in eastern Nevada.

The Manitou Formation in this region was deposited in very shallow water in a proximal setting on the east side of the Transcontinental Arch. These occurrences probably represent the most proximal environments that sponges of this type tolerated, based on paleobiogeographic data from this time interval.

INTRODUCTION

Sponges are relatively rare fossils in Upper Cambrian and Ordovician inner detrital belt rocks of North America. There are no published descriptions of any sponge faunas of this age from Colorado. A few passing comments in geologic reports, however, noted that fossil sponges do occur in the Lower Paleozoic section in Colorado (Bass and Northrup, 1953). The occurrence of a sponge fauna in the Manitou Formation was noted in an abstract by Myrow and Rigby (1996). That fossiliferous sequence produced by far the most diverse and best preserved Lower Paleozoic sponge assemblages from Colorado. They are from the Lower Ordovician Manitou Formation, from near Garden of the Gods Park, northwest of Colorado Springs and north of Manitou Springs (Fig. 1). The sponge fauna, described here for the first time, was collected from weathered outcrops on a short trail and in unweathered vertical faces at road level along Rampart Range Road, at approximately 520 m (1700 feet) east and 150 m (500 feet) south of the northwest corner of Section 28, T. 13 S., R. 67 W., on the Cascade 7.5-minute quadrangle (Fig. 1). The locality is at 38° 53′ 43″ north latitude, and at 104° 53′ 55″ west longitude, approximately 5 km north of the community of Manitou Springs, Colorado. Rampart Range Road

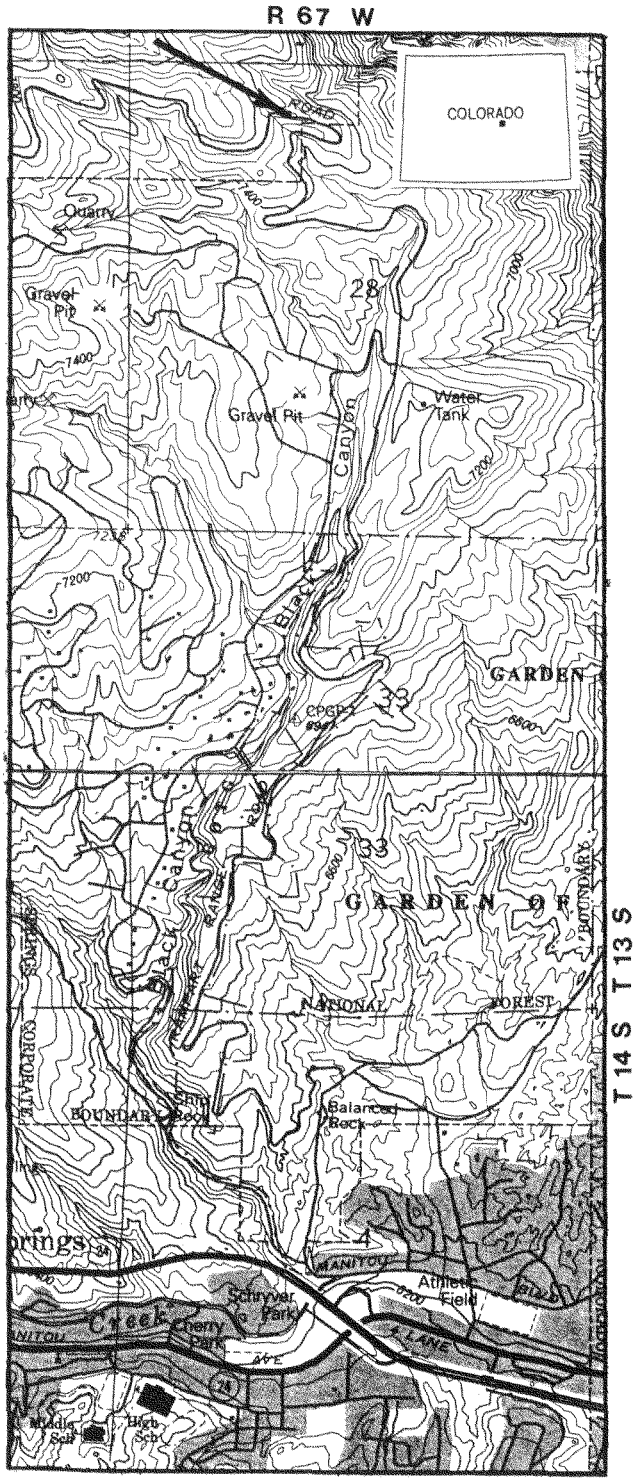

Figure 1. Index map to the sponge locality (arrow) along Rampart Range Road, in the north-central part of Sec. 28, T. 13 S., R. 67 W., on the Cascade 7.5-minute quadrangle, northwest of Garden of the Gods and north of Manitou Springs, in central Colorado. Scale 1:24,000.

is accessed from the park road less than 100 m from "Balanced Rock," which is just inside the southern entrance to Garden of the Gods.

Paleogeographic reconstructions of Colorado for the Cambrian and Ordovician indicate a northwest-southeast trending trough, the "Colorado Sag" (Lochman-Balk, 1956), cut across the Transcontinental Arch during this time (Fig. 2). The Homestake Shear Zone, a northeast-trending tectonic feature in western Colorado, strongly influenced sedimentation patterns and produced two sub-basins within the Sag (Allen, 1994). The southeast sub-basin was connected to the Midcontinental Sea (Gerhard, 1972, 1974; Myrow, et al., 1995). It was in this sub-basin that the sponge-bearing Manitou beds accumulated.

Cross (1894) proposed the Manitou Limestone for a carbonate succession between Upper Cambrian deposits of the Sawatch and Peerless formations and the overlying Ordovician Harding Sandstone. The formation was divided into the Helena Canyon, Ptarmigan Chert, and Leavick Tarn members by Gerhard (1974). The lower Helena Canyon Member consists of thin-bedded peritidal deposits with well-developed shoaling cycles (Myrow, 1995). The middle Ptarmigan Chert Member consists of thicker-bedded, chert-rich, nodular micrite and fine grainstone beds. Beds near the top of this member contain the well-preserved fossil sponges that are the subject of this report. The upper Leavick Tarn Member is a homogeneous, highly recrystallized, massive-weathering dolostone.

The sponge-bearing outcrop consists primarily of three carbonate lithofacies. The bulk of the outcrop is gray to red, bioturbated dolomitic mudstone with locally abundant thin chert nodules. Beds of this bioturbated mudstone facies range from 15 cm to 2 m thick. Sponge fossils are locally present in this facies (Fig. 3, arrows), and are particularly abundant in the interval from 5.8 to 6.4 m. Mudstone units are interbedded with thin, tabular beds of fine to very coarse grainstone. Beds of this facies range from 4 to 10 cm thick and occur individually and in packages up to 27 cm thick. Some beds show parallel lamination and a few thin beds contain dispersed cm-scale intraclasts.

The third facies consists of complex mixtures of bioturbated red mudstone, coarse grainstone, and stromatolitic structures that range from isolated heads to linked compound elements. Beds of this facies range from 35 to 65 cm thick. These beds are generally tabular over the limited lateral exposures of the outcrop, but in one case—5.6 to 6 m in the section (Fig. 3)—the stromatolitic heads define lenticular buildups that pinch out into bioturbated mudstone in one direction and are truncated by a thick, lenticular, channel-fill of coarse grainstone that is nearly 50 cm thick. Grainstone beds in this facies are generally lenticular and clearly cross-cut both bioturbated mud-

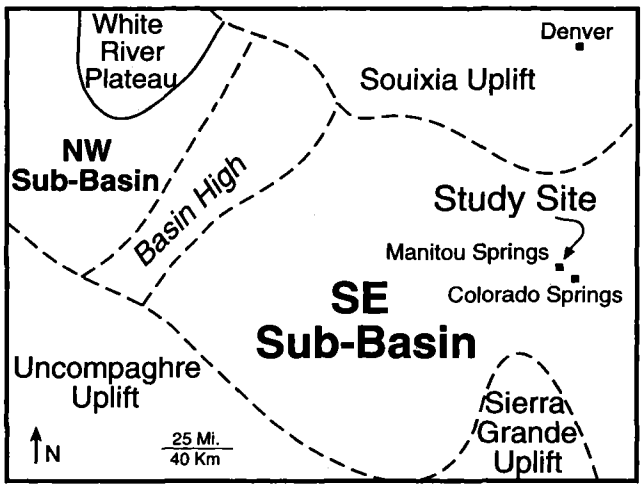

Figure 2. Paleogeographic reconstruction of Colorado for the Cambrian and Ordovician, showing the position of the sponge locality in a southeastern sub-basin, which was connected to the Mid-continental Sea and to the interior of North America, southeast of the Transcontinental Arch (modified from Gerhard, 1972).

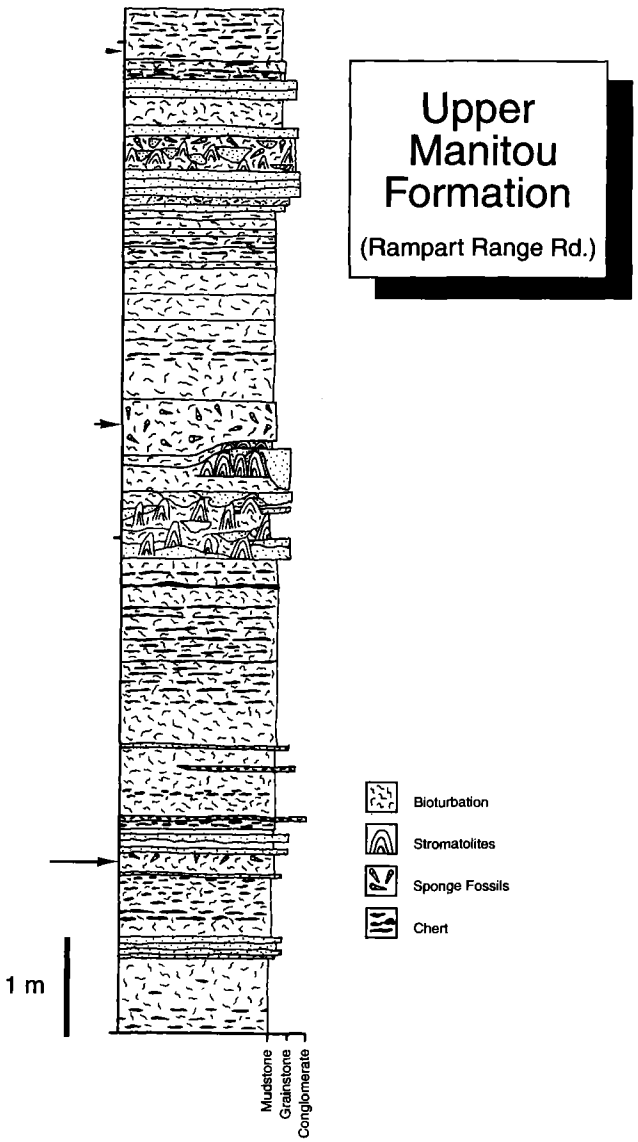

Figure 3. Detailed stratigraphic section of the upper Manitou Formation exposed along the Rampart Range Road. Stratigraphic occurrences of sponges in the section are shown by arrows. The sponges are commonly associated with small stromatolitic mounds, in intermound sedimentary units.

stone and stromatolitic laminations. Sponge fossils are common in the grainstone within this facies. Random orientations of the sponge fossils are consistent with simultaneous mechanical transport of both sponges and coarse clasts of the grainstone. Preservation of the overall forms and internal structures is consistent with short transport. It should be added that most of the sponges appear to be whole specimens, i.e., there is little evidence that individual sponges were broken and fragmented during transport.

These facies record shallow marine carbonate deposition in Early Ordovician seas of Colorado. The mudstone facies reflects low-energy deposition of micritic sediment and extensive bioturbation by marine invertebrate organisms. The tabular grainstone beds are likely thin event beds that were rapidly deposited, in some cases in upper plane bed conditions. The stromatolitic facies shows evidence of a complex depositional history. The microbial buildups apparently had some relief on the sea floor, either as individual heads, or as larger buildups. Micritic sediment accumulated between the heads and organisms burrowed within this sediment. Much of that bioturbation is marked by reddish infills that are commonly dolomitized. Strong currents cut channels through both stromatolitic heads and inter-head mud, or buildups and adjacent mud, and transported coarse grainstone and sponges. These coarse-grained channel-fills contain the best preserved fossil sponges.

These beds probably represent the most proximal environments in which sponges of these types could have thrived, or survived, at this time, based on paleogeographic data and lithology. Sponges are locally abundant and they occur with orthoceroid nautiloids and large low-spired gastropods, as in widely observed associations in Lower Ordovician faunas elsewhere in North America. None of the sponges observed in these rocks are in growth position. All have been transported and deposited in channel fills, or in bioturbated mudstones between the small stromatolite structures. Stromatolite heads are surrounded and separated by intensely bioturbated mudstones and grainstones.

AGES

There has been little published biostratigraphic data for Cambrian-Ordovician rocks of Colorado, although considerable work has been done recently (Myrow, et al., 1995; Myrow, et al., 1995; Bennett, et al., 1997; Brachle, et al., 1998). The most significant published work to date is the trilobite study of Berg and Ross (1959). They reported trilobite faunas from the Front Range that span Ross (1951) and Hintze (1951, 1952) Trilobite Zones B to E (or F) within the Manitou Formation. Trilobites recovered from the Manitou Springs area indicate the presence of Zones D through E or F, but few fossils were recovered from the upper 40 m of the approximately 65 m total thickness of the formation. Trilobites have recently been recovered somewhat higher in the section by John Taylor (personal communication, 1998).

Conodont data are also available from sections of the formation in Manitou Springs and elsewhere along the Front Range (R. L. Ethington, personal communication, 1998). These data are in general agreement with ages indicated by Berg and Ross (1959). The sponge locality described in this report, located a few kilometers north of Manitou Springs, contains specimens of the trilobite *Hystricurus oculilunatus* Ross, 1951 (J. Loche, personal communication, 1996), which places the sponge-bearing beds within Trilobite Zone F.

PALEONTOLOGY

The sponges present include anthaspidellid lithistid demosponges, all of which are characterized by skeletons of fused dendroclones, and an isolated astraeospongiid heteractinid spicule. Tips of the dendoclones in the anthaspidellid sponges are united to form major rod-like, upward-divergent and radially arranged linear structures, termed trabs. They are moderately well preserved as light gray structural elements, surrounded by dark mudstone matrix, or as darker vertical linear structures, separated by light chert, in the sponges described here. Trabs may or may not contain coring oxeas. Microstructure of the trabs and, in some cases, larger elements of the skeletons have been essentially destroyed because of crystalline replacement or intense dolomitization. Shafts of the dendroclones form rung-like elements in the skeletal net. Regularity of skeletal structures, their dimensions, relationships to canals, and gross morphology are utilized in taxonomy.

SYSTEMATIC PALEONTOLOGY

Class DEMOSPONGEA Sollas, 1875
Order LITHISTIDA Schmidt, 1870
Suborder ORCHOCLADINA Rauff, 1895
Family ANTHASPIDELLIDAE Miller, 1889
Genus ARCHAEOSCYPHIA Hinde, 1889

Type species.—*Petraia minganensis* Billings, 1859

Discussion.—*Archaeoscyphia* is one of the largest and most widely distributed sponges of the family. It has been broadly reported in North and South America, Asia, Europe, and Australia from Ordovician and Lower Silurian rocks. It is one of the most distinctive and common genera in the Manitou exposures.

Archaeoscyphia Hinde, 1889, is one of the most abundant sponges in the Manitou faunas. It is a tall form with prominent annulations on the exterior, and is pierced by a large, axial spongocoel, a major exhalant chimney-like structure. The annulate exterior is emphasized by the regular ring-like annulations. The several species of the genus are differentiated based on dimensions of the sponges, spacing and shapes of annulations, positions of inhalant and exhalant canals, and details and dimensions of spicule makeup and skeletal structure, as documented by De Freitas (1989) and Johns (1994), among others.

ARCHAEOSCYPHIA PULCHRA
(Bassler, 1927)
Plate 1, Figures 2, 3, 5; Plate 2, Figures 1, 2

Nevadocoelia pulchra BASSLER, 1927, p. 3392; BASSLER, 1941, p. 95–96.

Archaeoscyphia annulata CULLISON, 1944, p. 48, pl. 24, figs. 9–12.

Archaeoscyphia pulchra (Bassler, 1927), JOHNS, 1994, p. 44–47, pl. 4, figs. 1, 5, pl. 5, figs. 1, 3; RIGBY AND DESROCHERS, 1995, p. 18–19, fig. 6.5–6.8; LIU, et al., 1997, p. 197–198, figs. 4.1–4.4; RIGBY, LINFORD AND LEMONE, 1999, p. 110–111, pl. 2, figs. 1–3, pl. 5, figs. 1, 2.

Diagnosis.—"Sponge moderate size, conico-cylindrical with annulated exterior and deep tubular spongocoel; prominent annulations 11–26 mm apart. Spongocoel large, 35–60 percent of diameter; surface of pinnation approximately one-third wall thickness in from gastral margin with trabs meeting external surface 45–60°. Horizontal canals 0.5–1.4 mm in diameter, radially arranged and vertically stacked. Vertical or longitudinal canals 0.7–0.8 mm in diameter." (from Liu, et al., 1997, p. 198).

Description.—The species is represented by a few nearly complete sponges and by thin sections, where only fragments have been preserved. One of the larger specimens, USNM 480576, is an annulate subcylindrical fragment approximately 14 cm tall and with a flattened lower diameter of 22 x 23 mm and an upper preserved diameter of 20 x 33 mm. Walls are thin, ranging 3–6 mm thick, and are marked by ring-like annulae that are spaced approximately 1 cm apart, crest to crest, but range from 8 to 13 mm apart. Annular ridges range from rounded and droop-

ing to moderately sharp-crested and 4–5 mm high, radially, above the separating irregular to sharp indentations a few mm deep.

Radial canals are the only ones readily apparent in the somewhat diagonal sections available. They occur in vertically stacked series and are 0.5–0.6 mm wide and 0.7–0.8 mm high. These series are separated by parieties that are two trabs wide, with the trabs approximately 0.3 mm apart. Trabs are 0.06–0.10 mm in diameter and are cross-connected by rung-like dendroclones. These dendroclones have shafts 0.02–0.03 mm in diameter that enlarge toward the trabs. In the parietal sections, dendroclones are 0.2–0.3 mm apart, vertically, in the irregularly diagonal cut surfaces available. Details of spicule tips and internal structure of the trabs have been lost by extensive recrystallization of skeletal elements.

A surface of pinnation occurs near the gastral margin and trabs diverge upward and outward at angles of 20–30°, flexing somewhat more sharply to 40–50° in outer parts of the annular ridges. Trabs diverge toward the gastral margin at considerably lower angles.

A characteristic specimen on USNM 480587, thin-section ST-D, is a vertical section through approximately three annulations on the sponge fragment. It is 14 mm high and shows annulations 4–5 mm high, vertically, and 2–4 mm thick, radially. It has a moderately coarse skeletal structure, where trabs are 0.10–0.14 mm in diameter and dendroclones have shafts 0.03–0.04 mm in diameter. These dendroclones are spaced in the vertical ladder-like skeletal structure so that 7–8 dendroclones occur per millimeter in characteristic sequences.

A tangential subvertical section on USNM 480590, on thin section ST-F, is probably of the near-basal part of the sponge. It includes three annulations and a cluster of axial exhalant canals. The fragment is 18 mm high and has annulations each approximately 5 mm high, vertically, and 2–3 mm thick, radially, from the interannular depressions. They are rounded to somewhat asymmetrical with gently divergent lower profiles and steep upper profiles in the radial ridges.

The axial canal cluster is composed principally of hexagonal to subprismatic canals, in the center, to subcircular canals in the outer rings. The largest canals are 1.4–1.5 mm wide and are hexagonal in the center, but those outside the central part become subcircular and 1.0–1.2 mm in diameter. Outer canals appear to grade into lateral horizontal canals, 0.6–0.8 mm in diameter, that extend in vertical series between parieties. Five such series occur per 5 mm measured horizontally near the gastral surface. There the canals are separated by parieties formed by two series of moderately closely spaced trabs. Parieties are 0.3–0.6 mm wide.

Elsewhere in the skeleton, trabs are upwardly pinnate and curve laterally, parallel to the lower surface of annulations, but meet upper surfaces of those annulations at essentially 90°. The parietal trabs are mostly 0.10 mm in diameter and dendroclones are mainly I-shaped forms, with shafts 0.025–0.030 mm in diameter. Details of cladome tips are lost in the coarse crystallization, but shafts do thicken to approximately 0.10 mm in diameter near where the dendroclone tips form the trabs. Parietal dendroclones are 0.20–0.25 mm long, but dendroclones that separate canals into vertical series range up to 0.5 mm long, though of the same general diameter. In parieties, 7–8 dendroclones occur per millimeter along the ladder-like series.

A small diagonal section on USNM 480600, thin section ST-A2, shows coarse trabs and closely spaced dendroclones in a robust-appearing skeleton. Part of the specimen has been silicified and shows a few isolated dendroclones with branching clads associated with porous-appearing, ill-defined trabs. Orientation of the slice is uncertain but is probably tangential in the lower part of one of the shelf-like annulations.

A weathered specimen, photographed in the outcrop (Pl. 3, fig. 5), is a sponge cut diagonally and tangentially so that the annulations are prominent. The sponge is approximately 10.5 cm tall, with 11 well-defined annulations that occur as prominent rounded structures in the middle part of the specimen, which is cut more-or-less through the central part of the sponge. Annulations become somewhat more sharp-ridged and pronounced where cut only tangentially in the upper part. The sponge expands upward from an incomplete base, approximately 1 cm in diameter, to approximately 3.5 cm wide at the top. Upper thin, shelf-like annulations are regularly 5–6 mm thick and high. Those in the middle part of the sponge are more robust and approximately 1 cm high, vertically, and thick, radially, out from the somewhat more sharply rounded interannular depressions.

Material.—Definitive skeletal structure is shown in USNM 480587 and 480590, on thin sections ST-D and ST-F, and on figured specimen USNM 48057A-C, all from the weathered trail surface at the locality. Samples of the species collected in 1996 include USNM 480573–480577A, B, and two additional unnumbered specimens. Also included, although somewhat less certainly, is a tangential section, USNM 480600, on thin section STA-2. All these are from the middle Ptarmigan Chert Member of the Manitou Formation at the locality, northwest of Garden of the Gods.

Discussion.—The relatively coarse texture of both the skeleton and the canal patterns are considered characteristic of the species, as is the more distinctive sharply-ridged annulations common on the steeply obconical sponge. Specimens grouped here are thought to belong to the species because of the spacing of their annulations, their general form, and because of the relatively coarse canals that perforate their skeletons.

Archaeoscyphia pulchra Bassler, 1927, is an annulate form with a skeletal structure of relatively coarse trabs formed by ray tips of closely spaced dendroclones. Essentially contemporaneous examples of *A. pulchra* from the El Paso area, described by Rigby, et al., (1999), have radial canals that are 0.6–1.4 mm in diameter, nearly double the size of canals in these Colorado specimens, where radial canals are only 0.4–0.7 m in diameter, but Liu, et al., (1997, p. 197–198) observed that radial canals range 0.5–1.4 mm in diameter in their specimens of the species from China. Johns (1994) observed that radial canals range 0.5–1.2 mm in diameter in the somewhat younger holotype and other examples of the species he studied from Nevada and Missouri. From these studies, examples of the species from the Manitou Formation have canals that are within the range included by other authors, and are grouped there.

Presence of a cluster of axial exhalant canals in USNM 480590, thin section ST-F, suggests that section is from the near-basal part of the sponge. The same general skeletal and canal pattern occurs in USNM 480587, thin section ST-D, which appears to be from farther up in the sponge.

ARCHAEOSCYPHIA sp. B
Plate 1, Figures 1, 6; Plate 2, Figures 3, 4;
Plate 3, Figure 6

Description.—Several, tall, sub-cylindrical, annulate specimens of the species occur in the collections. Characteristic of the species is USNM 480572, which is a sponge approximately 9 cm tall with a complete oscular margin, but was cut tangentially near the rounded base where it is approximately 1 cm in diameter. It expands upward to approximately 18 mm across at the top. Most pronounced annulations are approximately 10 mm apart, but some minor annulations occur in the lower and uppermost part of the sponge; 10–12 annulations occur in the full height of the sponge. Generally speaking, these annulations range from 1–2 mm to 4–5 mm thick, radially, and form rounded to slightly asymmetric ridges, with the latter showing relatively gentle divergence of the lower part of the annulation, but somewhat steeper upper surfaces. They are generally separated by broad, rounded depressions so that individual annulations are up to approximately 8 mm tall, vertically.

The spongocoel is a simple axial tube that ranges from approximately 5 mm across, near the base, up to 9 mm across at the top. It has smooth to irregularly wavy walls and no prominent axial exhalant canals are evident.

The skeleton is characteristically anthaspidellid, with an upwardly divergent, ladder-like, skeletal structure and a surface of pinnation at or near the gastral margin. Trabs diverge at low angles within the wall, but curve out into the annulae where a weak surface of pinnation is developed within each annulation. Lower trabs are sub-parallel to dermal surfaces of annulations or locally meet that surface at 15–20°. Trabs continue with gentle curves and meet upper surfaces of annulations at 60–70°.

Individual trabs are 0.06–0.08 mm in diameter, as poorly preserved in the dolomitic replacement. Dendroclones and finer skeletal structure are even more poorly preserved, but locally shafts approximately 0.03–0.04 mm in diameter bridge between trabs that separate canals. Elsewhere dendroclones occur 4–5 per millimeter in the ladder-like series between canals and vertical series. The relatively open-textured, though fine-textured, skeletal structure shows in a tangential cut through the middle part of the wall near the base. There, three trabs occur per millimeter, measured horizontally in the regular skeletal structure. In this area dendroclones are not preserved, but the coarser trabs show as light crystalline rods. Canals are not well defined, but are approximately 0.2 mm in diameter in the poorly preserved structure.

Two diagonal, sub-transverse sections of the species are cut in USNM 480583C, thin section ST-K. They are dolomitized and the replaced skeletal structure is only locally preserved. The better preserved of these is a sponge approximately 10 mm in diameter, with a spongocoel 9 mm in diameter. It has been cut so that the walls show two or three irregular, rounded annulations as only node-like expressions on the exterior. Walls are 3–5 mm thick in areas between the annulations.

The skeletal structure shows as irregularly radiating trabs 0.06–0.08 mm in diameter and spaced approximately 0.3 mm apart. Dendroclones are locally preserved and are characteristically I-shaped and up to 0.3 mm long. Shafts have mid-length diameters of 0.03–0.04 mm and are best preserved in the outer part of the wall where the trabs appear to meet that outer wall at moderately high angles. Canals approximately 0.5 mm in diameter are only moderately defined and separated by parieties that are made of two or three trab series in a distinctly uniform-appearing texture.

The associated oblique section is of a sponge 14–15 mm in diameter, with a spongocoel 10–12 mm in diameter. Trabs in the crystalline replacement are 0.03–0.04 mm in diameter and are spaced approximately 0.3 mm apart in the parietal areas. Dendroclone shafts are approximately 0.03 mm thick where they are locally observable. Canals are ill-defined, but approximately 0.3–0.4 mm in diameter, where best preserved, and are most evident in the part of the section that cuts somewhat tangentially through the wall.

Materials.—Figured specimens included USNM 480572A, B, and USNM 480583B and 480579B, thin sections ST-J and ST-4, the latter of which contains two diagonal to subtransverse sections that are also considered

characteristic of the species. USNM 480598, thin section 9F-3, is also considered of the species, although it is poorly preserved and questionable. Also included are USNM 480573–480575 and four additional unnumbered specimens. All are from the middle Ptarmigan Chert Member from the Manitou Formation at the locality along Ramparts Range Road northwest of Garden of the Gods park.

Discussion.—The subcylindrical, moderately annulate sponge has thin walls and annulations that are spaced approximately 1 cm apart. The relatively gently upward divergent and open uniform skeletal structure of relatively fine trabs is also considered characteristic. This is probably a new species that documents early development in *Archaeoscyphia,* for it occurs in rocks of Trilobite Zone F of Ross (1951) and Hintze (1951, 1951). The sponge is not named here, however, because skeletal details are inadequately preserved in the dolomitic replacement.

The species is much smaller than *Archaeoscyphia minganensis* (Billings, 1859), *A. pulchra* (Bassler, 1927), or *A. mazourkensis* (Greife and Langenheim, 1963), It has much coarser annulations than *A. eganensis* Johns, 1994, or *A. rossi* Johns, 1994, and is a much larger sponge than either *A. nana* Beresi and Rigby, 1993, or *A. bassleri* Johns, 1994, among the Ordovician species of the genus described to date.. It appears to be most similar to the medium-sized *Archaeoscyphia pannosa* Johns, 1994, although somewhat taller, but annulations and canals are of the same proportions in the two species.

Genus CALYCOCOELIA Bassler, 1927

Type species.—*Calycocoelia typicalis* Bassler, 1927.

Diagnosis.—"Obconical, tubular or pedunculate with moderately thick wall and rounded or slightly irregular spongocoel extending nearly to base. Surface usually smooth, very rarely marked by poorly-developed, irregular annulations. Radial canals vertically stacked, upward arching. Vertical canals sinuous, concentrated in parietal spiculature near outer surface. Scalariform skeletal net, with one to three trabs between radial canals. Trabs separated by 0.1–0.5 mm and cored with oxeas with diameters of 0.07 mm. Amphiarborescent dendroclones dominate, very few polyclonid spicules; dendroclones attach at adjacent trabs horizontally. Dermal layer sporadically developed, but much finer than endosome" (Johns, 1994, p. 50).

Discussion.—Bassler (1927) included only the type species, *Calycocoelia typicalis,* in the new genus that he proposed, based on specimens from the Ikes Canyon area in the Toquina Range, Nevada. Johns (1994, p. 58–59) named the new species, *Calycocoelia murella,* for small, thin-walled, stem-like sponges from the Upper Ibexian Shingle Limestone in the southern Eagan Range in eastern Nevada. Rigby, et al., (1999) named the new species *Calycocoelia protera* from El Paso Group rocks in the southern Franklin Mountains near El Paso, Texas. The latter species is considerably finer textured than either *Calycocoelia typicalis* or *Calycocoelia murella* and extends the range of the genus farther down in the Lower Ordovician.

CALYCOCOELIA PROTERA
Rigby, Linford and LeMone, 1999
Plate 1, Figures 4; Plate 2, Figure 5;
Plate 3, Figures 2, 6

Calycocoelia protera RIGBY, LINFORD AND LEMONE, 1999, p. 113–115, pl. 1, figs. 6, 8; pl. 3, fig. 2; pl. 4, fig. 4; pl. 5, fig. 7.

Diagnosis.—"Steeply obconical to cylindrical, thin-walled, stem-like sponges with broad round spongocoel extending nearly to base and comprising 50–60% of the sponge diameter that ranges from 8 to 20 mm in diameter. Surface smooth without annulations. Radial canals 0.25–0.50 mm in diameter, vertically stacked, separated by parieties 0.2–0.7 mm thick. Surface of pinnation near gastral margin to near mid-wall, trabs diverge gently upward and arch outward to meet both the dermal and gastral surfaces at 30° or less. I-shaped dendroclones dominate, but Y-shaped spicules also occur." (Rigby, et al., 1999, p. 113).

Description.—Characteristic sponges occur in several thin sections and on polished surfaces in the collection. USNM 480593, thin section ST-M, best shows details of the skeletal structure. It is a sublongitudinal to tangential oblique section of a sponge at least 40 mm tall and with a diameter in the lower part of 7 mm, where it has a spongocoel with a diameter of 2.5–2.7 mm, with walls 2.0–2.5 mm thick. It is a smoothly subcylindrical to highly obconical form that lacks annulations and has a smooth gastral surface.

The skeletal structure diverges upward from a surface of pinnation at the gastral margin. Trabs gently curve outward to meet the dermal surface at approximately 20°. The skeleton lacks differentiated dermal and gastral layers. Trabs are relatively thin, 0.08 mm in diameter in the lower part and up to 0.10 mm in diameter in the upper part of the sponge. They are spaced 0.20–0.25 mm apart, horizontally, in the inner and midwall, but are up to 0.30 mm apart in the outer part of the wall. Dendroclones are mainly I-shaped, as best can be judged from the recrystallized skeleton. They are spaced 5–6 per 1 mm in a vertical ladder-like series.

Radial canals are 0.15–0.20 mm in diameter and are separated in a single vertical series by one or two dendroclones that are approximately 0.1 mm apart. Larger canals occur in the tangential upper part of the slice, and range 0.25–0.30 mm in diameter. They occur two per mm, measured both vertically and horizontally. Generally speaking,

only one trab separates vertical series in the wall interior, but parieties two trabs wide may separate canal series in the outer part of the skeleton.

Oblique subtransverse sections of the species occur on USNM 480584 and 480592, thin sections ST-A and ST-L. These range from approximately 10 to 18 mm in diameter around recrystallized fillings of spongocoels, which are 6 to 11 mm in diameter.

A sublongitudinal section of an only locally well preserved, dolomitized, example of the species occurs on USNM 480591, on thin section ST-G. Walls around an ill-defined spongocoel are 2.5–3.0 mm thick. The surface of pinnation is near the gastral side and trabs gently curve upward and outward to meet the dermal surface at approximately 30° and rarely to 45°. Trabs are 0.04 mm in diameter and rarely range up to 0.08 mm where questionably diagenetically thickened in the outer part of the sponge plate. Trabs are 0.3–0.4 mm apart in the outer part of the plate and approximately 0.2 mm apart in the middle part of the diverging structure. Individual dendroclones are dominantly I-shaped, with shaft diameters of 0.03 mm and lengths up to 0.4 mm. They are commonly 0.2 mm apart in the ladder-like series, so that three occur in 0.6 mm measured along a single series.

Material.—Figured specimens occur on USNM 480591 and 480593, thin sections ST-G and ST-M. Sections of the species also occur on USNM 480584 and 480592, on thin sections ST-A and ST-L, and less certainly as three irregularly preserved specimens on USNM 480601, on thin section ST-H. The species also occurs as weathered specimens on USNM 480573 and 480574.

Discussion.—*Calycocoelia protera* Rigby, et al., 1999, are moderately abundant sponges in the Manitou collections. They are smoothly cylindrical, nonannulate, and have a deep axial spongocoel and uniformly arranged skeleton. In vertical or longitudinal sections the surface of upward divergence of the trabs, the surface of pinnation, is near the gastral margin at the edge of the spongocoel. Transverse sections of species of *Calycocoelia* are coral-like in their regularity, with rows of vertically stacked horizontal canals between rows of "ladders" of trabs and interconnected smaller and closely spaced dendroclone series.

Calycocoelia protera is distinctly finer-textured and a much smaller species than the type species, *Calycocoelia typicalis* Bassler, 1927, described from central Nevada. It also has a finer-textured skeleton and canal system than those characteristic of *Calycocoelia murella* Johns, 1994, described from eastern Nevada.

De Freitas (1989) placed *Calycocoelia* Bassler, 1927, into synonymy with *Archaeoscyphia,* along with *Somersetella* Rigby and Dixon, 1979; *Rhopalocoelia* Raymond and Okulitch, 1940; and *Steliella* Hinde, 1889. We prefer to keep *Archaeoscyphia* with its prominent annulate form distinct from the smooth cylindrical to goblet-like, coarsely spiculed *Calycocoelia.* We have not worked with *Steliella. Somersetella* was proposed before the widespread occurrence of coring monaxon spicules in the trabs was documented in many related sponges. Whether this smooth digitate sponge should be placed with other smooth solitary unbranched forms is also debatable.

Genus PATELLISPONGIA
Bassler, 1927

Type species.—*Patellispongia oculata* Bassler, 1927.

Diagnosis.—"Palmate or discoidal, often becoming bowl- or funnel-shaped; with somewhat broadened attachment surface, rarely developed into a short stem. Surface usually smooth, occasionally undulose. Radial canals vertically stacked and sinuous, but penetrate the cortex at approximately right angles. Additional canal set often present, but with varying degrees of development; skeletal pores usually large. Surface of trab pinnation between dermal surface and midwall.

Scalariform skeletal net, with 1 to 3 trabs between radial canals, trabs usually cored by monaxons. Amphiarborescent dendroclones dominate, but polyclonid spicules common, particularly in dermal and gastral layers. Dermal and gastral layers well-developed, up to 2 mm thick, spiculature somewhat finer than that of endosome. Incurrent openings in dermal layer generally small and mimic underlying pattern of radial canals, but excurrent openings larger and more irregularly spaced over surface." (Johns 1994, p. 75).

PATELLISPONGIA OCULATA
Bassler, 1927
Plate 1, Figure 7; Plate 2, Figures 7, 8;
Plate 3, Figures 2, 4, 6

Patellispongia oculata BASSLER, 1927, p. 393; BASSLER, 1941, p. 97, pl. 22, figs. 1, 2; pl. 24, figs. 1, 2; LANGENHEIM, ET AL., 1956, p. 2089; JOHNS, 1994, p. 77–82, pl. 8, figs. 1–5; pl. 9, figs. 1–5; pl. 10, fig. 1; RIGBY, LINFORD AND LEMONE, 1999, p. 115–117, pl. 3, figs. 1–3, 6, 7; pl. 4, figs. 1–3, 7; pl. 5, fig. 3.

Patellispongia clintoni BASSLER, 1927, p. 393; BASSLER, 1941, p. 97–98, pl. 20, figs. 5–7.

Patellispongia magnipora BASSLER, 1927, p. 393; BASSLER, 1941, p. 98, pl. 21, fig. 6.

Patellispongia minutipora BASSLER, 1927, p. 393; BASSLER, 1941, p. 98, pl. 21, figs. 1,2.

Patellispongia cf. *oculata* GREIFE and LANGENHEIM, 1963, p. 569, pl. 63, fig. 7; pl. 65, figs. 1, 2.

Patellispongia sp. RIGBY, 1971, p. 49–50.

Description.—Several fragments of broad, flat, disc-shaped patellispongiids occur in the collection. These are commonly only plate-like fragments of the outer part of the sponge. Characteristic specimens are fragments of

plates a few centimeters across and 4–5 mm thick. Most of the sections are cut at angles to the principally radiating trabs so that some sections were cut essentially transverse to the trabs and others as sublongitudinal to fragments in these vertical sections. Most fragments show a pinnation surface at essentially mid-wall, from which trabs diverge both towards the gastral and dermal surfaces at up to 60–70°, although in some, as in USNM 480597, thin section 9F-2, trabs converge towards what is interpreted to be the dermal surface at 30–45°. Sections cut at high angles to the radiating structure of the trabs have ill-defined surfaces of pinnation. Trabs are approximately 0.20 mm in diameter, particularly in the outer part of the sponge plates. They are as small as 0.14 mm in diameter, however, in interior parts near the plane of pinnation.

Trabs are spaced 0.3–0.4 mm apart in outer parts of the plates, but may be only 0.2 mm apart near the surface of pinnation. Trabs are relatively rough, rod-like structures composed of tips of dendroclones, but those tips and the microstructure within the trabs are generally obscured in the crystalline replacement.

Dendroclones are characteristically I-shaped forms, with shafts that range up to 0.2–0.3 mm long through much of the skeleton, but up to 0.4 mm where they occur between parieties in those areas of canal development. Although details of trab microstructure are obscured in most sections where the trabs are cut transversely, many show a microcrystalline "core" approximately 0.10 mm in diameter, surrounded by an outer, more coarsely crystalline layer, 0.015–0.020 mm thick, presumably composed of tips of the united clads. Some Y-shaped dendroclones occur, particularly in areas between canals where rays of the spicules are 0.08–0.10 mm long and 0.03–0.04 mm in diameter. In most areas, however, these structures are vague and poorly preserved. Dendroclones commonly occur with three or four spicules per 0.5 mm in the series.

Canals are commonly ill-defined as a result of how sections cut through the plates. In some areas, however, small canals approximately 0.5 mm in diameter appear as somewhat darker matrix fills that interrupt the radial skeletal structure. In one relatively well preserved specimen, on thin section 9F-2, canals show in section and are oriented essentially normal to the gastral surface, where they range 0.8–1.0 mm in diameter. These are the coarsest canals seen in any of the fragments included in the species.

One section on USNM 480583, thin section ST-K, shows trabs with questionable lineated impressions of what may be coring oxeas approximately 0.04 mm in diameter, but elsewhere on other sections, there is no evidence of similar oxeas.

Material.—Figured specimens include USNM 480583C, on thin section ST-K; on USNM 480582A and 480582C, thin-section ST-I; and USNM 480579, on thin section ST4(26). Two side-by-side fragments of the species occur on USNM 480583, on thin section ST-J, and several as undulate plates on USNM 480583A. Figured specimen USNM 480597 occurs on thin section 9F-2. Thirteen additional samples collected in 1996 also include at least fragments of the species. In addition, less certainly identified fragments occur on USNM 480586 and 480595, thin sections ST-C and 9B. All of these are from the middle part of the Ptarmigan Chert Member of the Manitou Formation at the Rampart Range Road locality.

Discussion.—The plate-like form of sponges represented by the fragments suggest that these forms should be included in the genus *Patellispongia* Bassler, 1927. Johns (1994) placed the several species of *Patellispongia* described by Bassler into synonymy with the type species *Patellispongia oculata* Bassler, 1927. The spacing of canals and other definitive structures are not available to us because of limited samples. For this reason we have placed our specimens in the type species, but with some question.

Genus ZITTELELLA
Ulrich and Everett, 1890

Type species.—*Zittelella typicalis* Ulrich and Everett, 1890.

Original description.—"Sponges simple, pedunculate and attached, varying in shape from depressed obconical, turbinate or subspherical to subcylindrical, rarely lobate. Upper surface with a shallow central depression into which a variable number of thin-walled vertical tubes, extending through to the base of the sponge, open. Canal system consisting principally of a series of radiating canals, which may inosculate freely with each other, or only to a limited degree near passage through the walls of the sponge from the outer surface to the vertical central tubes. The radiating canals are closely arranged in vertical series, separated by spicular tissue from one to three times as wide as the canals. This arrangement of the canals gives the sponge the appearance of being divided by vertical fissures. Interior skeleton as in *Anthaspidella*, excepting that the capillary canals run parallel with the sides of the sponge wall, and open only at the under surface." (Ulrich and Everett, 1890, p. 267–268).

ZITTELELLA(?) VARIANS
(Billings, 1861)
Plate 3, Figure 1

Eospongia varians BILLINGS, 186la, p. 19; BILLINGS, 1861b, p. 956; BILLINGS, 1862, p. 228; BILLINGS, 1865, p. 1.

Zittelella varians (Billings) SCHUCHERT AND TWENHOFEL, 1910, p. 690; HOWELL, 1938, p. 31–33, pl. 1 (unnumbered), figs. 1–4; RAYMOND AND OKULITCH, 1940, p. 200–202, pl. 7, figs. 1–4; RIGBY AND

DESROCHERS, 1995, p. 26–28, figs. 8.7–8.12, 13.1–13.6.

non Zittelella varians TWENHOFEL, 1938, p. 36, pl. 5, fig. 2, pl. 6, figs. 3, 10.

Diagnosis.—"Sponges intermediate to small for genus, top-shaped to stalked obconical or conical-cylindrical, with central moderately deep spongocoel or oscular depression, into which extends cluster of vertical canals as subprismatic to circular openings, each approximately 1.0 mm in diameter. Convergent horizontal canals approximately 1.0 mm in diameter and in vertically stacked regular rows. Skeletal net with zittelellid structure, surface of pinnation approximately 2–3 mm from dermal surface. Trabs rise essentially normal to upper surface as parallel, subvertical, ladder-like structures, 0.2–0.3 mm apart and approximately 0.10 mm in diameter, composed of tips of dominantly I-shaped dendroclones in ladder-like series. Trabs remain essentially parallel away from zone of pinnation, in some specimens skeleton is dominated by X- and H-shaped dendroclones to produce moderately complex-appearing skeletal net, both in transverse and longitudinal sections." (Rigby and Desrochers, 1995, p. 26–27).

Description.—A subvertical to tangential section questionably referred to the species occurs on USNM 480582, thin section ST-I. It is of an obconical sponge that was at least 25 mm high. It expands upward from a steeply obconical base into a broader funnel-like, thin-walled, upper part, which is at least 17 mm wide. Upper walls are to 3.0–3.5 mm thick, with rounded upper margins. They gently diverge to produce a shallow spongocoel 13 mm wide, at the top, in a sponge 17 mm wide. The lower, relatively massive-appearing, stem-like part has a preserved or sectioned upper width of approximately 7 mm.

Prominent vertical exhalant canals occur in a central cluster in the lower part. They have circular cross sections, are uniformly approximately 0.6 mm in diameter, and are closely spaced. They are separated by only one or two trabs, which make up canal walls 0.1–0.2 mm thick. Canals are spaced such that three occur per 2 mm horizontally.

Upper walls are perforated by radial canals that are 0.30–0.35 mm in diameter. Such canals arch upward through the walls and have trends essentially normal to the divergent trabs.

A surface of trab pinnation occurs near midwall, from which trabs diverge gently upward to meet the gastral surface at approximately 30°, and the dermal surface somewhat more steeply, particularly in the upper right wall. That part of the wall is up to 3.5 mm thick.

Trabs are approximately 0.14 mm in diameter in the upper walls and are 0.08–0.10 mm in diameter in the lower interior part of the skeleton. Details of individual dendroclones were largely destroyed by crystalline dolomitic replacement.

Material.—The single oblique to tangential section on USNM 480582, thin section ST-I, is the only representative of the species in our collections.

Discussion.—The general form, canal pattern, and skeletal structure are striking similar to type specimens of *Zittelella varians*, redescribed and refigured by Rigby and Desrochers (1995, p. 26–28, figs. 13.1–13.6). Unfortunately, the section of the Manitou specimen, the only one known in the collections, is cut at an angle through the sponge. It is only tangential to the lower stemlike part of the sponge and does not cut through the central part of the axial cluster of exhalant canals. Consequently, dimensions of the more central canals, which may be the largest in the sponge, are unknown. Such canals in the type material of the species are approximately 1.0 mm in diameter, which is somewhat coarser than those in the Manitou sponge that are only 0.6 mm in diameter.

Trabs in the lower stemlike part of the sponge are parallel to the outer surface, as are those in *Zittelella varians* shown by Rigby and Desrochers (1995, fig. 13.3). Trabs diverge from a midwall surface of pinnation in the upper thin-walled parts of the sponge, as in Mingan Island specimens of the species.

The growth form, canal pattern, and skeletal structure are sufficiently like those in the type specimens of the species that the Manitou sponge is placed there with some confidence. However, dimensions of canals of the axial cluster and of the radial canals in the upper part of the sponge are smaller than similar canals in the type specimens. Because of these differences, and because only the irregularly oriented section of the sponge represents the species in the collection, we have referred the Manitou sponge to the species with question.

Genus OZARKOCOELIA
Cullison, 1944

Type species.—*Ozarkocoelia irregularis* Cullison, 1944.

Discussion.—Comparisons of several small genera of anthaspidellid sponges were discussed by Rigby, et al., (1999) in their study of sponges from the Ibexian rocks of the southern Franklin Mountains, Texas. Similar small sponges occur in the Manitou collection. These appear to have the same general skeletal structure that was observed in sponges referred to *Ozarkocoelia* in the El Paso assemblage. We have questionably included a few rare sponges in our collections in that genus.

OZARKOCOELIA(?) sp.
Plate 2, Figure 6

Description.—A sublongitudinal to tangential section of the form included here occurs on USNM 480596, thin

section 9F-1. It is a smooth cylindrical sponge at least 38 mm tall and 8.5 mm in diameter, with walls approximately 2 mm thick around an axial spongocoel 4.0–4.3 mm wide or in diameter.

The skeletal structure is anthaspidellid, with a surface of pinnation at or near the gastral surface, from which trabs diverge upward and outward to meet the dermal surface at 30–45° in the upper part, but at 60–70° in the lower part. Trabs remain approximately 0.04–0.06 mm in diameter in the interior and upper part of the sponge, but thicken abruptly to approximately 0.10 mm in diameter in the outer 0.5 mm in the lower part, to form a distinct, more dense, dermal layer. Trabs are 0.3–0.4 mm apart, horizontally, in midwall, but are only 0.25 mm apart in the outer part of the wall. I-shaped dendroclones are 0.20–0.25 mm apart, vertically, in single ladder-like series in the interior, but are only 0.10 mm apart in the dense dermal layer.

An oblique subtransverse section of the species occurs on USNM 480585, thin section ST-B. It is of a sponge 13 mm in diameter, with an axial spongocoel 6 mm in diameter. Walls are approximately 4 mm thick and have radial canals up to 0.40 mm in diameter, although most are ill defined and smaller. The distinctive dense dermal layer is approximately 0.5 mm thick and composed of relatively closely spaced trabs, up to 0.10 mm in diameter. They are connected by I-shaped, and rarely Y-shaped, dendroclones that have shafts up to 0.2 mm long and 0.018–0.020 mm in diameter. These spicules are spaced approximately 0.10 mm apart in rung-like structure between parallel adjacent trabs.

Material.—Figured specimen, USNM 480596, on thin section 9F-1, and USNM 480585, on thin section ST-B, are the only known representatives of the species from the locality.

Discussion.—Sections of the sponge are similar in general appearance to those of *Calycocoelia protera* Rigby, et al., 1999, but are differentiated by the distinct development of the thickened trabs, their abrupt flexure to meet the dermal surface at steep angles, and closely spaced dendroclones in the dermal layer in *Ozarkocoelia* sp. The smooth, cylindrical form separates it from species of *Archaeoscyphia* or *Patellispongia* that also occur in the assemblage.

Class CALCAREA Bowerbank, 1884
Order HETERACTINIDA
De Laubenfels, 1955
Family ASTRAEOSPONGIIDEA
Miller, 1889
Genus ASTRAEOCONUS
Rietschel, 1968

Type species.—*Astraeoconus calcarius* Rietschel, 1968.

(?)ASTRAEOCONUS CALCARIUS
Rietschel, 1968
Plate 2, Figure 9; Plate 3, Figure 2

Astraeoconus calcarius RIETSCHEL, 1968, p. 18–19, pl. 1, fig. 1.

Description.—A single small sexiradiate occurs on thin section ST-K. It consists of a central disc approximately 0.20 mm in diameter, from which radiate 6 horizontal rays that are equally spaced and separated by approximately 60°. The longest ray fragments are 0.40 mm long. They taper from basal diameters of 0.08 mm to 0.04 mm at their outer preserved edges. Presumably, they tapered to sharp tips when complete.

Material.—A single small sexiradiate occurs on USNM 480583C, thin section ST-K, from the middle of the Ptarmigan Chert Member of the Manitou Formation from exposures northwest of Garden of the Gods and Manitou Springs.

Discussion.—Isolated small sexiradiates and a small cluster of spicules of the same general form as present here in the Manitou Formation were recovered from the McKelligon Canyon Formation, in rocks of essentially the same age, from the El Paso, Texas region. Those spicules were questionably placed in *Astraeoconus calcarius* Rietschel, 1968, by Rigby, et al., (1999). They discussed the possibly related heteractinid genera known from the Ordovician, based on stratigraphic occurrence of the various genera and the general form of the spicules. They placed those similar spicules within the monospecific *Astraeoconus*, as we have also tentatively placed the small spicule here. Such a generic and specific assignment is very questionable, but the small spicule does represent the occurrence of astraeospongiid heteractinids in the Manitou Formation, in the Manitou Springs area.

DISCUSSION

Some of the sponges show limited borings, although much bioturbation and burrowing is common in matrix around the sponges, and in spongocoel fillings. The originally siliceous opalline skeletons must have persisted long enough for some lithification to have taken place before the skeletal materials were generally replaced by calcite, often microspar, or by chert. Such preservation is common in Early Paleozoic sponges, not only in these sponges, but in other moderate to shallow water assemblages, too. Only rarely are these sponges preserved as pyrite to limonite replacements.

Similar sponge communities are known from Lower Ordovician occurrences in the USA (Johns, 1994) and Canada (Rigby and Desrochers, 1995), in Argentina (Beresi and Rigby, 1993), and in southern China (Zhu, et al., 1993; 1995; Liu, et al., 1997; Rigby, et al., 1995), among others.

These occurrences are also commonly associated with microbial or algal-stromatolite mounds of at most a few meters across and high. Where the mounds are of moderate size, the sponges played frame-builder roles. However, where the mounds are small, low, or digitate, these anthaspidellid sponges play minor roles, if present at all, and are commonly accessory or flank dwellers. In both circumstances they are often transported into intermound depressions or into channels, as they are in these Colorado occurrences. The rigid fused skeletons of the lithistid sponges must have been strong enough to have remained essentially intact during limited transport and to be three-dimensionally preserved, even where calcareous mudstone compacted around them. The Manitou sponges, although not well preserved from a detailed microstructure viewpoint, are important, for they document the occurrence of that association in the Ordovician of Colorado.

Rousseau Flower (1952) concluded that *Dictyorhabdus priscus* Walcott, 1892, originally described as a chimaeroid fish, then transfered to the cephalopods, was really an hexactinellid sponge. It was reported as a sponge by De Laubenfels (1955, p. E-73). That fossil from the Harding Sandstone near Canyon city is not a sponge, however, and must remain a Problematica.

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PLATE 1

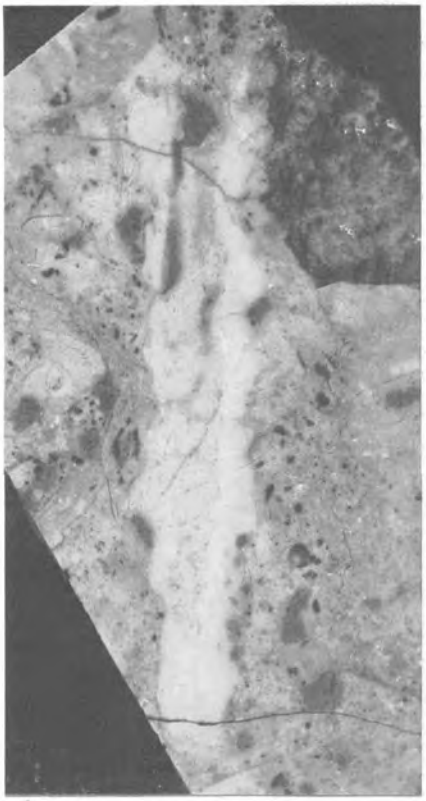
Sponges of the Ptarmigan Member of the Manitou Formation from the locality along the Rampart Range Road, Colorado Front Range, near Manitou Springs.

Figures *1, 6, Archaeoscyphia* sp. B, *1,* sublongitudinal section showing the general subcylindrical form of the species, its simple tubular spongocoel, and regular low-amplitude annulations in the calcareous replacement; dark areas on this and associated specimens are dolomitized "worm" burrows, USNM 480572A, x 1; *6,* weathered surface showing gently annulate specimen of *A.* sp. B (A) in the lower part, with associated non-annulate, thin-walled, steeply obconical *Calycocoelia protera* Rigby, Linford, and LeMone, 1999 (C), in the upper part, beside a stromatolite mound (M), in the upper left, USNM 480573, x 1.

Figures *2, 3, 5—Archaeoscyphia pulchra* Bassler, 1927; 2, vertical section with a large open axial spongocoel and regular, pronounced, annulations of the thin walls in a calcareous replacement, USNM 480576A x 1; *3,* oblique, sublongitudinal, section of thin-walled sponge with large axial spongocoel nearly filled with dolomite replacement of burrows; regular shelf-like annulations show best along the right side where marked by intervening dolomite-filled burrows, USNM 480577, x 1; *5, small, near-basal* sponge with narrow, dark, matrix-filled spongocoel and flared thickened walls forming an annulation in the upper part, USNM 480578, x 1.

Figure *4, Calycocoelia protera* Rigby, Linford and LeMone, 1999, a weathered surface showing a transported example of the small, smooth, obconical to tubular species, *C. protera* (C), associated with a weakly annulate *Archaeoscyphia sp.* B (A), in the transported debris of the intermound facies, USNM 480574, x 1

Figure *7, Patellispongia oculata* Bassler, 1927, several plate-like fragments (P) occur in channel filled with worm-burrowed debris between small stromatolite mounds (M), on the left and right; the plates are standing on end in the fill, and show differing degrees of light calcite replacement, USNM 480580A, x 1.



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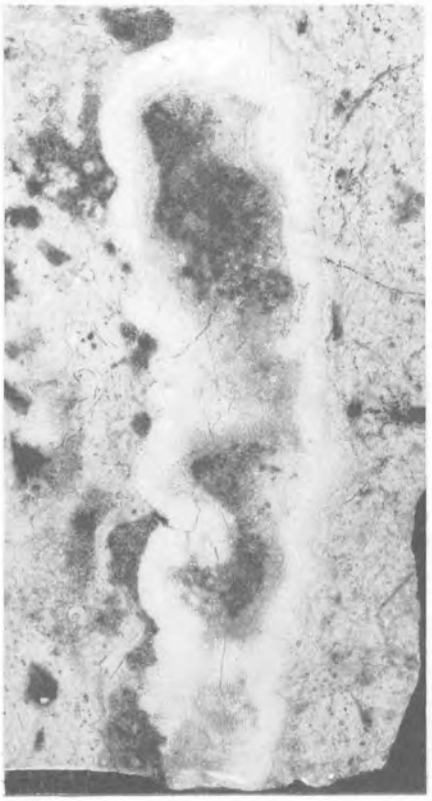

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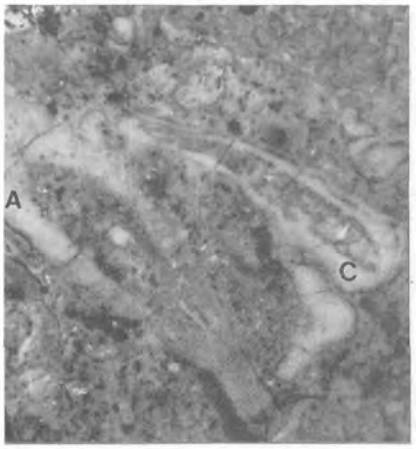

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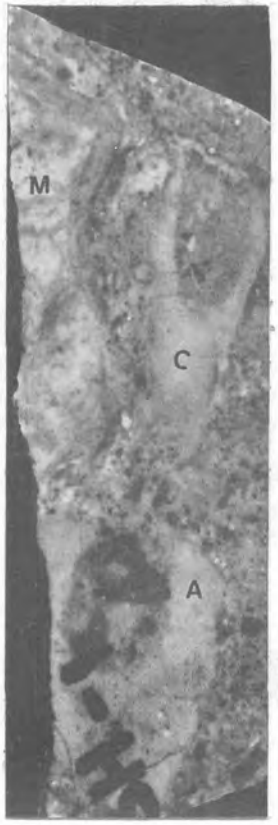

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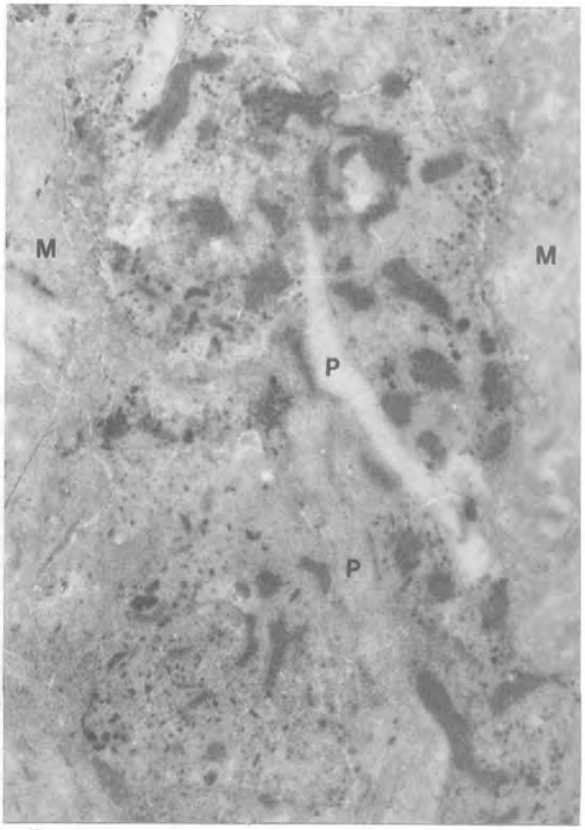

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PLATE 2

Photomicrographs of sponges from the Ptarmigan Chert Member of the Manitou Formation, Rampart Range Road, near Manitou Springs.

Figures *1, 2, Archaeoscyphia pulchra* Bassler, 1927, *1*, vertical section of parts of two annulations showing upward and outward divergence of discontinuous-appearing trabs, cross-connected in the lower center by rung-like short dendroclones; a circular cross section of a dolomitized worm burrow (B) occurs in the recess between the annulations, on the left, USNM 480590, thin section ST-F, x 10; 2, near-vertical section of the wall showing upward divergent calcareous trabs in the dark dolomitic matrix; rung-like dendroclones are crudely preserved in the lower left and left center, USNM 480587, thin section ST-D, x 10.

Figures *3, 4, Archaeoscyphia* sp. B, 3, tangential section of the near-dermal part of a ring-like annulation, showing delicate, well-preserved dendroclones in the center, transverse sections of trabs are the larger light dots formed by crystalline calcite in the dark calcareous matrix, USNM 480583B, thin section ST-J, x 10; *4*, transverse section through the wall showing darker-appearing inhalant radial canals separated by lighter, spicule-defined parieties; near-vertical trabs show as larger light dots connected by the thin dendroclones, USNM 480579, thin section ST-4, x 10.

Figure 5, *Calycocoelia protera* Rigby, Linford and LeMone, 1999, vertical section of the wall showing upward divergent, light gray, delicate rod-like trabs near the dermal surface (D), and less well-defined trabs near the gastral surface (G), at the margin of the spongocoel; thin dendroclones bridge between two curved trabs in the upper right. USNM 480591, thin section ST-G, x 10.

Figure 6, *Ozarkocoelia*(?) sp., vertical section through the thin wall showing upward and outward curving rod-like trabs that are thickened in the dermal part of the wall where rung-like dendroclones are best preserved, in the lower left center, dolomitized matrix fills the spongocoel on the right; a subvertical tangential section of the wall with segments of thin trabs shows in the upper right, USNM 480596, thin section 9F-1, x 10

Figures *7, 8, Patellispongia oculata* Bassler, 1927, *7*, oblique section through a horizontal plate showing an ill-defined surface of pinnation near the lower dermal margin, in the lower part of the figure, above which the trabs curve upward toward the left to meet the gastral surface at steep angles; trabs are relatively coarse elements and are cross-connected with less well-preserved delicate dendroclones throughout the figure, USNM 480583B, thin section ST-J, x 10, *8*, near-vertical section through a plate of the sponge showing a surface of pinnation in the dermal part of the wall, on the right, marked by upward divergence of the coarse, calcite replaced, trabs that meet the gastral surface at high angles, on the left; plate rotated 90° compared to 5.7, USNM 480597, thin section 9F-2, x 10.

Figure *9*, (?)*Astraeoconus calcarius* Rietschel, 1968, isolated sexiradiate spicule (arrow) probably of the genus, USNM 480583C, thin section ST-K, x 10.

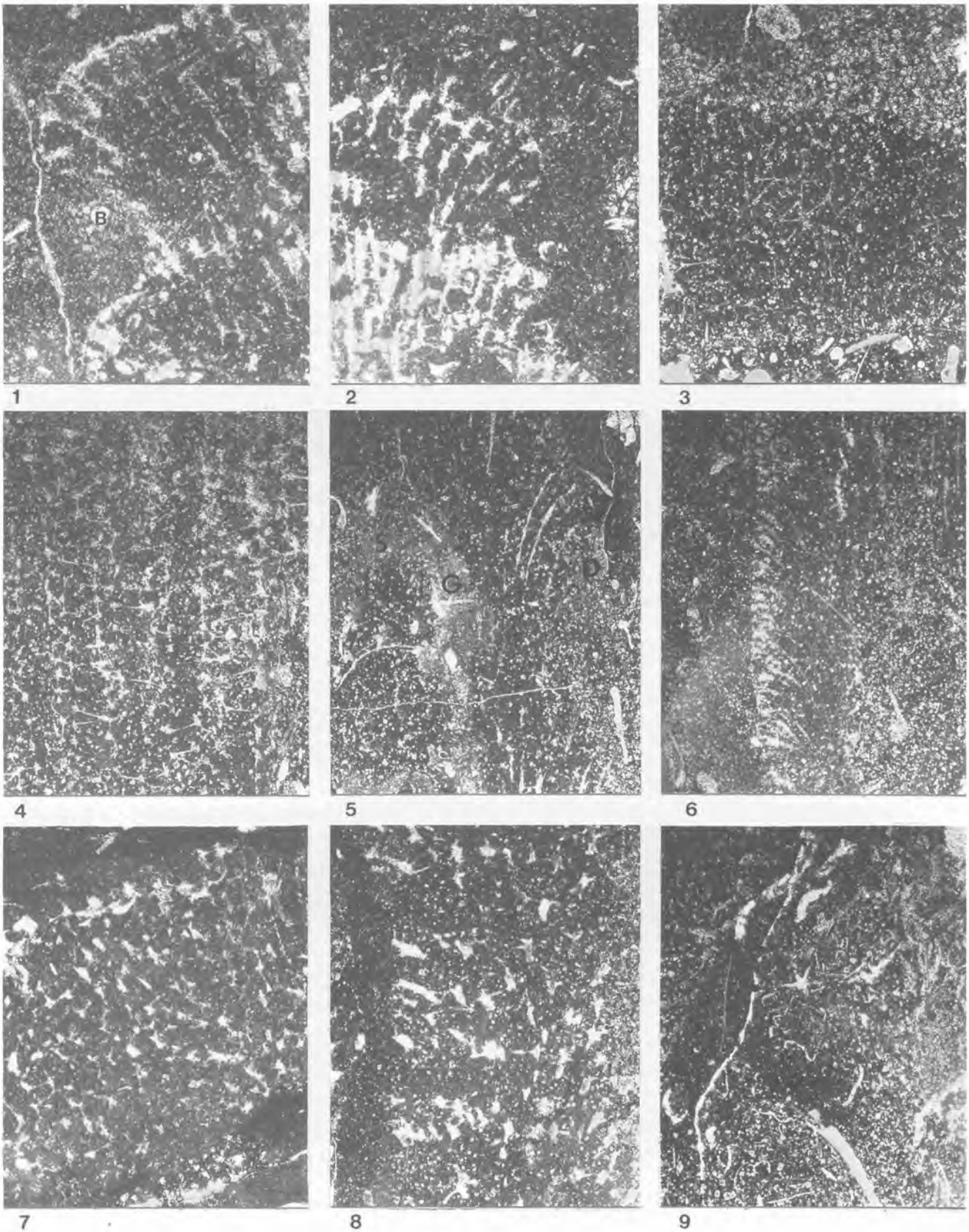
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PLATE 3

Sponges of the Ptarmigan Chert Member of the Manitou Formation on the Ramparts Range Road, near Manitou Springs.

Figure *1*, *Zittelella*(?) *varians* Billings, 1861, oblique thin section showing the obconical flaring sponge, with a lower stem and upper thin-walled funnel-like part, an axial cluster of vertical exhalant canals is cut in the lower part; smaller radial canals pierce the upper walls, best seen in the upper right; rod-like trabs are parallel to the dermal surface in the lower left, but develop a surface of pinnation at mid-wall in the upper part of the sponge, USNM 480582B, thin section ST-I, x 10.

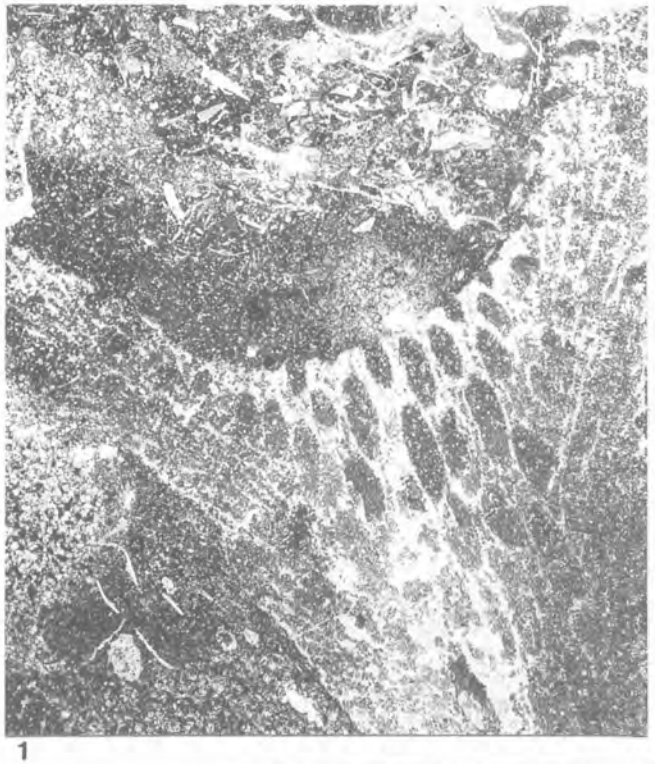
Figure 2, *Calycocoelia protera* Rigby, Linford, and LeMone, 1999 (C), in the lower right, *Patellispongia oculata* Bassler, 1927 (P), in the upper center; and (?)*Astraeoconus calcarius* Rietschel, 1968 (arrow), in the right center, showing relative dimensions of skeletal structures in the coarse *Patellispongia* and finer *Calycocoelia*, but only an isolated spicule of (?)*Astraeoconus calcarius* Rietschel, 1968, USNM 480583C, thin section ST-K, x 10.

Figure 3, *Archaeoscyphia pulchra* Bassler, 1927, transverse section of part of the thick wall of an annulation showing radial canals in the replaced skeleton, above dolomite-replaced burrows in the matrix between dense limestone of stromatolite mounds (M), USNM 480579A, x 1

Figure 4, *Patellispongia oculata* Bassler, 1927 (P), as a thin, light gray, horizontal plate in debris adjacent to a small stromatolite mound (M), on the right, USNM 480581, x 1.

Figure 5, *Archaeoscyphia pulchra* Bassler, 1927, showing prominent annulations in a weathered tangential section, in an outcrop along Shoot Trail; scale indicated in the upper part.

Figure 6, *Archaeoscyphia* sp. B (A), *Calycocoelia protera* Rigby, Linford, and LeMone, 1999 (C), and *Patellispongia oculata* Bassler, 1927 (P), in weathered outcrops along the trail above the Ramparts Range road, showing dense packing of the calcareously replaced sponge debris in some channel fills in the member, scale indicated in the upper center.



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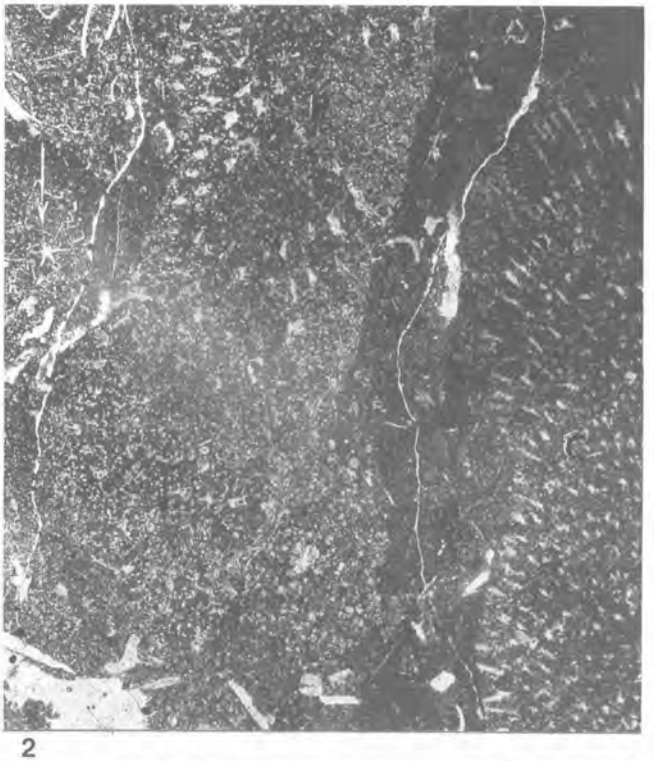

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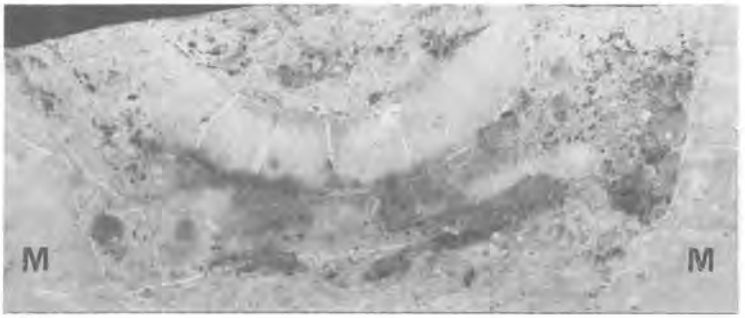

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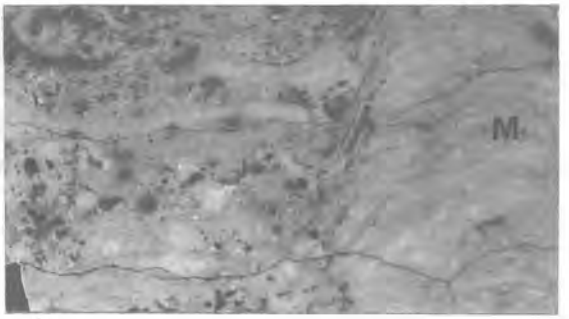

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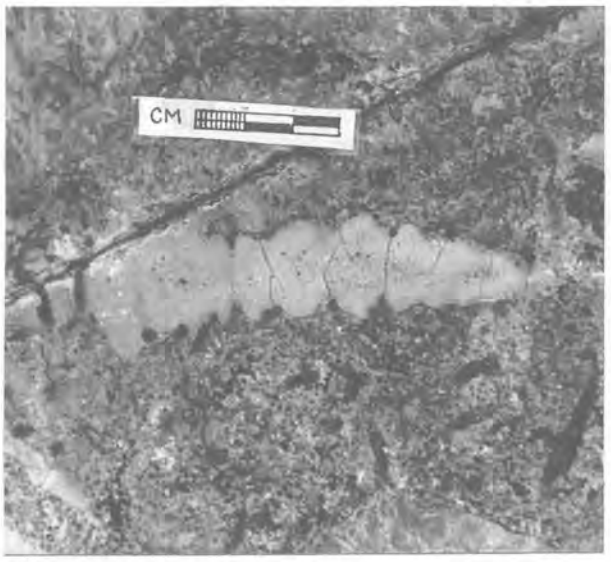

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