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CONTENTS

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Sponges from the Ibexian (Ordovician) McKelligon Canyon and Victorio Hills Formations in the Southern Franklin Mountains, Texas

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ABSTRACT

Fossil sponges are moderately common in small reef-like mounds and in interreef beds at several horizons throughout the McKelligon Canyon Formation and in the Victorio Hills Formation on the south end of the Franklin Mountains at El Paso, Texas. Although the sponges are locally abundant, they represent only limited diversity throughout the sequence, and nearly all are in the family Anthaspidellidae Miller, 1889. Most common of these are the distinctly annulate *Archaeoscyphia pulchra* (Bassler, 1927) and *A. minganensis* (Billings, 1859), the latter occurring in growth position in some mounds. *Patellispongia oculata* Bassler, 1927, is also common in some areas as plate-like fragments of the broadly obconical or discoidal sponge. Only a few specimens of *Calycocoelia protera* n. sp., a relatively open-textured, small, cylindrical to tubular branching sponge, are present. Only one well-preserved specimen of the broadly obconical *Anthaspidella clintoni* Bassler, 1927, and one of a weakly annulate cylindrical *Zittelella*(?) sp. occur in our collections. Relatively rare Streptosolenidae are represented by only a few specimens of the irregularly canalled *Ozarkocoelia irregularis* Cullison, 1944. These specimens document the earliest reported occurrences of *Archaeoscyphia, Calycocoelia,* and *Patellispongia.*

The calcareous heteractinid sponges are represented by a small cluster of sexiradiate spicules and an isolated small spicule. They are questionably *Astraeoconus calcarius* Rietschel, 1968.

Sponges throughout the section are most commonly associated with small reefoidal mounds and intermound beds that have been interpreted as the deepest, though still shallow, water facies in the recurring cyclic shallow sequences. The sponge fauna is evidently composed of those genera and species that were able to adapt to the shallow-water environments represented by the mound and intermound beds.

INTRODUCTION

Fossil sponges and sponge-like organisms are relatively common elements in some of the massive thrombolitic mounds and interbedded carbonates in Lower Ordovician (Ibexian) rocks exposed in the southern Franklin Mountains near El Paso, Texas (fig. 1). The systematics of the sponge fauna is the primary focus of this paper. Nearly all sponges recorded are anthaspidellid lithistid demosponges, although Toomey and Nitecki (1979) also figured isolated spicules of hexactinellid and heteractinid sponges.

Richardson (1904, 1908) included the El Paso Limestone in the Lower Ordovician rocks exposed along the eastern flank of the fault-block Franklin Mountains. Cloud and Barnes (1948) subdivided the El Paso section into a series of units designated A-C (fig. 2). Our sponges came largely from their units B_1 and B_{2a} in the Scenic Drive area, at the southern tip of the mountains, and in McKelligon Canyon, to the north, near the park caretaker's cabin (fig. 1). The informal units of Cloud and Barnes were formalized by Flower (1964) and his names correspond, roughly, with units designated B and C of Cloud

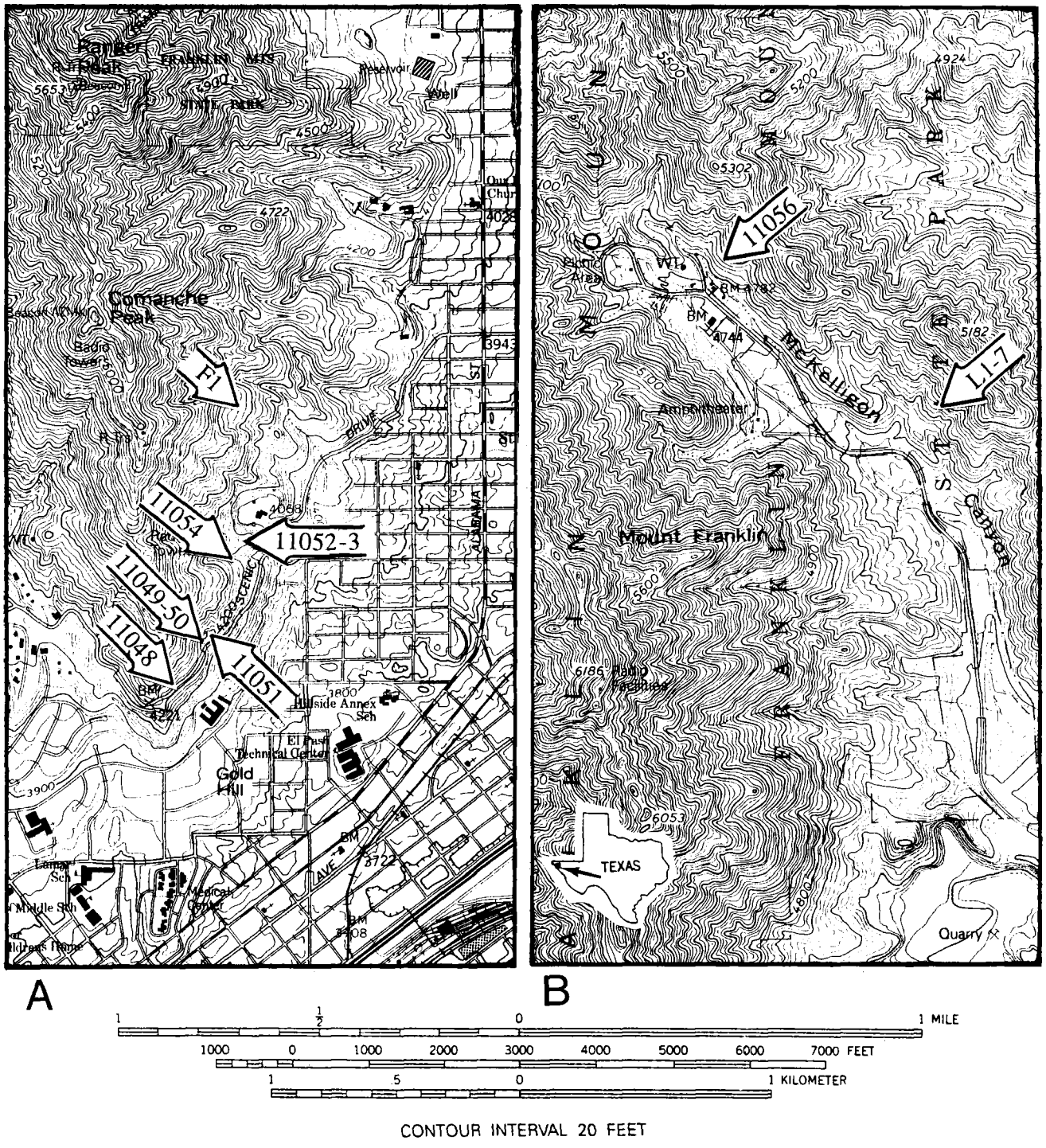

Figure 1. Index map to sponge localities, numbered arrows, in the Scenic Drive area (A) in central El Paso, and in McKelligon Canyon (B), north of El Paso, in the southern Franklin Mountains of Texas (base map, El Paso, Texas, 1:24,00 quadrangle map). For explanation of numbers see locality descriptions in the text.

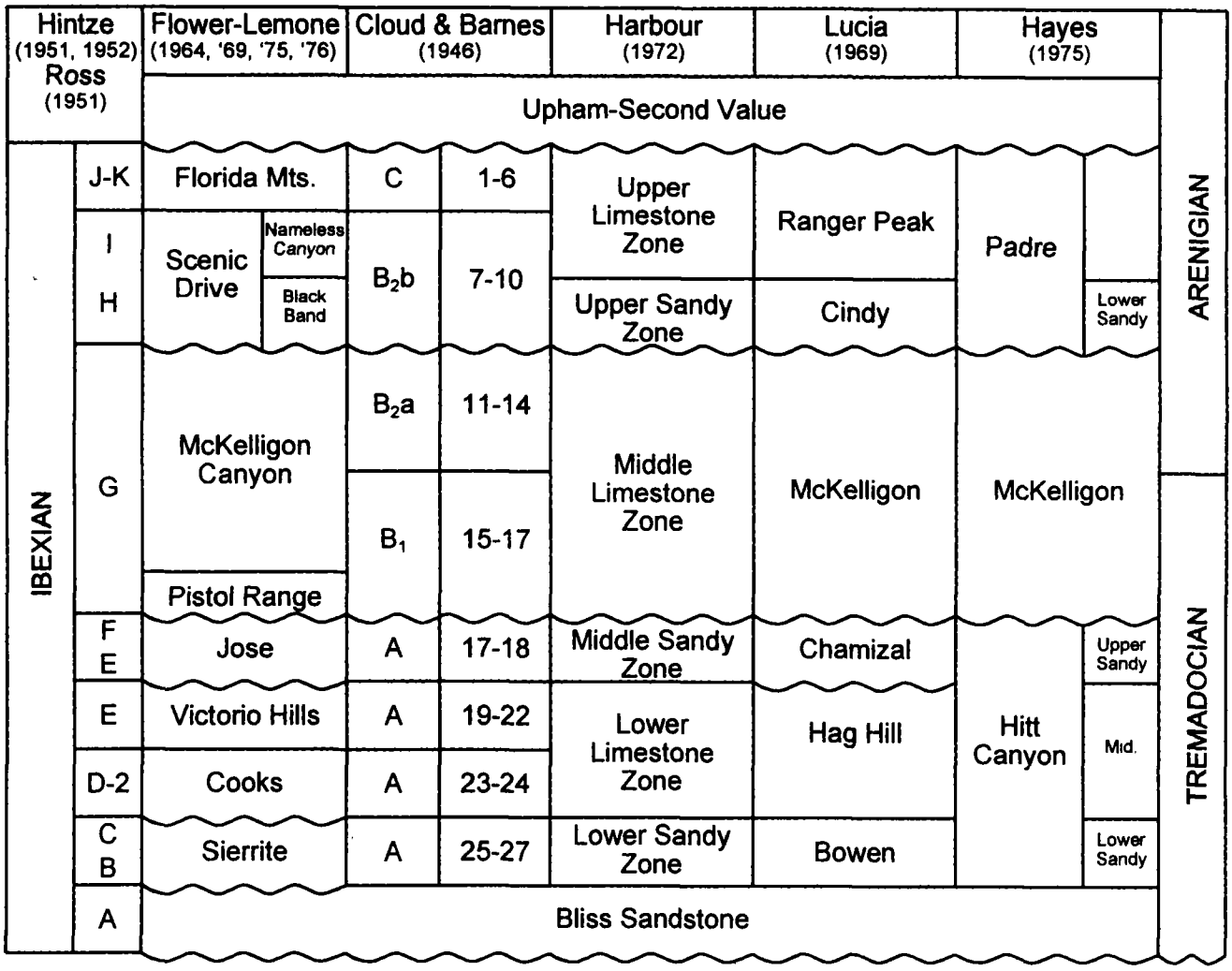

Figure 2. Stratigraphic nomenclatures of Ibexian, Lower Ordovician, rocks of the El Paso Group in the southern Franklin Mountains near El Paso, Texas (modified from Goldhammer et al., 1993).

and Barnes (1948), in the upper part of what is now termed the El Paso Group. Unit A was subdivided by Flower into four formations (fig. 2), however, these are below the sponge-bearing beds.

Flower (1964) recognized seven of his ten regional El Paso Group formations in the southern Franklin Mountains. Lucia (1969a, b) published in-house Shell Oil Company nomenclature for the El Paso beds, and the boundaries of the lower units he proposed are slightly different from those of Flower (1964). Later nomenclatures more or less parallel the formations of Flower, and seem to offer no major advantage, either paleontologically or sedimentologically, to those originally proposed by Flower (1964) and LeMone (1975, 1976). Harbour (1972) utilized a relatively informal nomenclature for the subdivisions that Lucia (1969a, b) proposed. Comparisons of these nomenclatures and that of Hayes (1975) are shown in figure 2.

Toomey (1970, 1981) described the sponge-bearing mounds of the middle McKelligon Canyon Formation and illustrated the common forms that occur within the mounds. The large Lechuguilla Mound was further described by Toomey and Nitecki (1979) and by Toomey (1981), and the occurrence of the lithistid sponges, principally the form they termed *Archaeoscyphia annulata* Cullison, 1944, and the steeply obconical receptaculitid *Calathium* were noted. Toomey's (1981, fig. 2-2) reef-mound horizon,

including the Lechuguilla Mound, occurs in the top of unit B_1 of the upper part of bed 15 of Cloud and Barnes (1946), in the middle part of the McKelligon Canyon Formation. Most of the sponges described here are from these units.

Pulchrilamina Toomey and Ham (1967) appears to have functioned as a binder in the reef fabric and to be a major consituent in some of the more digitate or irregular mound-like small reefs. Examples of lithistid sponges, and of *Calathium* Billings, 1865, and *Pulchrilamina,* from the McKelligon Canyon mounds were shown by Toomey (1981) in his figures 2.3 and 2.5.

Goldhammer et al., (1993) examined the stratigraphic section of the El Paso Group in some detail and evaluated it in terms of origin of high-frequency platform carbonate cycles and third-order sequences. The El Paso Group was carefully examined again by Wilkinson et al., (1997) during their investigation for stratal order in the peritidal sequence, like in Ordovician cycles in central Texas. In their figure 9, they showed the clustered distribution of the sponge-bearing thrombolite mounds, which they interpreted as the deepest-water facies in the recurring cyclic sequences.

Goldhammer et al., (1993, fig. 4) interpreted the unconformity at the base of the McKelligon Canyon (Pistol Range Member) as a sequence boundary and assigned it an age of 491 million years. The boundary between upper and lower McKelligon Canyon beds, or approximately between sequences B_1 and B_{2a} of Cloud and Barnes (1948), was dated at 489 million years, and the disconformable unconformity at the top of the McKelligon Canyon Formation at 487 million years.

Goldhammer et al., (1993) described the sponge-algal mounds as massive, barrel-shaped structures, with individual mounds ranging from 0.3 to 5 m thick and up to a few meters wide. Most of the thrombolitic structures do not contain sponges, but the larger mounds do. They also observed that *Archaeoscyphia* and the sponge-like organisms *Calathium* and *Pulchrilamina* are conspicuous elements in the structures and help produce the skeletal framework that "allowed the bioherms to exist as isolated bodies" (Goldhammer et al., 1993, p. 320). They concluded that lithification was rapid within the mounds, that depositional relief on the mounds was less than a meter, and that the mound complexes appear very similar to the subtidal stromatolites of the Little Bahama Bank oöid shoals (Dill, et al., 1989). Goldhammer et al., (1993, p. 321) observed that, "based on the Bahamian analogs, paleo-water depths for the sponge-algal bioherms were probably on the order of 5–10 meters."

The sponges described here include material collected by Rigby in 1961, by Rousseau Flower and LeMone in subsequent years, and Field Museum specimens collected by M. H. Nitecki and D. F. Toomey.

LOCALITIES

All localities are from the south end of the southern Franklin Mountains in northern El Paso, Texas; and all except those noted otherwise are from the McKelligon Canyon Formation.

BRIGHAM YOUNG UNIVERSITY LOCALITIES

11048, Small sponge-stromatolite masses 10 feet below the top of unit 11 of Howe's Section 7 (1959, p. 2290), approximately 130 feet below the top of the El Paso beds, north of Scenic Drive, at approximately 31° 47′ 05″ N., 106° 28′ 39″ W.

11049, Sponges and *Calathium* in the top of unit 11 of Howe's (1959) Section 7 sponge beds, in the lower end of a small gully on the northwest side of Scenic Drive, approximately 305 m (1000 feet) northeast of the lookout parking area at the southern tip of the range; at approximately 31° 47′ 05″ N., 106° 28′ 39″ W.

11050, *Calathium* reef core, top of unit 11 of Howe (1959), at 31° 47′ 05″ N., 106° 28′ 39″ W., in the same gully as 11049.

11051, 60 feet stratigraphically below locality 11050, in the lower end of the eastern of two small gullies on the northwest side of Scenic Drive, approximately 305 m (1100 feet) northeast of the lookout parking area at the southern tip of the range; at 31° 47′ 07″ N., 106° 28′ 37″ W.

11052, Reefy limestone, 50 feet above the base of unit B_1 of Cloud and Barnes, in one of the lowest reefy beds, two ledges downslope from locality 11053 on the same ridge as 11053, at 31° 47′ 18″ N., 106° 28′ 28″ W.

11053, Reefy limestone 80 feet above the base of unit B_1 of Cloud and Barnes (1948), above the dolomite in the Second *Piloceras* zone of Flower (1964), on the ridge crest immediately south of the west end of the Pistol Range Quarry, northwest side of Scenic Drive, in massive light-gray limestone, at 31° 47′ 18″ N., 106° 28′ 28″ W., south 57° west of the flagpole in the Pistol Range and north 15° east of the double powerline pole on the ridge crest.

11054, Reef mass on the south side of the gully (south of the ridge south of the Pistol Range Quarry) near the gully bottom, due north of the double powerline pole; 20 feet

stratigraphically above a prominent brown cherty band, two-thirds of the way up in bed 15 of unit B_1 of Cloud and Barnes (1946); at 31° 47′ 17″ N., 106° 28′ 30″ W.

11056, Top of the blue-gray-appearing reefy limestone in the gully, 150 m (500 feet) north (upstream) of the caretaker's house, in the east fork of McKelligon Canyon off the main canyon at the picnic grounds, in the top limestone of Cloud and Barnes (1948) unit B_1, at approximately 31° 50′ 37″ N., 106° 29′ 10″ W.

ROUSSEAU FLOWER LOCALITIES

F-1, Limestone of bed 19, in unit A of Cloud and Barnes (1948), in the first *Piloceras* zone below the oolitic José Formation, above the main *Piloceras* reefs, in the Victorio Hills Formation in the Scenic Drive section at approximately 31° 47′ 37″ N., 106° 28′ 37″ N.

F-2, Bed 15 of Cloud and Barnes (1948), from unit B_1, in the Scenic Drive area.

F-3, Second *Piloceras* zone, unit B_1 of Cloud and Barnes (1948), Scenic Drive section.

DAVID LEMONE LOCALITIES

L-1, Middle or upper reefs in McKelligon Canyon at approximately 31° 50′ 17″ N., 106° 28′ 37″ W., on the east side of the southern Franklin Mountains.

L-4, Middle or upper reefs in the middle McKelligon Canyon Formation, in McKelligon Canyon at approximately 31° 50′ 17″ N., 106° 28′ 37″ W.

L-5, Middle reefs of the McKelligon Canyon Formation, in McKelligon Canyon at approximately 31° 50′ 17″ N., 106° 28′ 37″ W.

L-6, Middle McKelligon Canyon Formation, Scenic Drive section, at approximately 31° 47′ 19″ N., 106° 28′ 29″ W.

L-7, Middle or upper reefs of the McKelligon Canyon Formation in McKelligon Canyon at approximately 31° 50′ 17″ N., 106° 28′ 37″ W.

FIELD MUSEUM OF NATURAL HISTORY LOCALITIES

Thin sections PP22832, 22858 and 22859 are from mound rocks in the mound layer in Cloud and Barnes (1948) unit B_1 in the McKelligon Canyon Formation from the Scenic Drive section, and PP22861 and 22862 are from the same stratigraphic unit, but from the McKelligon Canyon area. Thin section PP22857 is from mound rocks questionably in unit B_1 of Cloud and Barnes (1948) in the Scenic Drive section at the southern end of the Franklin Mountains.

SYSTEMATIC PALEONTOLOGY

Class DEMOSPONGEA Sollas, 1875
Order LITHISTIDA Schmidt, 1870
Suborder ORCHOCLADINA Rauff, 1895
Family ANTHASPIDELLIDAE Miller, 1889
Genus ANTHASPIDELLA
Ulrich and Everett, 1890

ANTHASPIDELLA CLINTONI
Bassler, 1927
Plate 1, figs. 1, 2; Plate 4, fig. 8

Anthaspidella clintoni BASSLER, 1927, p. 394; BASSLER, 1941, p. 99–100, pl. 23, fig. 9; JOHNS, 1994, p. 30–34, pl. 1, figs. 1–6, pl. 2, figs. 1–2.
Anthaspidella cf. *A. scutula* Ulrich and Everett, 1890, LANGENHEIM ET AL., 1956, p. 2093.
Anthaspidella inyoensis PESTANA, 1960, p. 864–865, pl. 109, fig. 7.
Anthaspidella traini BASSLER, 1927, p. 394; BASSLER, 1941, p. 100, pl. 23, figs. 7, 8.

Diagnosis.—Broadly obconical to flaring funnel-shaped and flattened discs up to 20 mm thick. Lower or dermal surface smooth to irregularly weakly nodose. Gastral or upper surface marked by clusters of irregularly radiating exhalant canals, with up to 25 canals per cluster. Clusters separated up to 25 mm apart, from center-to-center, and range up to 12 mm across; composed of canals 0.7–1.9 mm in diameter, at the surface; additional canals vertically stacked in regular radial series, canals to 1.4 mm in diameter and separated to 1.6 mm. Skeleton characteristic ladder-like net with parieties of two to four trabs. Surface of pinnation in mid-wall to near the dermal surface. Trabs to 0.3 mm in diameter, cored by two or three oxeas. Trabs meet upper dermal surface nearly at right angles in the inner part of the disc and commonly at approximately 45° in the outer part of the disc and at the dermal surface. I-shaped dendroclones dominate; dermal and gastral layers may be developed.

Description.—A moderately well-preserved fragment of the species, USNM 480535, is approximately one-third of the disc of a broadly upward-expanding, obconical to funnel-shaped, sponge. The fragment has a radius of 5–6 cm and a height of approximately 4 cm, from the broken base to the upper arching surfaces of the discoidal part of the sponge. The inner, more juvenile and most depressed part of the sponge fragment has a diameter of approxi-

mately 3 cm, from which the sponge expands upward and outward in relatively straight, broadly obconical fashion at approximately 30°, curving upward to approximately 45°, but then bending sharply laterally to become almost horizontal in the outer half of the preserved fragment. The wall is approximately 1 cm thick in the central and lower part of the sponge, but thins uniformly upward and outward to approximately 5 mm thick near the rounded, outer margin.

The upper gastral surface is marked by two moderately irregularly spaced rings of clusters of star-like radiating exhalant canals. These clusters are separated 10–15 mm apart, within rings, which are approximately 20 mm apart radially.

Centers of the stellate clusters are composed of vertical exhalant canals 0.8–1.0 mm in diameter. Outer canals in the cluster bend outward and become subtangential to the surface, where they continue as radial canals, 0.5–0.8 mm wide. These canals may branch radially and lose their identity in the skeletal structure at mid-distance between adjacent canal clusters. There are seven to nine clearly defined canals in each cluster where the radiating structure is prominent.

The skeletal structure is typically anthaspidellid and composed of trabs that diverge from a pinnation surface that is 1–2 mm in from the dermal surface. The trabs diverge gently from that surface, but curve abruptly upward, meeting the gastral surface at approximately 80° in the inner part of the funnel-like sponge, but at lesser angles in the outer part of the wall, where trabs meet the gastral surface at approximately 30°. Trabs flex downward from the pinnation surface to meet the lower dermal surface at approximately 20–30°. Trabs are spaced 0.3–0.5 mm apart and are cross-connected by dominantly I-shaped dendroclones.

Trabs in the species are among the coarsest evident in any of the sponges from the El Paso sequence. Characteristic trabs range from 0.15 to 0.18 mm in diameter and are largely composed of merged cladomes of I-shaped dendroclones. Such dendroclone spicules have shafts 0.20–0.30 mm long that have mid-length diameters of approximately 0.06 mm. Individual cladome rays are recognizable on some of the calcareously replaced spicules and are up to 0.06 mm long. These small bifurcating rays diverge from one another at angles of 90–140°. Individual cladomes are approximately 0.02 mm in diameter. They thin distally to where they merge with those of other tips to produce the trabs.

Sections of coring oxeas are evident in some trabs and are commonly 0.02–0.03 mm across, but some of these coarse oxeas range up to 0.04 mm in diameter. Two or three oxeas may occur per section so that much of each trab is composed of coring spicules, with the clad-produced coating around the coring oxeas only 0.02–0.04 mm thick, in trabs that are approximately 0.14 mm in diameter. Coarsest trabs, to approximately 0.20 mm in diameter, occur in the dermal layer.

Radial canals parallel the more-or-less uniformly radiating, diverging skeletal structure and are approximately 0.8–1.2 mm in diameter. Only a few inhalant canals are evident. These tend to be upward arcuate canals that are essentially normal to the trabs, so they swing upward and inward towards the center of the disc, arching through as much as 70–80° from nearly normal to the dermal surface on the lower part of the sponge. These canals are commonly 0.6–0.8 mm in diameter and lose their identity in the upper part of the discoid skeleton where exhalant and radial canal series are most dominant. Details of inhalant ostia dimensions and distributions are not known because the base of the sponge is buried in matrix.

Discussion.—Johns (1994, p. 31) included the several species reported from western North America in the type species of the genus, *Anthaspidella clintoni* Bassler, 1927. Johns measured various parameters of the sponge skeleton and canal structure and concluded that plots of cluster size vs. cluster spacing were the most informative measurements. He also concluded that the forms previously separated as *Anthaspidella clintoni* and *Anthaspidella traini* by Bassler (1941, p. 97–98) cannot be separated because they appear to be only sections along a continuum, ranging from small, closely-spaced clusters to larger, widely-spaced clusters. He did not attempt a revision of the various species of *Anthaspidella* described by Ulrich and Everett (1890) from the Platteville Limestone near Dixon, Illinois. We have not evaluated those species either, but our sponge is very similar to the type specimen, USNM 79643, figured by Bassler (1941, pl. 20, figs. 5, 7) from the Ikes Canyon area in the Toquima Range in Nevada, and we have included our specimen in the type species.

Material.—USNM 480535 was collected from Locality L-1, from the middle or upper reefs of the McKelligon Canyon Formation in McKelligon Canyon. An additional obconical specimen, USNM 480536, from Locality L-5 is questionably included in the species.

Genus ARCHAEOSCYPHIA Hinde, 1889

Discussion.—*Archaeoscyphia* is one of the largest and most widely distributed sponges of the family. It has been reported throughout 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 El Paso Ordovician stratigraphic section.

Type species.—*Petraia minganensis* Billings, 1859

ARCHAEOSCYPHIA MINGANENSIS
(Billings, 1859)
Plate 1, figs. 3–5; Plate 2, fig. 4;
Plate 5, fig. 6

Petraia minganensis BILLINGS, 1859, p. 346.
Archaeocyathus minganensis BILLINGS, 1861, p. 5.
Archaeocyathus minganensis BILLINGS, 1865, p. 354, figs. 342a, b, 343, 343a, 344a.
Ethmophylluum minganensis WALCOTT, 1886, p. 77, figs. 6–8.
Archaeoscyphia minganensis HINDE, 1889, p. 143, pl. 5, figs. 12–14; RIGBY AND DESROCHERS, 1995, p. 17–18, fig. 6.1; LIU ET AL., 1997, p. 196–197, fig. 7.5.
Archaeoscyphia annulata Cullison, 1944, TOOMEY AND NITECKI, 1979, p. 17, fig. 6b.

For a complete synonymy see Rigby and Webby (1988, p. 29), and De Freitas (1989, p. 1874).

Diagnosis.—"Large obconical to conical cylindrical, tubular, annulate, anthaspidellid with smooth subcylindrical to steeply obonical spongocoel. Exterior marked by horizontal, ringlike, annulations projecting to 14 mm or more from dermal surface, gastral surface lacks annulations of exterior. 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 upward and outward to meet exterior at from high angles to essentially normal, but trabs meet gastral margin at somewhat lower angles. Gastral layer little differentiated, although thin dermal layer may be locally present, particularly along margins of some annulations. Three canal series evident, most prominent vertically stacked, radial, essentially horizontal to upward arched series, separated by parieties of skeletal mesh; second series, subvertical, of interior canals that arch upward and outward, roughly parallel to trabs; smaller third series interconnects larger canals." (from Rigby and Desrochers, 1995, p. 17–18).

Description.—Two moderately well preserved fragments of a large sponge are from Locality 11053. USNM 480537 is the more completely preserved. It is a fragment of the lower part of a sponge that is approximately 8 cm tall with an upper diameter of 45 mm. The upper spongocoel in that section has a diameter of approximately 35 mm, surrounded by a wall 4–5 mm thick. Somewhat distant, moderately sharply ridged or relatively low annulations are spaced 20–30 mm apart and extend laterally approximately 5–6 mm out from the broad depressions between annulations.

The skeleton is characteristically anthaspidellid with a surface of pinnation at mid-wall, from which diverge the well-defined, cylindrical trabs that meet the dermal and gastral surfaces at approximately 30°, except on upper surfaces of the annulations, where they meet those surfaces at high angles. Prominent radial canals are essentially straight to slightly up-arched in the center, normal to the trab trend. Most are approximately 1.0 mm wide and 1.5 mm high. They are commonly separated by two or three trabs in the parietal series and occur three series per 5 mm measured horizontally around the periphery. The specimen shows a thickened skeletal structure, 0.4–0.5 mm thick, as a dermal layer with swollen elements on both annulations and interannular depressions.

USNM 480538 is a fragment approximately 8 cm high, that shows part of one wall with moderate annulations spaced 20–22 mm apart, crest to crest. The annulations rise 5–7 mm radially from interannular depressions, where the wall is 4–5 mm thick, making the wall 9–12 mm thick at the crest of the annulations. The trabs show a mid-wall pinnation and a divergence of approximately 30°, but curving somewhat more to meet the upper sloping surfaces of the annulation at high angles, but nearly paralleling the lower annulation surface as they curve outward in the thickened wall segments. Other dimensions of the sponge cannot be defined because only a vertical section through one wall is preserved at the edge of the fragment.

One well exposed, somewhat diagonal transverse section of the species, USNM 480539, occurs in collections from Locality F-1. It shows the prominent, open, tubular spongocoel and the walls pierced by coarse, radial canals in the moderately large sponge. This specimen is approximately 70 mm in diameter, but with a broken edge, and has walls 15–18 mm thick surrounding the prominent spongocoel that is 40–45 mm in diameter. Low nodes, or annulae, are questionably spaced 20–25 mm apart on the incomplete broken edges. These show as weak ridges, not prominent shelves.

Coarse radial canals are generally straight, slightly up-arched and show prominently in the interannular area cut by the section. They produce a coral-like, almost septate appearance because of their regularity and straight radial courses. These canals are 1.0–1.4 mm in diameter and are spaced such that five occur per 10 mm, measured horizontally near both the dermal and gastral surfaces. This spacing results in parieties between the vertically stacked canals being somewhat narrower, 0.6–1.0 mm wide, in the gastral area rather than 1.0–1.2 mm wide, as in the dermal area. The canals are partially matrix-filled in the weathered fragment.

Distinct vertical canals, 1.2–1.4 mm in diameter, occur in parietal areas, as well as cross-connecting the vertically stacked, horizontally radial canals. Vertical canals are most prominent in the middle and inner, or gastral, part of the wall and range from side-by-side to separated 1.0–1.5

mm. There is no evidence of concentric horizontal canals in the weathered specimen.

Discussion.—The gently sloping, sharp-crested, low and widely spaced annulations in the species contrast sharply to the relatively thin, shelf-like, curving, and more closely spaced annulations that characterize *Archaeoscyphia pulchra* (Bassler, 1927). Most other species of Ordovician *Archaeoscyphia* described have much more closely spaced and smaller annulations on the subcylindrical to steeply obconical sponges. *A. minganensis* is a common species in the reefoidal mounds in the McKelligon Canyon Formation and is often preserved there in growth position in the massive limestone.

Material.—Four specimens from Locality 11053 include USNM 480537 and three less complete sponges from reef mounds and associated debris. A single unnumbered specimen from Locality 11056 is also included here. Also included in the species are USNM 480538 from Locality L-2, USNM 480539 from Locality F-1, and a fragment from Locality F-3. Two small fragmental specimens, one each from Locality L-5 and Locality L-7, are questionably placed in the species. The occurrence of the species at Locality F-1 is the earliest reported for the species and genus, from Ibexian Trilobite Zone E in the Victorio Hills Formation.

ARCHAEOSCYPHIA PULCHRA (Bassler, 1927)

Plate 2, figs. 1–3; Plate 5, figs. 1, 2

Nevadocoelia pulchra BASSLER, 1927, p. 392; 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.

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.—Numerous specimens of the species occur in our collections, commonly only as tangential sections showing the prominent annulations, or as subtransverse sections. Among the better preserved are samples from Locality 11056, including USNM 480540 A and B. The sponge has been cut tangentially and prominent annulations shown on the weathered reverse side of block A. The fragment is 6.5 cm tall and expands upward in steeply obconical form, prominent shelf-like annulations extend radially at regular intervals, are spaced approximately 1 cm apart, center to center, with gaps between the somewhat drooping shelf-like annulations 3–5 mm high and 1–1.5 cm deep, and end in sagging round tips.

Prominent inhalant canals are arranged in vertically stacked radial series. They are vertically elongate in cross-section and range from 0.7 to 1.1 mm wide and 1.5–2.0 mm high. Radial series are generally spaced 2–3 trabs apart, so that approximately 5 radial series occur per centimeter in the inner part of the wall, as measured horizontally, and in the outer wall they are spaced two to four trabs apart. Canals are stacked five or six per centimeter and separated by one or two dendroclones in a vertical series.

In areas between canals, trabs are commonly 0.4–0.6 mm apart, horizontally, but range 0.1–0.7 mm apart and are essentially vertical in interior parts of the walls. They bend upward and outward and are essentially horizontal in areas between the shelf-like annulations, but flex sharply downward from a plane of divergence in the lower third of each annulation, meeting the lower surface of the those shelf-like projections at high angles. Trabs diverge upward from that plane somewhat less steeply in upper parts of annulations, but meet the upper surface also at high angles. They define small canals that descend steeply from the upper surface and curve abruptly laterally to merge with the major inhalant canals in the central part of the walls.

The skeleton is typical of the species, with subparallel vertical trabs making up much of the interior part of the wall. There individual trabs are moderately continuous and range 0.10–0.20 mm in diameter, in the rather coarsely crystalline preservation. Whether coring oxeas are present in the trabs is not known because of their crystalline calcareous replacement. Individual dendroclones in that skeletal structure range from 0.03 to 0.07 mm in diameter and are commonly 0.2–0.4 mm long. They bridge between adjacent trabs that are formed largely of their ray tips, as seen in the cellulose acetate peels.

An associated specimen, USNM 480541, from Locality 11056, is an oblique sublongitudinal section, but it does give measurements of the circular central spongocoel, which is approximately 33 mm across in the sponge that is approximately 45 mm across. That impression has irregular weak bases of annulations of essentially the same dimensions as in the better-preserved specimen, and it has walls 4–8 mm thick between annulations. Those annulations appear to extend as somewhat downward-flexed, shelf-like extensions of the walls. The sponge also displays

the distinctly fine, almost septate-appearing canals and skeletal structure that make up much of the interior wall of the sponges.

Two well-exposed essentially transverse sections are in the collection. One, USNM 480542, shows a weathered surface through the wall and the lower parts of shelf-like annulations. The wall is 15–20 mm thick and surrounds a prominent spongocoel, 18 by 22 mm in diameter, as a central tubular opening. The entire sponge appears to be 60–65 mm wide from opposite outer edges of the shelf-like annulations and with the suggestion of a diameter of approximately 50 mm in the interannular narrowed areas between the "shelves."

Sections of the wall show long, horizontal, radial canals that branch only locally, but with somewhat meandering courses in some areas. These canals are 0.08–1.2 mm in diameter, with most approximately 1.0 mm across. They are spaced such that approximately eight occur per centimeter around the gastral wall, where measurements can be made and where the parieties between the vertically-stacked canal series are 0.3–0.6 mm thick, near the gastral margin. Similar measurements cannot be made around the outer margin because of the irregular weathered surface, but parieties appear to be somewhat thicker there.

A few rare vertical canals occur in the inner part of the wall and near the gastral margin. These are 0.8–1.0 mm in diameter and appear to connect through the vertically stacked, horizontal radial canal series, but few of the vertical canals are evident and that relationship is not certain.

The other moderately well preserved transverse section of the species, USNM 480543, is a somewhat diagonally weathered surface. Prominent, thin, shelf-like annulations are separated by light matrix around the relatively thick inner wall. That wall appears to be 12–15 mm thick and surrounds a matrix-filled spongocoel, 15 by 18 mm in diameter. Light matrix-filled radial canals, mostly 0.8 mm in diameter but ranging up to 1.0 mm across, converge toward the spongocoel margin. These exhalant openings of the canal system are separated by parieties 0.3–1.0 mm wide, and occur approximately eight per centimeter, measured horizontally around the periphery of the spongocoel. No vertical canals are evident in the relatively rough weathered surface.

Discussion.—Nevadocoelia pulchra was named by Bassler (1927, p. 392; 1941, p. 95–96, pl. 20, figs. 1–4) from specimens that were part of a collection from the Upper Pogonip Limestone, from the Ikes Canyon area, in the Toquima Range in central Nevada. Johns (1994, p. 44–47) concluded that sponges termed *Archaeoscyphia annulata* Cullison, 1944, from the Lower Ordovician of the Ozark Uplift in Missouri, are the same species, or that there is not enough difference to separate the species.

Archaeoscyphia pulchra is characterized by prominent, broad, downward curving, shelf-like annulations, and because of that it is one of the most ornate-appearing, deeply sculptured species of the genus. Bassler (1941, pl. 20, figs. 1, 2) illustrated the species with the prominent annular rings curving upward rather than downward and, thus, showed the holotype of the species upside down from its original growth position. Johns (1994, pl. 4, figs. 1, 3) illustrated the specimens correctly.

Archaeoscyphia pulchra is a much more prominently and more finely annulate sponge than *Archaeoscyphia minganensis* (Billings, 1859), which also occurs in the lower part of the McKelligon Canyon Formation, as well as widely around the world.

Archaeoscyphia nana Beresi and Rigby, 1993, also has prominent sloping annular rings, but it is a finer textured form and is uniformly smaller than specimens of *Archaeoscyphia pulchra.*

Archaeoscyphia rossi Johns, 1994, and *Archaeoscyphia eganensis* Johns, 1994, both have considerably more closely spaced and smaller annular rings and either finer canals or finer spicular structure than *A. pulchra.* Johns (1994, p. 46) observed that the skeleton in *Archaeoscyphia pulchra* shows only very slight pinnation of the trabs, unlike other archaeoscyphiid sponges.

Toomey and Nitecki (1979) identified some sponges from the lower Ordovician McKelligon Canyon reef mounds as *Archaeoscyphia annulata* Cullison, 1944. Those specimens, however, are not like *Archaeoscyphia pulchra* and belong to other species, as was pointed out by Johns (1994, p. 46–47).

Material.—The collection includes USNM 480540A and B, USNM 480541, and three unnumbered specimens from Locality 11056; one certainly identified specimen and one questionable specimen from Locality 11052; one small specimen from Locality 11054; USNM 480543 from Locality F-2; USNM 48544 from Locality L-1, and USNM 480542 from Locality L-2.

Genus ZITTELELLA
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 upper surface.

Under surface sometimes covered with a dense dermal layer." (Ulrich and Everett, 1890, p. 267–268).

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

ZITTELELLA(?) sp.
Plate 3, fig. 8; Plate 5 figs. 8, 9

Description.—One specimen, a tall, subcylindrical, weakly annulate, tubular sponge, USNM 480545, occurs in our collection. It has thin walls and a distinct central area occupied by numerous subparallel, vertical, exhalant canals that extend from near the base to the summit. The specimen is approximately 7 cm tall, expanding upward from a broken base, approximately 8 mm in diameter, to approximately 18 mm across a short distance below the incomplete summit. Weak annulations extend 2 or 3 mm out from the general obconical surface and are spaced 15–20 mm apart, vertically, as low, rounded, ridges separated by somewhat sharper indentations. Walls with relatively dense skeletal structure range 4–6 mm thick and contrast sharply to the open, tubular, exhalant canalled area along the axis of the sponge.

The prominent exhalant canals are thin-walled and extend as continuous, vertical, subprismatic to subcircular tubes from the base to the summit. These tubes range 2.0–2.5 mm in diameter and are side-by-side, separated by thin walls approximately 0.04–0.05 mm thick. The spicular nature of those walls is obscured in the crystalline calcareous replacement. Canal walls are interrupted by pores that range from 0.1 to 0.15 mm in diameter and that appear to be separated by single I- or Y-shaped dendroclones, but details are lost.

The skeleton is pierced by horizontal radial canals that occur in vertically stacked series. These canals range from 0.4 to 0.5 mm wide and up to 0.1 mm high, although commonly less. Vertical rows of these canals may be separated by parieties that are commonly two trabs thick, so that four or five vertical canals series may occur per 5 mm, measured horizontally on the exterior. These canals appear to empty into the exhalant canals of the axial region.

The skeletal structure is typically anthaspidellid, with the plane of pinnation essentially at mid-wall. Trabs in the outer part curve to meet the dermal surface at 50–60°, but curve less abruptly gastrally to meet the gastral margin at 10–20°. Individual trabs range to 0.20 mm in diameter, but more commonly are approximately 0.06–0.08 mm.

Dendroclones appear as I-shaped spicules and as "rungs" in the ladder-like skeletal structure. Such dendroclones are spaced approximately six per millimeter within a single series. They are commonly 0.14–0.16 mm long and 0.03–0.04 mm in diameter in the crystalline calcareous replacement. Locally, there is a suggestion of coring oxeas, approximately 0.02 mm in diameter, within the trabs. The granular crystalline replacement obscures the microstructure in most of the skeleton, however, so that evidence of coring spicules is equivocal.

Discussion.—Only a single specimen of the species occurs in our collection. It was initially considered a species of *Archaeoscyphia* because of its cylindrical, weakly annulate, form until the long, tubular, axial canals that extend from the base to the summit were recognized. Such canals are common in basal areas of *Archaeoscyphia* and several other sponges within the family, but generally extend only a short distance above the base and the remainder of the spongocoel is a simple tubular opening. Only in *Zittellella* have these types of canals been described as extending from the base of the sponge to near the summit, particularly in those forms with regular anthaspidellid skeletal nets.

Eospongia Billings, 1861, has numerous vertical tubes that are common in the axial area, but they are also scattered throughout the sponge in the type species, *Eospongia roemeri* Billings, 1861, as that species was described by Rigby and Desrochers (1995). *Eospongia varians* (Billings, 1861) was included in *Zittellella* by Schuchert and Twenhofel (1910, p. 690), as it was by Bassler (1915, p. 1338) and Raymond and Okulitch (1940, p. 200–201). *Zittellella varians*, however, is a small form and is commonly steeply to broadly obconical and, thus, it differs from the subcylindrical form here. In that species, trabs diverge upward and outward very prominently in the stem and lower parts of the sponge, but less prominently in upper expanded parts. Species of *Zittellella* from Illinois have trabs that are essentially vertical and parallel, rather than diagonal, in a structure that contrasts with the upward and outward pinnate development in the skeleton seen here. *Zittellella grossa* Rigby and Desrochers, 1995, described from the Mingan Islands of southeastern Quebec, is a coarse-textured pyriform to pedunculate or stalked sponge with horizontal canals that are approximately 2.0 mm in diameter and occur two to four rows of canals per centimeter. That canal pattern is distinctly coarser than the one in this El Paso species.

Material.—USNM 480545A and B, from Locality 11056. The sponge has been cut sublongitudinally so that parts of the tubular sponge occur on both blocks.

Genus CALYCOCOELIA 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 in the new genus that he proposed, based on the 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 Shingle Limestone in the southern Egan Range in eastern Nevada, from upper Ibexian rocks. The occurrence of the genus here in Ibexian Trilobite Zone E in the Victorio Hills Formation, at Locality F-1, is the oldest reported.

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

CALYCOCOELIA PROTERA n. sp.
Plate 1, figs. 6, 8; Plate 3, fig. 2;
Plate 4, fig. 4; Plate 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 0.25–0.40 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.

Description.—The holotype of the species, USNM 480546, is a thin-walled, cylindrical form, approximately 8.5 mm high, and nearly complete at the base, but incomplete at the top. The sponge expands upward from a diameter of approximately 9.5 mm at the base to 12 mm at the preserved summit. A broad open spongocoel extends virtually through the full length of the specimen, expands upward from a subspherical base, approximately 7.5 mm in diameter, to a maximum diameter of 9.5 mm at the broken summit. The exterior is smooth to weakly undulate, although not annulate, and the gastral surface of the spongocoel is similarly smooth inside the thin wall. That wall thickens upward from 0.7–0.8 mm in the lower part to approximately 1.2 mm thick in the upper part of the simple, tubular form.

Radial, essentially horizontal, canals are mostly 0.3 mm in diameter, but range to 0.4 mm as coarse openings. Ostia in the dermal surface are spaced eight or nine per 5 mm in vertically stacked series, with 9 to 11 such vertical series per 5 mm, measured horizontally in the upper part.

Skeletal structure is typically anthaspidellid and relatively coarse-textured, with the surface of pinnation at the gastral margin, so that trabs diverge gently upward and outward, meeting the dermal surface at low angles of approximately 30°. Trabs appear relatively coarse and generally range from 0.14 to 0.20 mm in diameter. They are formed of ray tips of moderately widely spaced, I-shaped dendroclones, with shafts generally 0.02 mm in diameter at their thinnest, but which thicken to 0.08 mm in both directions toward the trabs. Short cladome rays range to 0.04 mm in diameter and are locally preserved in the weathered trab margins. Coarse trabs may include coring oxeas, but these are not preserved in the crystalline replacement on the holotype, but are in some reference sections, such as FMNH 22852 from the McKelligon Canyon Formation mound layer.

Some of the weathered skeletal structure suggests moderate definition of parieties, 0.5–0.7 mm thick. Such parieties are composed of two vertical series of trabs, separated by relatively small openings only 0.10–0.15 mm in diameter. These openings contrast to the larger canals that range to 0.4 mm in diameter in vertically stacked series separated by the parieties. In other areas, parietal definition is less evident and coarse ostia in the dermal area, particularly, occur in vertical series and alternate in position with those of laterally adjacent series, so that one or two small openings may occur between dendroclones in a ladder-like series between coarse ostia of canals in the same vertical series.

Two additional small paratypes occur on USNM 480547, from Locality 11056, and show the same general skeletal and canal structure. These specimens, at first appearance, were thought to be branches of an *Ozarkocoelia*, but they have the coarser skeletal structure and aligned canal pattern of *Calycocoelia protera* n. sp. They were each approximately 35 mm tall before being cut, and have broken bases, but essentially complete summits. The larger of the two has a diameter of 11 mm and the smaller a diameter of approximately 8 mm at midheight. Both are weathered and show vertical longitudinal sections that have the skeletal structure moderately well defined. Both have thin walls approximately 2 mm thick and only five or six trabs thick, radially, that surround open, deep, tubular spongocoels, 5 mm in diameter in the smaller specimen

and 7.5–8 mm in diameter in the larger one. Both dermal and gastral surfaces appear smooth and non-annulate and lack nodes.

The skeletal structure in both is moderately open, with a surface of pinnation near the gastral margin, with only gentle divergence of perhaps 10° toward the gastral surface, but with curved trabs in the outer part of the wall so that they meet the dermal surface at approximately 30°. Trabs appear relatively coarse in the crystalline replacement and range from 0.10 to 0.20 mm in diameter. They are composed of branching tips of I-shaped dendroclones that have shafts 0.03–0.04 mm in diameter and up to 0.3 mm long in areas where coarse canals are moderately well defined. Elsewhere, in possible parietal areas, lengths range to 0.2 mm in dendroclones with shaft diameters of 0.03–0.04 mm. In a single ladder-like series, dendroclones are spaced 0.2–0.3 mm apart.

In transverse sections of the two sponges, trabs have a common diameter of approximately 0.10–0.15 mm, although some range up to 0.20 mm in diameter. They are cross-connected by I-shaped dendroclones 0.03–0.04 mm in shaft diameter and up to 0.4 mm long, although most are only 0.25–0.30 mm long. The longest spicules bridge between trabs that separate the coarse canals in the vertical series. Shorter spicules are probably those characteristic of parieties between the canal series. Differences between parieties and canal-bearing series are not clearly defined in transverse sections and the structure seems relatively uniform. Trabs are spaced approximately 0.3–0.4 mm apart, horizontally, in much of the transverse sections of both the large and the small fragments.

An additional small tubular paratype, USNM 480548 from Locality 11056, shows in oblique subvertical section. It is approximately 12 mm in diameter, with a spongocoel 7.0 mm across and with walls 2.0–3.0 mm thick. In these walls the distinct upward-and-outward divergence of outer trabs and the very gentle gastral divergence of inner trabs from a surface of pinnation almost at the gastral margin shows moderately well. Outer trabs meet the dermal surface at approximately 30°, whereas those at the gastral margin are parallel or perhaps diverge toward the gastral margin at 5°–10°. As in the other specimens of the species, trabs appear relatively coarse and approximately 0.20 mm in diameter. They are spaced 0.3–0.4 mm apart near the dermal surface.

A subtangential weathered surface of the near gastral part of the wall in the lower part of the specimen shows canals 0.3–0.4 mm in diameter, in regular vertically stacked series. Some small circular openings, 0.15–0.20 mm in diameter, may occur above and below these circular canals in the same vertical series, where five or six vertical canals occur per 2 mm in a vertical series. Only fragments of I-shaped dendroclones are preserved between adjacent trabs in the weathered surface, but these appear to be of essentially the same dimensions as in other more complete specimens.

A somewhat diagonal subtransverse reference section (Pl. 3, fig. 2) also occurs on USNM 480550, associated with other taxa. The small stem is approximately 9 mm across and perforated by a large central spongocoel approximately 4.5 mm across. Walls are approximately 2 mm thick and show the characteristic open anthaspidellid skeleton, with relatively small, widely spaced trabs connected by thin, long-rayed, dendroclones. Trabs are commonly 0.4–0.5 mm apart in transverse section across the upward and outward diverging skeletal structure. Trabs do not flex sharply toward the dermal surface, but appear to meet that surface at relatively low angles. Individual dendroclones range to 0.4 mm long and have shaft diameters of approximately 0.04 mm in the long I-shaped spicules. There is a suggestion of a finer-textured dermal layer in the outer 0.3 mm, where smaller dendroclones define somewhat smaller skeletal openings and are in somewhat more irregular orientation than in the interior of the walls. That structure is still relatively open-textured and does not show the robust skeletal structure of *Ozarkocoelia.*

One oblique section of a small tubular sponge, approximately 6.0 mm in diameter and with a central axial spongocoel approximately 2.0 mm in diameter, occurs on FMNH PP22857. It shows the characteristic open skeleton composed of trabs that are cored by one or possibly two oxeas in some of the well-preserved trab segments. Those oxeas are 0.02 mm in diameter and segments of the tapering spicules up to 0.6 mm long occur along some of the better preserved trabs. Dendroclones in the section are up to 0.2 mm long and 0.04 mm in diameter. Some of them show well-defined clads that articulate with clads of adjacent spicules. These clads range 0.020–0.025 mm in diameter where they become distinct from the shafts of the dendroclones and range up to 0.10 mm long. They have irregular root-like outer ends that have united with other similar spicule tips to produce the outer layer of the cored trabs of the skeleton.

Discussion.—Calycocoelia protera n. sp., is a small, subcylindrical, thin-walled form with a broad open tubular spongocoel and a relatively coarse, gently upward diverging anthaspidellid skeletal net. *Calycocoelia protera* n. sp. is a considerably finer-textured species than either *Calycocoelia murella* Johns, 1994, or *Calycocoelia typicalis* Bassler, 1927, for it has 9–10 ostia per 5 mm, both horizontally and vertically, nearly double the ostia of radial canals in the latter species. *Calycocoelia protera* also has a more robust-appearing and more closely spaced skeletal net than in the Nevada species.

Gentle upward divergence of the trabs in *Calycocoelia protera* n. sp., as well as in the type species *Calycocoelia typicalis* Bassler, 1927, from Nevada, contrasts markedly with the strongly divergent trabs characteristic of *Ozarkocoelia irregularis* Cullison, 1944. In *Calycocoelia typicalis* trabs diverge upward and outward very abruptly, meeting the dermal and gastral surfaces at high angles, rather than the low angles seen here. In addition, dendroclones in *Calycocoelia protera* n. sp. are relatively large and coarse, several times the dimensions of the tiny spicules that bridge between the closely spaced trabs in *Ozarkocoelia irregularis*.

Material.—The holotype, USNM 480546, from Locality F-1; three specimens, including a paratype, USNM 480547, on the large block from Locality 11056; and paratype USNM 480548 on a small block from the same locality. Also included in the species is a small specimen, USNM 480549, exposed only in weathered transverse section from Locality 11052, and a diagonal to subtransverse section on a sample, USNM 480550, with *Patellispongia oculata* Bassler, 1927, and *Ozarkocoelia irregularis* Cullison, 1944, from Locality 11056. An oblique section of a small sponge occurs on FMNH thin section PP22857 from mound rocks questionably in unit B_1 of Cloud and Barnes (1948) in the Scenic Drive area at the southern end of the Franklin Mountains.

Etymology.—*Proteros*, Greek, earlier, in reference to the stratigraphically early representation of the genus.

Genus PATELLISPONGIA 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 one to three 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).

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

PATELLISPONGIA OCULATA Bassler, 1927

Plate 3, figs. 1–3, 6, 7;
Plate 4, figs. 1–3, 7; Plate 5, fig. 3

Patellispongia oculata BASSLER, 1927, p. 393; BASSLER, 1941, p. 97, pl. 22, figs. 1, 2; pl. 24, figs. 1, 2; JOHNS, 1994, p. 77–82, pl. 8, figs. 1–5; pl. 9, figs. 1–5; pl. 10, fig. 1.

Patellispongia oculata(?) LANGENHEIM ET AL., 1956, p. 2089.

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

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 sp. RIGBY, 1971, p. 49–50.

Diagnosis.—Patellispongiids discoidal to funnel-shaped, with walls to 13 mm thick, perforated by stacked canals 0.2–1.0 mm in diameter, usually separated 0.1–0.7 mm; surface of pinnation one-third to one-half wall thickness in from dermal surface and parallel to gastral surface; trabs curve to meet dermal surface at approximately 45°; spicules of main skeleton almost exclusively I-shaped dendroclones; well-defined gastral layer to 1.8 mm thick perforated by irregularly spaced exhalant openings to 1.8 mm in diameter, to which may converge shallow tangential exhalant canals; inhalant openings 0.4–0.7 mm in diameter and more regularly spaced.

Description.—Several fragments of broad, flat, disc-shaped patellispongiids occur in the collection. These range from only plate-like fragments of the outer part of the sponge to a few fragments of the steeply upward-expanding, obconical central and initial parts of the sponge.

One vertical section of a specimen of the species from Locality 11056, USNM 480550, shows the upper plate-like part of the skeleton above a steeply obconical solid stem, now cut in somewhat oblique section. That stem is approximately 11 mm tall and rises upward from a rounded base to a width of 11–12 mm immediately below the plate-like lateral expansion of the upper part of the skeleton. That latter expansion is approximately 3 mm thick from near the stem to outer rounded edges. Most other fragments of the plate-like parts of skeletons are somewhat thicker than that and range up to approximately 1 cm thick in some of the more massive plates.

Skeletal structure within the stem is typically anthaspidellid; most trabs in the inner part are vertical and in typi-

cal ladder-like structure. Trabs in the outer 1–2 mm of the stem show upward and outward divergence and meet the dermal surface at 25–35°. They diverge from "pinnation" surfaces around where the trabs are vertical. Those pinnation surfaces continue upward and curve laterally into the plate-like structure where the trabs diverge downward to meet the dermal surface at 45–50° and curve upward to meet the gastral surface at up to 60°. The surface of pinnation in the outer plate-like part is approximately 1 mm above the lower dermal surface. Several canals, approximately 0.5 mm in diameter, appear to be subvertical and separated by two or three trabs in the central part of the stem. These are considered to be moderately coarse exhalant canals that would have emptied onto the upper surface. No well-defined inhalant canals can be identified connecting with these. Some of these exhalant canals are up to 0.7 mm in diameter in the upper part of the sponge. They are not closely packed and do not form an axial cluster, like that present in some related genera. However the section could be tangential through the outer part of the stem and have missed an axial cluster, if such were present.

Trabs are up to 0.10 mm in diameter in the upper part of the plate-like sponge, but most trabs in the interior of the sponge are only approximately 0.06 mm in diameter. Interior trabs are commonly 0.25–0.30 mm apart in a uniform pattern, interrupted only by the relatively coarse exhalant canals. Rare coring oxeas are preserved in some of the coarser trabs, particularly in the near-gastral surface. These spicules are small, straight rods, approximately 0.015–0.020 mm in diameter, and some of these are at least 0.3 mm long, but could be much longer.

Most spicules preserved in the ladder-like structure are I-shaped dendroclones with shafts up to 0.25 mm long in the central part of the skeletal structure, but are somewhat shorter and up to approximately 0.20 mm long in the dermal and gastral parts of the skeleton. These spicules have shaft diameters of 0.02–0.03 mm, but thicken near shaft ends where ill-defined clads diverge from the shafts to unite with other clads to form much of the trabs. Canal structures in the plate-like parts of the skeleton are not well-defined in these vertical sections.

Many plate-like fragments where canals are clearly differentiated also occur in the collections. These are fan-shaped to rectangular fragments up to 7 cm tall and 4–5 cm wide and commonly expose the upper or gastral surface of the sponges. Canal patterns are most definitively shown where the thin, upper gastral layer has been removed by erosion, apparently prior to burial of the fragments. These sponge fragments show distinct radial rows of exhalant openings separated by parieties of varying widths.

Canals in specimens USNM 480552 and 480553, from Locality F-1, are commonly 0.7–0.8 mm wide or in diameter. Many of them have oval ostia, elongate radially in the direction of upward and outward divergence of the canals, so they range from circular, where the canals are more-or-less vertical, to ostia that may be up to 2 mm long where the canals diverge at moderate angles to the gastral surface. Canals occur six or seven per centimeter measured along individual radial tracts, and five to seven tracts of canals occur per centimeter, measured at right angles to the radial pattern. These tracts are separated by parieties 0.5–1.0 mm wide, with most 0.5–0.7 mm wide.

Numbers of trabs vary, but apparently range up to three or four trabs per pariety between the canal series. There is no clustering of exhalant canals nor development of a tangential series as in *Anthaspidella*.

Somewhat finer canals and closer canal spacing is shown in USNM 480554, an associated specimen from Locality F-1. Most exhalant canals there appear to be subcircular, 0.5–0.6 mm in diameter, and spaced seven to nine per mm radially along an individual stacked series. Radial series occur eight or nine per cm in the distinctly aligned structure. Parieties range from 0.3 to 0.7 mm wide and are, thus, somewhat narrower than in some of the associated specimens of the species.

Insertion of radial series of canals and division of parieties, or branching of radial canal series with insertion of new parieties, both allow radial expansion of the skeletal structure and canal system.

Specimen USNM 480555, from Locality L-2, is a fragment that shows a probable dermal weathered surface. It documents a somewhat irregular distribution of the relatively fine inhalant ostia that are 0.3–0.5 mm in diameter. They are only crudely arranged in radial series and are 0.5–1.0 mm apart. The dermal skeletal net between the canals is marked by high-angle emergence of relatively coarse trabs up to 0.08 mm in diameter, but commonly only half that size. Trabs are cross-connected by I-shaped dendroclones with shafts up to 0.2 mm long and 0.02 mm in diameter, in a characteristic anthaspidellid skeletal structure. A dermal layer is not uniformly preserved on the specimen, for the regular ladder-like skeletal structure of the interior rises to the surface.

Discussion.—Patellispongia oculata Bassler, 1927, is a common species in intermound rocks of the McKelligon Canyon Formation, although complete specimens are rare. Apparently, the thin, plate-like, discoidal sponges were easily broken by currents that must have swept between the mounds.

Johns (1994, p. 81) concluded that the species *Patellispongia magnipora*, *Patellispongia minutipora* and *Patellispongia clintoni*, all named by Bassler (1927) from the Ordovician of Nevada, are synonyms of *Patellispongia oculata* Bassler, 1927, the type species of the genus. The range of pore sizes and spacing in specimens of the larger

collection that Johns studied show no consistent grouping of features that he measured. In addition, Johns (1994, p. 80) observed that Bassler, "mistook ectosomal pores for true prosopores and apopores, and used the variation between these ectosomal structures as a basis for erecting different species." Johns concluded that utilizing such structural detail cannot be justified based on more extensive collections and examinations and he placed Bassler's other species of the genus into synonymy with *Patellispongia oculata* Bassler, 1927. Consequently, we have elected to include the somewhat variable forms from El Paso in the type species as well, although there is a modest range in spacing and measurements of skeletal elements in our samples.

Material.—Several specimens occur in the collection from Locality 11056, including USNM 480550, 480557-480559; and several other large blocks, including USNM 480556, which may contain 10 to 15 plate-like fragments. In addition, USNM 480552-480554, came from Locality F-1; USNM 480555 from Locality L-2; and one large, fan-like specimen from Locality L-5. The occurrence of the species at Locality F-1 in Ibexian Trilobite Zone E, in the Victorio Hills Formation, is the oldest reported.

Family STREPTOSOLENIDAE
Johns, 1994

Diagnosis.—"Variously shaped, from discoidal and palmate to cylindrical, branching, or funnel-shaped. Fine irregular spiculature composed of monoclonid and polyclonid dendroclones fused at tips to form trabs, latter often cored by oxeas; trabs and dendroclones usually of comparable diameter. Complex, intertwining canal system typical; apopores emptying into cloaca or forming into individual, but clustered oscula. Surface usually smooth but surficial ridges or nodes sometimes present. Dermal and gastral layers variably developed; spicules of endosome and ectosome often of comparable size." (Johns, 1994, p. 87–88).

Discussion.—Rigby (1983, 1991) suggested that two very distinct, but unnamed, groups had historically been included within the family Anthaspidellidae. Subsequently, Johns (1994) erected the family Streptosolenidae for forms with the somewhat irregular skeleton that lacks vertical stacking of the radial canals. He included, among others, the genera *Streptosolen, Lissocoelia, Ozarkocoelia,* and *Hesperocoelia* in the new family. He also included the genera *Hudsonospongia* Raymond and Okulitch, 1940; *Aulocopella* Rauff, 1895; *Aulocopium* Oswald, 1847; *Perissocoelia* Rigby and Webby,1988; and *Pseudopalmatohindia* Rigby and Webby, 1988. These latter five genera were retained in the family Anthaspidellidae by Rigby and Desrochers (1995). *Eospongia* Billings, 1861a, has an irregular skeleton and should probably be included with the small-spiculed *Lissocoelia* and others in the family Streptosolenidae.

OZARKOCOELIA
Cullison, 1944

Diagnosis.—Cylindrical to irregularly branching small streptosolenid sponges with smooth dermal surface and a tubular axial spongocoel in each branch; prominent radial canals irregularly spaced in outer part of wall, but in vertical series in gastral part; skeleton with surface of pinnation at or near gastral margin, from which vertical trabs flex sharply, dermally, to meet dermal surface at high angles to essentially normally, trabs thicken dermally, trabs formed of tips of closely spaced I- and Y-shaped dendroclones that are in ladder-like arrangements throughout the skeleton.

Discussion.—The diagnosis, above, is based upon type specimens of *Ozarkocoelia irregularis* Cullison, 1944, from the Rich Fountain Formation in the Ozark region of Missouri. Several small cylindrical to branching genera similar in some respects to *Ozarkocoelia* occur in the Anthaspidellidae and Streptosolenidae. For example, *Caliculospongia* Rigby and Chatterton, 1989, is a Silurian branched to unbranched, twig-like, form but it lacks a spongocoel. *Dunhillia* Rigby and Webby, 1988, from the Ordovician of Australia is tubular with a large spongocoel but has a skeleton where trabs are essentially vertical and parallel, and where tile-like dermal spicules form a prominent layer interrupted only intermittently by coarse ostia. More similar is *Calycocoelia* Bassler, 1927, from the Ordovician of Nevada. It is a tubular form with regular vertical rows of inhalant ostia in the regular skeleton that has gently upward divergent trabs in moderately open skeletons.

Lissocoelia Bassler, 1927, also originally described as an Ordovician sponge of Nevada, is a branched form with a deep axial spongocoel in each branch. Radial canals are in variously regular vertical rows in a skeleton of somewhat irregularly oriented dendroclones, although organized trabs may be nearly at right angles to the dermal surface in the outer part of the skeleton. *Ozarkocoelia* is probably most similar to *Lissocoelia* but has ostia of radial canals irregularly spaced in the outer surface and a strongly divergent skeletal structure that is more regular than in the smaller, more obviously branched, species of *Lissocoelia.*

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

OZARKOCOELIA IRREGULARIS
Cullison, 1944
Plate 1, figs. 7, 9; Plate 3, fig. 2;
Plate 4, figs. 5, 6; Plate 5, figs. 4, 5

Ozarkocoelia irregularis CULLISON, 1944, p. 47–48, pl. 24, figs. 1–8.

Archaeoscyphia sp. TOOMEY, 1970, p. 1330, fig. 14.
Lithistid sponge, TOOMEY and NITECKI, 1979, fig. 8a.

Diagnosis.—Small, cylindrical to steeply obconical, rarely branching sponges with a round tubular central spongocoel in each branch that is 35–60% of branch diameter. Surface smooth with poorly developed irregular annulations. Radial canals essentially horizontal, uniformly packed, but not in regular vertically stacked series, in more or less checkered pattern and to 0.4 mm in diameter. Surface of pinnation essentially at gastral margin; trabs ascend steeply and flex sharply, becoming subhorizontal through most of the thin walls, meeting the dermal margin at essentially 90°.

Trabs robust, to 0.06–0.08 mm in diameter and spaced three to four trabs per millimeter, measured horizontally in transverse sections. Dendroclones commonly I-shaped, closely spaced, and relatively robust, bridging between adjacent trabs.

Description.—The most informative specimen of the species in our collection, USNM 480560, is a cylindrical sponge approximately 65 mm tall. The uniform tubular sponge extends upward from a flared root-like base of attachment to an incomplete summit. It is more or less uniformly 12 mm in diameter from above the basal attachment zone to the preserved upper end. It is pierced throughout by a somewhat elliptical tubular spongocoel, 5.5 by 6.5 mm in diameter, with smooth to weakly undulating gastral surface. Walls are 3.5–5.5 mm thick so the spongocoel amounts to 45–54% of the diameter of the sponge.

The dermal surface is smooth except for one round surficial node or incipient branch, near mid-height, that extends 2 mm out from the surface and is approximately 4 mm in diameter. Root-like structures at the base are somewhat digitate, with elements 2 or 3 mm across and long, apparently attached to coarse skeletal debris, although the fragment and that debris may have been transported.

Canals principally radially arranged and commonly 0.20–0.30 mm in diameter, with gastral pores somewhat larger than canals in the middle of the wall, or in the dermal area where some are 0.15 mm across. Canals are uniformly packed, though not in vertical nor horizontal series, with most separated by one trab between openings in the midwall. Canals are essentially horizontal, parallel to trabs in the outer part of the wall, but in transverse section remain essentially horizontal, to empty into the spongocoel, also in uniformly packed but not vertically stacked positions. These canals occur two or three per millimeter measured horizontally and vertically.

The surface of pinnation is essentially at the gastral margin to perhaps 1 mm in from the gastral margin. Trabs diverge sharply upward, but flex abruptly to become subhorizontal through most of the wall and meet the dermal surface essentially at right angles. Individual trabs appear robust, 0.06–0.08 mm in diameter in mid-wall and on dermal ends where they can be easily measured. They are formed by merger of tips of rung-like, I-shaped dendroclones that are approximately 0.04 mm in diameter and spaced 0.06 mm apart, so that essentially one dendroclone occurs per 0.10 mm in any of the ladder-like trab series. Dendroclones are to approximately 0.15 mm long where they bridge between adjacent trabs in the fine-textured skeleton composed of relatively small spicules.

A small fragment of the sponge occurs on USNM 480550, associated with other taxa, as a diagonal section in what was apparently a branched specimen. The stem is 6.0–6.5 mm across and includes an open spongocoel approximately 2.5 mm across. The dense, closely spaced, skeletal structure characteristic of the species is cut parallel to some of the coarse trabs, on one side, but at high angles to the trabs on the other side of the base of the branch. Individual trabs are robust and 0.08–0.10 mm in diameter. They are closely spaced and occur approximately five per millimeter, measured at right angles to the trab direction. They are approximately 0.10 mm apart in the compact skeleton. Small dendroclones bridge that distance from trab to trab and occur 10–12 per millimeter in a single series. These dendroclones range 0.03–0.04 mm in diameter in the weathered surface. Details of clads are not preserved in the moderately coarsely crystalline replacement. Spicules appear to be dominantly I-shaped dendroclones, but some Y-shaped forms may occur, particularly associated with some of the larger canals that are 0.4–0.6 mm across in the interior of the specimen. Sizes of the radiating canals are difficult to determine because of angles at which the weathered surface cut through the specimen.

Transverse diagonal sections of the species are included on thin sections FMNH PP22861 (figured by Toomey and Nitecki, 1979, fig. 8a) and PP22862, parallel sections of the same specimen. These show a tubular sponge 15–18 mm across, with a spongocoel 6–7 mm across, and somewhat more elongate because of the diagonal nature of the section. The walls clearly show two zones. The outer zone is approximately 1.5 mm thick where the coarse trabs are essentially horizontal and range 0.10–0.20 mm in diameter, with most approximately 0.10–0.12 mm across. In this same zone the short "robust" dendroclones are approximately 0.10 mm long and apart in the ladder-like series. In the inner part of the wall the trabs are cut transversely or somewhat diagonally because they are oriented at high angles to the plane of the thin section. They do show radiating dendroclones that are characteristic of this and related

sponges. The abrupt flexure from upward divergence to essentially horizontal in the skeletal structure is well demonstrated by the zonation in the wall in the thin section.

Smaller specimens, on thin section FMNH PP22832, include a sponge approximately 9 mm in diameter, that is cut essentially transversely. It also shows the thickened trabs, approximately 0.10–0.12 mm in diameter, connected by short, thick, dendroclones whose shafts are 0.10–0.20 mm long and 0.04 mm in diameter. They are robust-appearing and closely spaced, only 0.06–0.12 mm apart in the characteristic skeletal structure.

A somewhat more irregularly cut specimen occurs on thin section FMNH PP22858, and has the diagnostic, robust, parallel trabs of the outer part of the wall and the short interconnecting dendroclones characteristic of the species. On the same thin section, a small sponge 10–11 mm in diameter, with a spongocoel approximately 5 mm in diameter, also shows the coarse trabs and short dendroclones. Prominent canals near the gastral margins in the tangentially cut part of the section are 0.5 mm in diameter. Similar canals in the sponge on thin sections FMNH PP22861 and 22862 are distinctly radial and straight. They range 0.3–0.4 mm across in the outer dermal area, but appear to widen somewhat gastrally.

Discussion.—A few specimens of small cylindrical tubular sponges from the McKelligon Canyon Formation are placed in *Ozarkocoelia irregularis* Cullison, 1944, with moderate confidence. These are relatively thin-walled sponges with radial canals irregularly stacked in skeletons that have relatively robust trabs that are essentially horizontal in the outer parts of the wall. These trabs and the closely spaced short dendroclones contrast with more widely spaced elements in the tubular *Calycocoelia protera* n. sp., with which they are associated.

Small specimens of *Archaeoscyphia* have an annulate form and contrast with the more smoothly tubular *Ozarkocoelia*. Species of *Archaeoscyphia* in the El Paso fauna also have more open-textured anthaspidellid skeletons that have regularly stacked radial canals.

Radial canals in our material are of essentially the same size and distribution as in outer walls of type specimens from Missouri (Cullison, 1944, p. 47). Inner parts of canals are also densely packed in our specimens, but such are reported as arranged in regular rows in the type specimens (Cullison, 1944, p. 47), in description of the genus. In other respects, however, the McKelligon Canyon sponges are like the types, which are of nearly the same age from the School Mine Ledge of the Rich Fountain Formation, or Jefferson City Dolomite, from southern Missouri.

Calycocoelia murella Johns, 1994, and *Calycocoelia protera* n. sp. are also small subcylindrical forms, but they have radial canals in vertically stacked regular series and much less compact skeletons. The trabs in *C. murella* diverge upward from a zone of pinnation within the wall or near the gastral surface and intersect dermal surfaces at 45° to 60°, in contrast to trabs that are normal to the dermal surface in outer parts of the wall and parallel to the gastral surface in inner parts of *Ozarkocoelia irregularis.* Specimens of the new species *Calycocoelia protera* and *Calycocoelia murella* Johns, 1994, have considerably thinner walls and a more open regular skeletal structure than do stems of *Ozarkocoelia irregularis* of essentially the same size.

Material.—The most complete and well-defined specimen in our collection, USNM 480560, is from locality L-2. An additional fragment from Locality 11056 is associated with *Patellispongia oculata* Bassler, 1927, and a fragment of *Calycocoelia protera* n. sp., on USNM 480550. A specimen included in the species with some question occurs on USNM 480561 from Locality 11052. Thin section FMNH PP22832 is from mound rocks in the mound layer in Cloud and Barnes (1948) unit B_1, as are thin sections FMNH PP22858, 22859, 22861, and 22862. The latter two are from McKelligon Canyon, and the former two are from the Scenic Drive section in the southern tip of the Franklin Mountains. All are from the McKelligon Canyon Formation.

OTHER TYPES OF SPONGES

Spicules of hexactinellid and heteractinid sponges and probable demosponge monaxons were figured from mound rocks of the McKelligon Canyon Formation by Toomey and Nitecki (1979, figs. 14a–c). They suggest the occurrence of hexactinellid sponges by presence of large monaxon root-tuft spicules (fig. 14a), but more distinctively by spicules showing four tangential rays as fragments in the muddy matrix (fig. 14b). No moderately complete hexactinellids nor moderately intact fragments of hexactinellid skeletal nets were recovered in our collections, nor apparently were they by Toomey and Nitecki (1979).

Numerous monaxial spicules, probably oxeas, are scattered throughout matrix in the mound rocks of Cloud and Barnes (1948) unit B_1. They are common in all FMNH thin sections of the mound rocks, but do not occur in the coarse grainstones of the channels that cut the mounds. In some bioclastic units the spicules occur as organic elements in transported grains, as for example in FMNH 22823. In the mound rocks they are usually irregularly oriented and show as only diagonally-cut sections of isolated spicules. These spicule sections range up to 0.16 mm in diameter, although most are only half that size or smaller. Some low-angle oblique cuts, up to 2 mm long, through what appear to be oxeas occur scattered throughout the matrix. They probably represent dissociated

spicules that may have been locally aligned by gentle currents rather than as parts of skeletal nets. These types of spicules appear to have been utilized in linings of burrows, 2 or 3 mm in diameter, but no certain evidence of intact skeletal relationships was observed. These spicules were probably from loosely spiculed demosponges that are otherwise unrepresented in our collections.

Class CALCAREA Bowerbank, 1884
Order HETERACTINIDA De Laubenfels, 1955
Family ASTRAEOSPONGIIDAE Miller, 1889
Genus ASTRAEOCONUS Rietschel, 1968
(?)ASTRAEOCONUS CALCARIUS
Rietschel, 1968
Plate 3, figs. 4, 5

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

Diagnosis.—"Kleine rüben- bis birnförmige Schwammkörper mit zentralem Hohlraum. Die Wand wird von mehreren Lagen dicht gepackter, kleiner octactinellider Nadeln aufgebaut." (Little turnip- to pear-shaped sponge body with central spongocoel. The wall is constructed of several layers of thickly packed, small octactinellid spicules.) (Rietschel, 1968, p. 19).

Description.—A small cluster of sexiradiate spicules from Locality 11052 occurs on USNM 480563. The cluster is approximately 5 mm in diameter and consists of 8 nearly complete spicules and other additional rays. The sexiradiate spicules are unfused and generally slightly arched so that ray tips are buried or interdigitate with those of adjacent spicules. Rays of major spicules are generally similarly oriented so that rays of adjacent spicules are subparallel, although in a layered wall.

Coarsest or first-order spicules have six tangential rays to 2.25 mm long, although most are fragments only 1.0–1.6 mm long. They taper distally to sharp points from basal ray diameters of 0.08–0.10 mm. They radiate at approximately 60° from adjacent rays and from a central disc approximately 0.40–0.60 mm in diameter. Bases of rays are in virtual contact around the periphery of the central disc.

Somewhat smaller second-order spicules appear beneath and occasionally interdigitate with rays of first-order spicules. Second-order spicules have central discs approximately 0.3 mm in diameter and rays up to 1.2 mm long. These rays have basal diameters near the central disc of 0.06 mm and, like those of the larger spicules, taper to sharp points.

First-order spicules are 0.7–1.5 mm apart, from center-to-center, and second-order spicules lie between them and beneath them in a more gastral position, judging from similar gastral curvature of rays in spicules of related genera. Triangular openings occur in the moderately loosely packed skeleton between rays of the two orders of spicules preserved.

We recovered an isolated small sexiradiate in matrix on USNM 480562, from Locality 11050. It has a central disc 0.08 mm in diameter, from which radiate six, straight, equally spaced tapering rays to 0.2 mm long and with basal diameters of 0.04–0.05 mm.

Discussion.—Only the fragment of multiple spicules and an isolated small similar sexiradiate spicule represent the species in our collections. Toomey and Nitecki (1979, fig. 14c) also show what appears to be a relatively robust sexiradiate that has six radiating, essentially horizontal, straight rays in a common plane. Additional rays of what may have been an octactine of a heteractinid sponge are not preserved in the thin section.

Rietschel (1968) described *Astraeoconus calcarius* based on specimens from the Pooleville Member of the Middle Ordovician Bromide Formation from the Criner Hills in Oklahoma. The holotype of the species is a laterally flattened obconical sponge, approximately 20 mm tall, that has a flattened width of approximately 10 mm at the upper end. The thin wall, 0.5–2.0 thick, is composed of sexiradiate spicules with reported diameters of 0.6–1.0 mm. These spicules are somewhat smaller than those represented in the cluster from El Paso, but they appear to have the same relative orientation and packing as seen in our material. Because of that, and the general form of the spicules, we have placed our specimens within the monospecific genus, but with question because of the incompleteness of our material.

Toquimiella (Rigby, 1967) was initially described from the lower part of the Ordovician section from Nevada, but that heteractinid has sharply flexed, geniculate-appearing, rays with a form quite different from the relatively robust, though small, spicules in our collection and the one figured by Toomey and Nitecki (1979).

The Middle Ordovician *Asteriospongia* Rigby, 1977a, was based on material from Middle Ordovician beds from Melville Peninsula and Baffin Island in eastern Canada. This thick-walled, inverted bowl-shaped sponge also has a skeleton made of small octactines or octactine-based derivatives, such as sexiradiates, although the outer part of the wall in that genus is dense as a result of calcareous overgrowths on spicules. *Astraeospongium* is a much more common sponge of the family, but it ranges down only into the Upper Ordovician.

Constellatospongia Rigby, 1977b, is a later Ordovician sponge from the Churchill River Group, from near Churchill in Manitoba, in the northern part of the Hudson

Bay Lowland. This thick-walled, saucer-shaped sponge, however, has spicules that are relatively fine octactines that commonly have grotesque overgrowths and are clearly not like the McKelligon Canyon spicules.

The spicules from the McKelligon Canyon Formation are probably of *Astraeoconus,* but we cannot be certain because only the small cluster and two isolated spicules have been recovered. Those spicules do represent the occurrence of the Heteractinida, however, and the family Astraeospongiidae Miller, 1889, in the El Paso beds.

Material.—The small cluster of spicules, USNM 480563, is from Locality 11052, and the isolated spicule, USNM 480562, is from Locality 11050. These are the only representatives of the Heteractinida that we have recognized in our collections.

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PLATE 1

Anthaspidella, Archaeoscyphia, Calycocoelia, and *Ozarkocoelia* from El Paso Group rocks, southern Franklin Mountains, Texas

Figure *1*, *Anthaspidella clintoni* Bassler, 1927, showing some gastral canal clusters filled with light-gray matrix forming an incomplete ring in the lower center of photograph, and less well-defined similar canals in the depression, marked by an arrow, on the gastral surface of the broadly obconical sponge, USNM 480535, Locality L-1, McKelligon Canyon Formation, x 1.

Figure 2, (?)*Anthaspidella clintoni* Bassler, 1927, a broadly funnel-shaped specimen viewed from below, showing the prominent cluster of axial exhalant canals where the basal part of the sponge has been broken away and the radiating skeletal structure of the dermal part of the skeleton, USNM 480536, Locality L-5, McKelligon Canyon Formation, x 1.

Figures *3–5*, *Archaeoscyphia minganensis* Billings, 1859, *3, 4*, USNM 480537A, Locality 11053, McKelligon Canyon Formation, *3*, reverse polished side of the block, polished and etched, shows a diagonal cut through the sponge wall, tangential to the spongocoel in the lower part, but through the thin walls in the upper part, which show the gentle, widely spaced annulations characteristic of the species, x 1; *4*, weathered front of the block showing dimensions of the spongocoel, walls, and annulations in the lower part, and a tangential view of the gastral surface in the upper part, where the vertically stacked exhalant canals form the light-gray matrix-filled grooves, x 1. *5*, Section through one thin wall, arrow, showing low and distant annulations, associated with other sponge debris, USNM 480538, Locality L-2, McKelligon Canyon Formation, x 1

Figures *6, 8, Calycocoelia protera* n. sp., *6*, holotype showing the thin-walled cylindrical form of the species, light matrix fills the axial spongocoel, USNM 480546, Locality F-1, Victorio Hills Formation, x 1; *8*, paratype, a transverse section, arrow, showing the general dimensions of the spongocoel and thin wall, USNM 480549, Locality 11056, McKelligon Canyon Formation, x 1

Figures *7, 9, Ozarkocoelia irregularis* Cullison, 1944, *7*, subcylindrical specimen with an expanded root-like base and thick walls, matrix fills the spongocoel, which has been cut diagonally in the upper part of the specimen, a low node marks the upper left dermal part of the skeleton, USNM 480560, Locality F-1, Victorio Hills Formation, x 1; *9*, a transverse section, arrow, showing the general tubular form of the species, with moderately thick walls and a broad, open, spongocoel, associated with other sponge and fossil debris, USNM 480561, Locality 11052, McKelligon Canyon Formation, x 1.

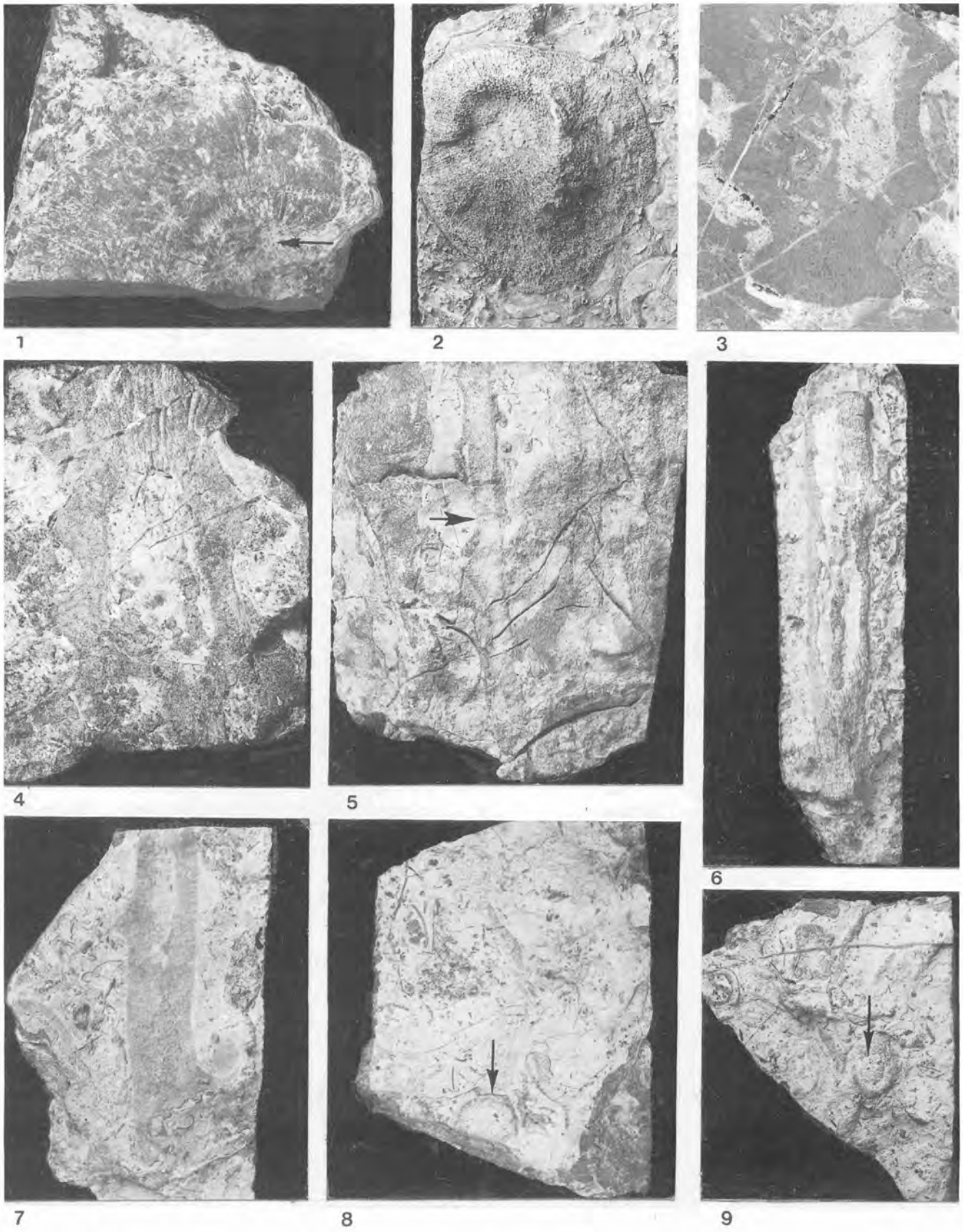
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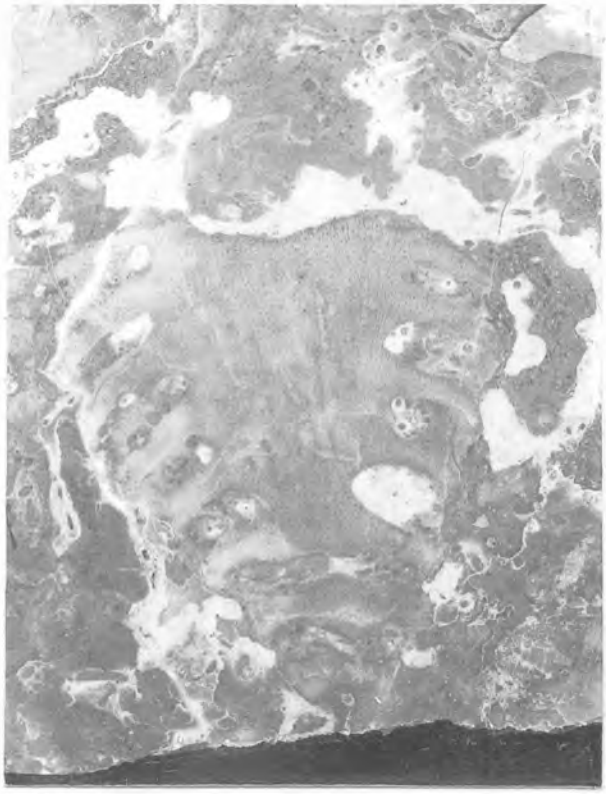
PLATE 2

Archaeoscyphia pulchra (Bassler, 1927) and *Archaeoscyphia minganensis* (Billings, 1859) from the McKelligon Canyon and Victorio Hills formations in the southern Franklin Mountains near El Paso, Texas.

Figures *1–3, Archaeoscyphia pulchra* (Bassler, 1927); *1,* cut and etched subvertical section, tangential to the outer wall in the upper part and through some of the annular ridges in the lower part, those annular ridges form the sloping shelf-like margins along both sides of the sponge, USNM 480540, Locality 11056, McKelligon Canyon Formation, x 1; *2,* weathered transverse section, seen from below, showing relatively fine convergent exhalant canals filled with light matrix, around the matrix-filled spongocoel; two dark annular ridges are separated by light matrix in the upper part, USNM 480543, Locality F-2, McKelligon Canyon Formation, x 1; *3,* weathered transverse section from above, showing the large central spongocoel and branched, convergent, horizontal exhalant canals; ragged margin is produced by irregular annular ridges, USNM 480542, Locality L-2, McKelligon Canyon Formation, x 1.

Figure *4, Archaeoscyphia minganensis* Billings, 1859, subtransverse section shows coarse, straight, horizontal canals and the large spongocoel, USNM 480539, Locality F-1, Victorio Hills Formation, x 1.



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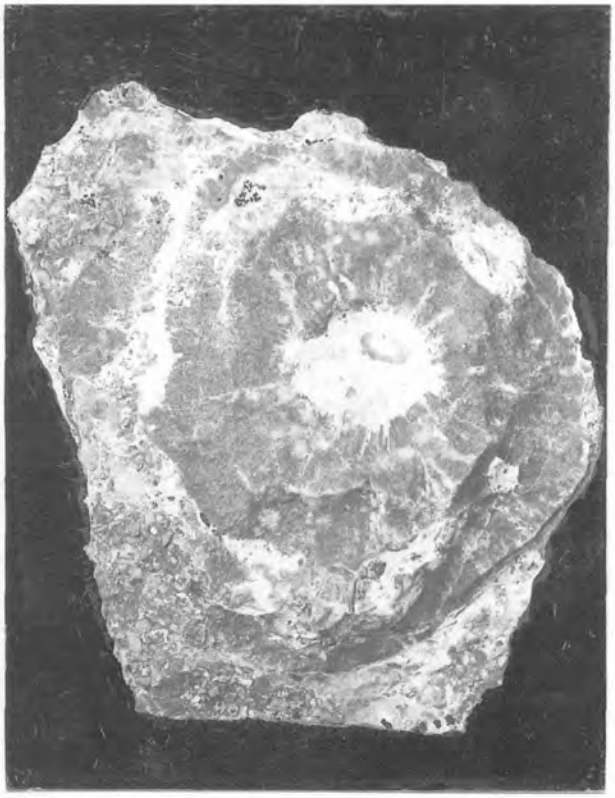

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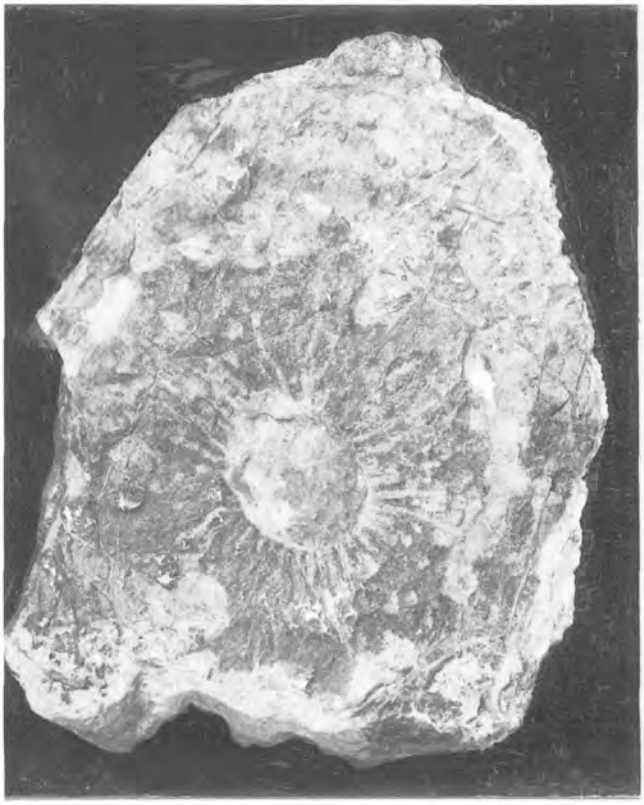

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PLATE 3

Patellispongia, Calycocoelia, Ozarkocoelia, Astraeoconus(?), and *Zittelella*(?) from the Victorio Hills and McKelligon Canyon formations in the southern Franklin Mountains near El Paso, Texas.

Figures *1–3, 6, 7, Patellispongia oculata* Bassler, 1927, *1,* gastral(?) surface of the calcareous plate showing light matrix-filled ostia of canals aligned in radial series, USNM 480553, Locality F-1, Victorio Hills Formation, x 1; *2,* vertical section of *Patellispongia oculata* (P) with lower stems and expanded horizontal upper plate, with diagonal slice through an associated plate of the species (p) near the base and in the upper and left center; a paratype of *Calycocoelia protera* n. sp. (C), above, that shows the thin wall and large spongocoel in diagonal section; and *Ozarkocoelia irregularis* Cullison, 1944, (O) near the base, with a small spongocoel and dense skeleton; all on USNM 480550, Locality 11056, McKelligon Canyon Formation, x 1; *3,* dark thin plates of the species as aligned clasts that are cut vertically and show variations in thicknesses of the plates, USNM 480556, Locality 11056, McKelligon Canyon Formation, x 1; *6,* gastral(?) surface of small flat fragment with coarse ostia as dark, radially aligned, depressions, USNM 480552, Locality F-1, Victorio Hills Formation, x 1; *7,* small fragment with relatively fine ostia on the gastral(?) surface, USNM 480554, Locality F-1, Victorio Hills Formation, x 1.

Figures *4, 5,* (?)*Astraeoconus calcarius* Reitschel, 1968, skeletal fragment, a cluster or two orders of oriented sexiradiate spicules of the thin wall, USNM 480563, Locality 11052, McKelligon Canyon Formation, x 10, *5,* isolated sexiradiate spicule, USNM 480562, Locality 11050, McKelligon Canyon Formation, x 20.

Figure *8, Zittelella*(?) sp., longitudinal oblique cut surface, with sponge partially outlined by light dolomite-filled burrows; the relatively thin walls of the weakly annulate sponge surround an axial cluster of dark, matrix-filled, vertical axial canals, USNM 480445A, Locality 11056, McKelligon Canyon Formation, x 1.

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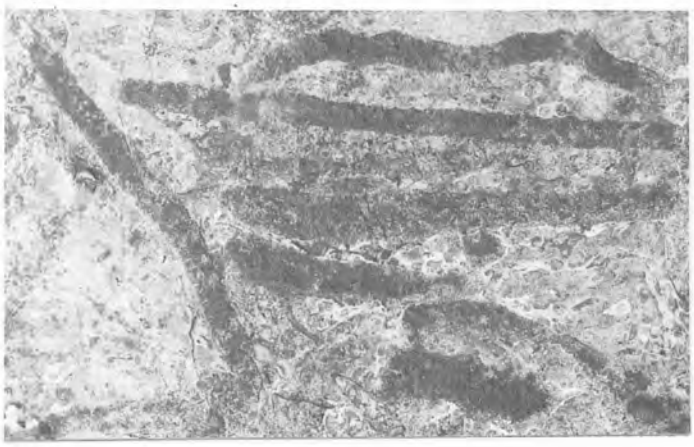

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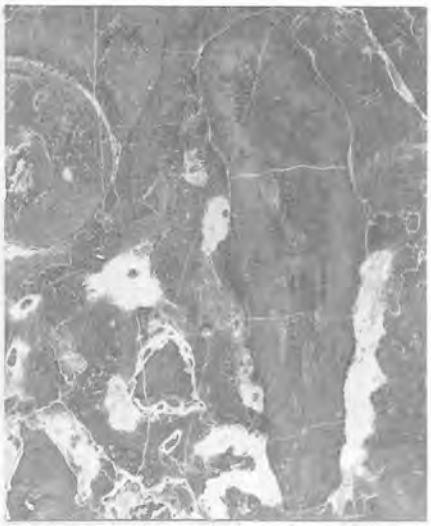

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PLATE 4

Patellispongia, Calycocoelia, Ozarkocoelia, and *Anthaspidella* from the McKelligon Canyon Formation, southern Franklin Mountains, Texas.

Figures *1–3, 7, Patellispongia oculata* Bassler, 1927, McKelligon Canyon Formation; *1,* weathered surface of upper left of basal stem and adjacent part of lateral plate showing upward divergence of trabs, locally connected by ladder-like dendroclones, as in the upper center and upper right, on USNM 480550, x 10; 2, lateral horizontal plate with a plane of pinnation in the lower part, with trabs diverging upward to the gastral surface, and downward to the dermal surface, plate on right part of stem shown in *1* and in *5.2,* on USNM 480550, Locality 11056, x 10, 3, horizontal weathered section through part of a plate showing radiating skeletal structure as roughly horizontal trabs, with scattered coarse canals, as for example, the dark opening in the upper center, on USNM 480550, Locality 11056, x 10; 7, weathered dermal surface showing scattered inhalant ostia as larger circular openings, and smaller openings between trabs, which are essentially normal to the surface and interconnected with thin dendroclones, perhaps best shown on the right, USNM 480553, from Locality 11056, x 10.

Figure *4, Calycocoelia protera* n. sp., paratype, a transverse section showing the relatively large spongocoel and the open-textured skeletal net of the wall with cross-sections of the steeply ascending trabs interconnected by moderately long dendroclones, on USNM 480550, Locality 11056, McKelligon Canyon Formation, x 10.

Figures *5, 6, Ozarkocoelia irregularis* Cullison, 1944, on USNM 480550, Locality 11056, McKelligon Canyon Formation; *5,* transverse section showing the relatively small spongocoel in the stem and moderately massive trabs near the right margin, x 10; *6,* diagonal section through part of a branch showing the robust trabs connected by short dendroclones, particularly in the upper right and center, x 10.

Figure *8, Anthaspidella clintoni* Bassler, 1927, photomicrograph of a cellulose peel of a vertical cut through the upper, nearly horizontal, outer part of the sponge, showing coarse trabs bent down toward the dermal surface, best shown on the left, with connecting dendroclones in the ladder-like structure, and with some trabs with traces of coring oxeas (arrow), USNM 480535, Locality L-1, McKelligon Canyon Formation, x 10.

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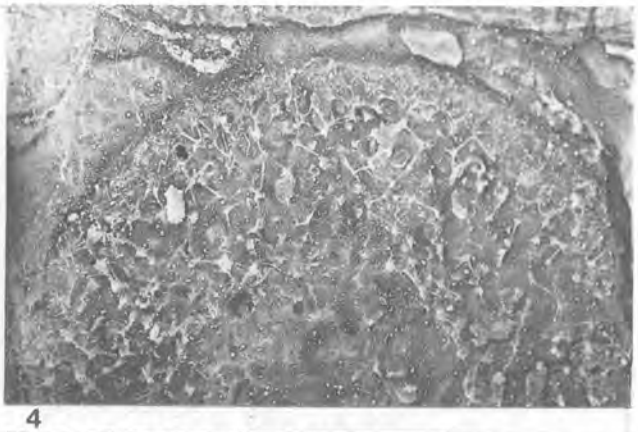

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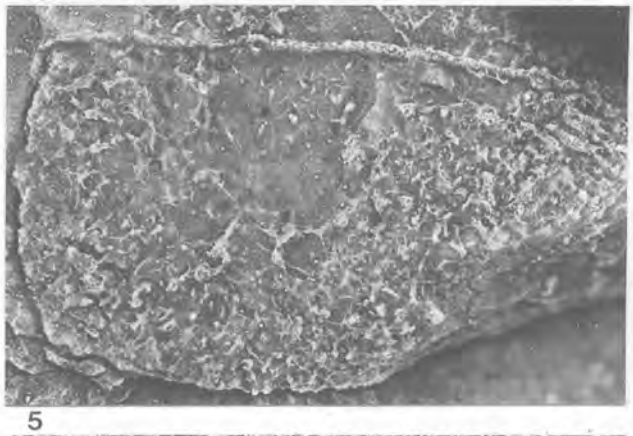

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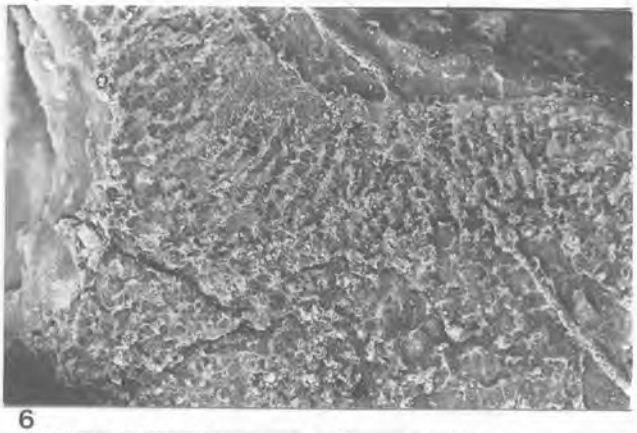

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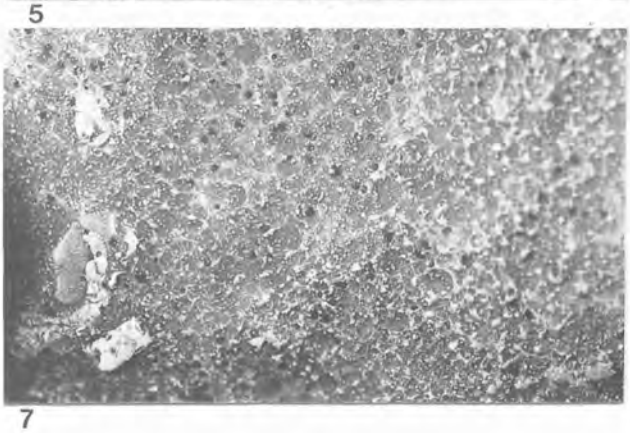

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PLATE 5

Photomicrographs of *Archaeoscyphia, Patellispongia, Ozarkocoelia, Calycocoelia,* and *Zittelella*(?).

Figures *1, 2, Archaeoscyphia pulchra* (Bassler, 1927), cellulose peel, USNM 480540 A, from Locality 11056, McKelligon Canyon Formation, x 10; *1,* vertical section showing upward divergence of trabs in the interior of the wall and somewhat more compact dermal structure in the near-basal part of an annulation, *2,* vertical section in the interior of the wall showing dark matrix-filled canals separated by parities that are commonly 2 trabs wide.

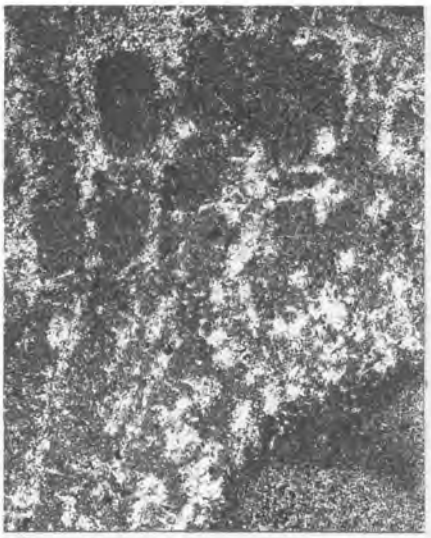
Figure *3, Patellispongia oculata* Bassler, 1927, weathered gastral surface showing regular radial series of dark matrix-filled canals, insertion of a new canal series, and thick parietal development between canals, USNM 480554, Locality F-1, Victorio Hills Formation, x 10.

Figures *4, 5, Ozarkocoelia irregularis* Cullison, 1944, projection prints of thin sections; *4,* diagonal transverse section showing moderately open skeletal structure of the inner part of the wall, with some matrix of the filled spongocoel showing on the right, and robust trabs of the outer part of the wall, on the left, composed of tips of short, closely spaced dendroclones that are ill-defined here; FMNH thin section PP22861, *Calathium* bed of McKelligon Canyon Formation, in McKelligon Canyon, x 10, *5,* transverse section of cylindrical sponge showing open skeletal structure of the inner part of the wall and dense trabs in the outer part, where short dendroclones are evident in the ladder-like structure in the upper left (arrow); FMNH thin section PP22832, from mound rocks in bed 15 of Cloud and Barnes (1948) in the Scenic Drive section, x 10.

Figure *6, Archaeoscyphia minganensis* (Billings, 1859), projection print showing the coarse radial canals separated by long dendroclones (arrow) within series and by thin parieties made of parallel trabs in the gently divergent structure; FMNH thin section PP22858, from mound rocks in bed 15 of Cloud and Barnes (1948), x 10.

Figure *7, Calycocoelia protera* n. sp., projection print of a diagonal section showing the relatively small spongocoel in the lower center, with open-textured skeletal structure of divergent trabs in the walls; FMNH thin section PP22857, from mound rocks in bed 15 of Cloud and Barnes (1948), x 10.

Figures *8, 9, Zittelella*(?) sp., photomicrographs of a cellulose peel, USNM 480498 B, from Locality 11056, McKelligon Canyon Formation, *8,* vertical section through the wall showing the upward divergent trabs and arched dendroclone pattern on the left, with matrix-filled inhalant canals showing best on the upper left; a matrix-filled vertical axial exhalant canal is cut longitudinally on the right, with a thin wall best defined on the right in the gastral part of the wall, x 10; *9,* vertical section showing parts of two coarse exhalant canals that occupy the axial region of the sponge; and the inner part of the wall with coarse, gently divergent, subvertical trabs, on the right, x 10.



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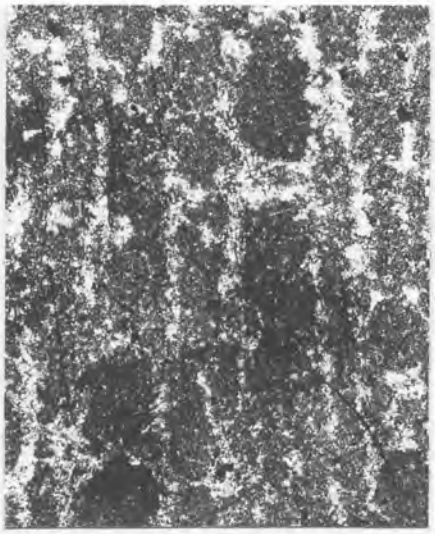

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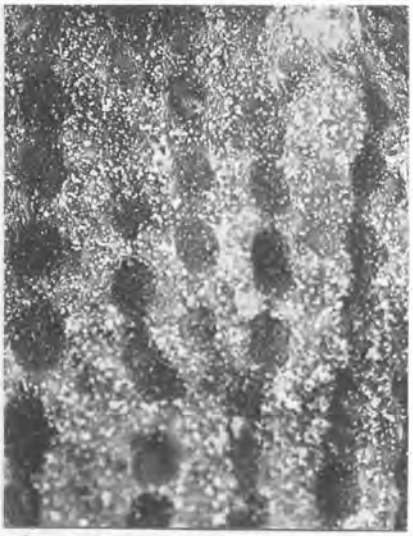

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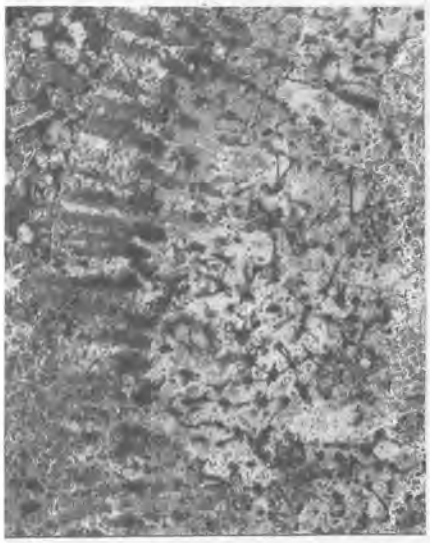

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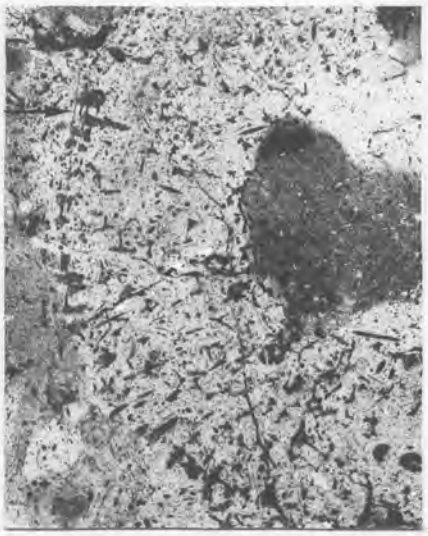

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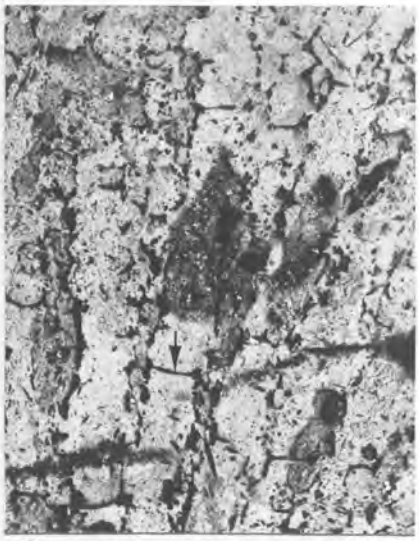

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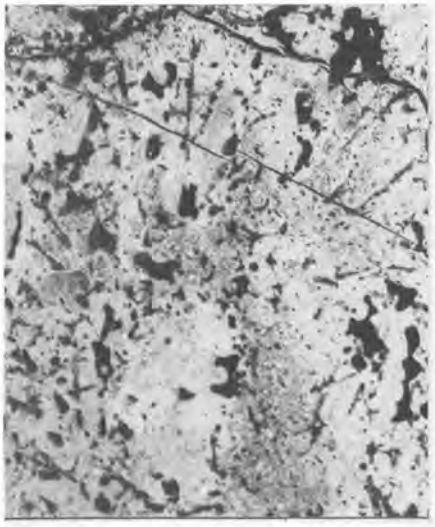

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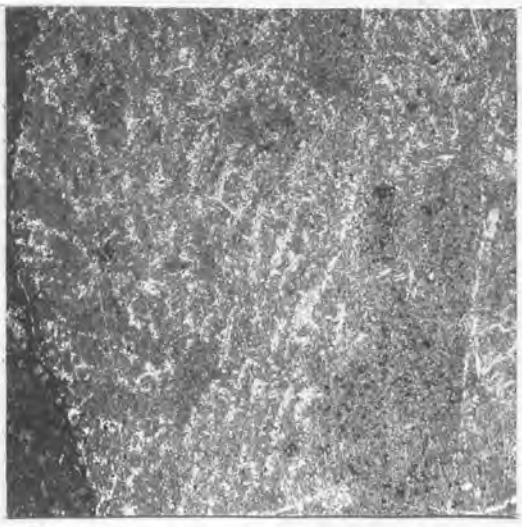

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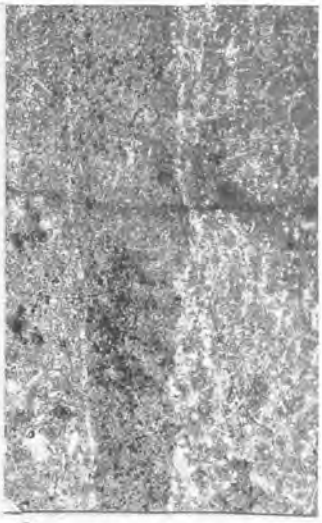

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