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Sponges of the Permian Upper Capitan Limestone Guadalupe Mountains, New Mexico and Texas

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ABSTRACT

Demosponge "sphinctozoans" and inozoid calcareous sponges are major constituents of the Upper Permian, Upper Capitan Limestone in the Guadalupe Mountains of New Mexico and Texas. Systematic description, taxonomy, and the stratigraphic distribution of these sponges are documented in collections from exposures of the Upper Capitan Limestone in the vicinity of Carlsbad Caverns in New Mexico. The fauna appears diverse on a local scale, but when compared to diversity of assemblages of similar age in Tunisia and in Southern China, the assemblage is species poor, with 34 species of "calcareous" sponges and demosponges. Whether this is a local time or geographic gradient must wait additional investigations of sponge faunas from older parts of the Guadalupian series in the Guadalupe Mountains, as well as in localities southward in Texas and Mexico. Upper Capitan exposures near Carlsbad Caverns are at the northernmost end of the long Delaware Basin that was restricted by the Hovey channel to the south. As a consequence of either that restricted ecologic limitation or a time stratigraphic factor, Late Capitan assemblages are characterized by abundant individuals of only a few endemic species, and by relatively primitive cosmopolitan genera and species that were able to persist beyond the ranges of more specialized forms.

Species in the collections include the ceractinomorphid porate "sphinctozoans" *Cystothalamia guadalupensis* (Girty, 1908a), *Amblysiphonella* cf. *A. merlai* Parona, 1933, *Amblysiphonella* species A, *Amblysiphonella* species B, *Discosiphonella mammilosa* (King, 1943), *Tristratocoelia rhythmica* Senowbari-Daryan and Rigby, 1988, *Exaulipora permica* (Senowbari-Daryan, 1990), type species of the new genus *Exaulipora*, *Parauvanella minima* Senowbari-Daryan, 1990, and *Platythalamiella*(?) sp., all from the families Sebargasiidae Steinmann, 1882, and Colospongiidae Senowbari-Daryan, 1990. The family Solenolmiidae Engeser, 1986 is represented by the new species *Preverticillites parva*.

Among the ceractinomorphid Aporata, the family Thaumastocoeliidae Ott, 1967 is represented by *Sollasia ostiolata* Steinmann, 1882, and *Girtyocoelia beedei* (Girty, 1908b). The sclerospongiid Guadalupiidae Termier and Termier, in Termier, et al., 1977a, which includes the family Guadalupiidae Girty, 1908a, is represented by the species *Guadalupia zitteliana* Girty, 1908a, and *Guadalupia explanata* (King, 1943), *Lemonea cylindrica* (Girty, 1908a), *Lemonea conica* Senowbari-Daryan, 1990, *Lemonea polysiphonata* Senowbari-Daryan, 1990, and the new species *Lemonea exaulifera* and *Lemonea micra*.

The Calcarea are represented within the subclass Aspiculata Rigby and Senowbari-Daryan, 1996a, and order Inozoida Rigby and Senowbari-Daryan, 1996a, by the Auriculospongiidae Termier and Termier, 1977a, which includes the large *Gigantospongia discoforma* Rigby and Senowbari-Daryan, 1996b, and *Cavusonella*

caverna Rigby, Fan, and Zhang, 1989b. Also included are the Peronidellidae Wu, 1991, represented by the species *Peronidella* cf. *P. rigbyi* Senowbari-Daryan, 1991, *Peronidella(?) delicata* new species, and *Minispongia constricta* (Girty, 1908a), and the new genus and species *Bicoelia guadalupensis*. The family Virgulidae Termier and Termier, 1977a, is redefined to include the genus *Virgola* and the species *Virgola neptunia* (Girty, 1908a), and *Virgola rigida* (Girty, 1908a). The family Polysiphonellidae Wu, 1991, (not Polysiphonellidae Belyaeva in Boiko, et al., 1991) is interpreted to include most of the subfamilies originally included by Rigby and Senowbari-Daryan (1996a) in the Virgulispongiidae. The sponge *Grossotubinella parallela* Rigby, Fan, and Zhang, 1989b is included there in the Preeudinae, with *Pseudovirgula tenuis* Girty, 1908a.

Heliospongid demosponges are represented in the Upper Capitan by *Heliospongia ramosa* Girty, 1908b, *Heliospongia vokesi* King, 1943, and *Neoheliospongia*(?) cf. *N. typica* Deng, 1981. Fossils of unknown taxonomy, possibly sponges, hydrozoans or algae, are included in Form A and Form B.

INTRODUCTION

Sponges of the Capitan Limestone in the Guadalupe Mountains of western Texas and New Mexico (Figs. 1–4) constitute one of the remaining undescribed major Permian sponge assemblages of the world. The thrust of the present paper is principally a taxonomic investigation of these sponges from the Upper Capitan Limestone exposed in New Mexico near Carlsbad Caverns (Fig. 2), as a step towards understanding their systematic paleontology and distribution. Interpretation of paleoecologic relationships, abundance, orientations, and community structure is the thrust of accompanying efforts by Fagerstrom and Weidlich (Fagerstrom, et al., 1995; Weidlich, et al., 1995; Senowbari-Daryan, et al., 1995). Since the pioneer work of Girty (1908a), most researchers on the Permian deposits in the Guadalupe Mountains have recognized that fossil sponges are relatively common in the Capitan Limestone, but despite their importance, little detail systematic paleontology has been done on them in the approximately ninety years since Girty's effort.

Newell, et al., (1953) added much to the documentation and interpretation of physical and lithologic relationships of the reef complexes, building on the monumental works of P.B. King (1934, 1942, 1948), but did no major systematic work on the sponges. Newell, et al., (1953, p. 227) listed fourteen sponge species from the Capitan Limestone but presented no quantitative data. Discussion of the sponges in their text does not allow any evaluation of the taxonomy or of the importance of sponges as potential reef-frame builders. Newell, et al., (1953) observed that calcareous sponges are abundant, however, in most reef exposures but not in all outcrops, and that the sponges were commonly crowded in upright positions surrounded and separated by calcareous sand matrix. They concluded that the sponges apparently functioned as rigid and effective traps for the loose sand. The sponges listed were identified from field samples and provide little additional information beyond their occurrence.

Finks (1960) described silicified demosponges and hexactinellid sponges from acid-etched residues from Guadalupe and Glass Mountains exposures (Fig. 1) and, incidentally, noted the presence of a few taxa of calcareous sponges. In general, however, the assemblages studied by Finks represent sponges of the lower and middle part of Capitan Limestone and equivalent beds, rather than the youngest assemblages like those examined here. Although Finks (1983, 1995) has extended his research in progress to the calcareous sponges, he has published only limited additional information on them.

Yurewicz (1977) made some general interpretations on the functions of sponges in the Capitan Limestone, as a whole, as part of a broad study. He provided no information on individual sponge species nor on their occurrences and, apparently, no major taxonomic investigations were made, for neither internal nor external morphological data, descriptions, nor illustrations necessary for identification of sponge genera and species in the Capitan Limestone were published.

Senowbari-Daryan (1990), as part of a major world-wide investigation of sphinctozoan sponges, described some sponge species collected from the Upper Capitan Limestone in the vicinity of Whites City and Carlsbad Caverns (Figs. 3, 4). His study concerned a major monographic analysis of taxonomy, evolution, biostratigraphy, and biogeography of all sphinctozoans described to 1990. His was the most recent major taxonomic work dealing with the calcareous sponges of the region, but his analysis was based upon only a moderately small and localized collection of Upper Capitan fossils. Since his paper was published, Rigby and Senowbari-Daryan (1996b) have described a large inozoid sponge, and Senowbari-Daryan and Rigby (1996a, b) have published papers on the occurrence of brachiopod mounds and the problematic *Lercaritubus* as part of the present study.

The assemblages described here include forms classically included in the sphinctozoans, as well as in the inozoids,

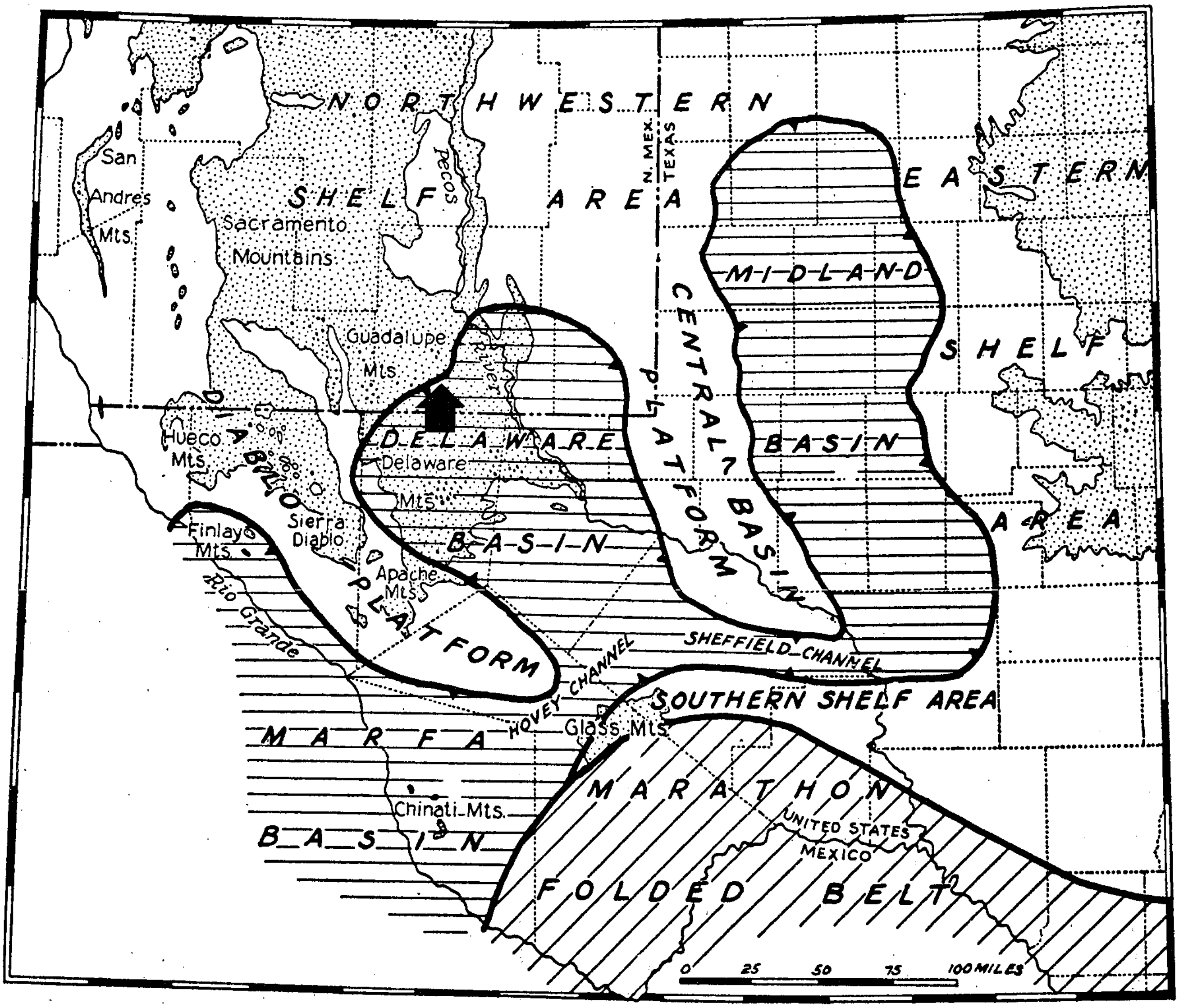

Figure 1. Structural features of Permian rocks in western Texas and southeastern New Mexico with the position of the area of our study indicated by the large arrow in the northwestern part of the Delaware Basin and the northeastern part of the Guadalupe Mountains in New Mexico (after P. B. King, 1934).

and both groups are investigated as part of our study (Senowbari-Daryan, et al., 1995).

STRATIGRAPHIC NOMENCLATURE AND INTERPRETATION

Cys (1971, 1977), Toomey and Babcock (1983, p. 237–250), Rigby and Millward (1988) and Rigby, et al., (1995) have summarized the history of geologic research in the Guadalupe Mountains and adjacent areas, and highlighted controversies surrounding different interpretations of the origin of the spectacular features exposed in the Guadalupe Mountains. Publication of mapping and stratigraphic analysis of the southern part of the mountain range by King (1948), and later investigation of the stratigraphy and paleoecology of the reef complexes by Newell, et al., (1953) provided a modern basic framework for more detailed later studies.

Hayes (1957, 1964) mapped the northern Guadalupe Mountains in New Mexico, including the areas of the localities from which our sponges were collected. Hayes and Koogle (1959) mapped the geology of the Carlsbad Caverns West quadrangle.

Tyrell (1969) summarized fusulinid occurrences in the Tansill-Capitan-Lamar carbonates and correlation of the

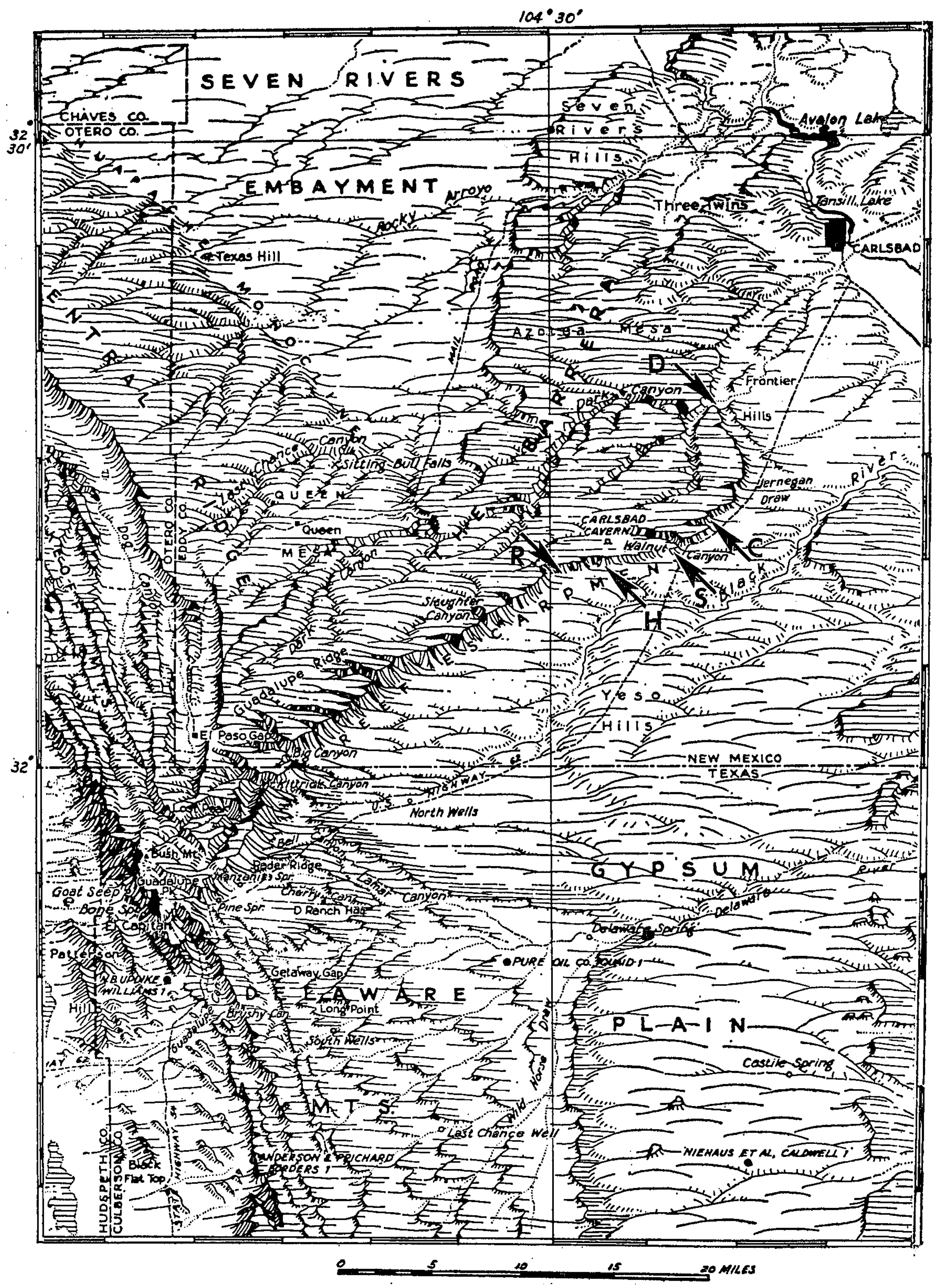

Figure 2. Geomorphologic sketch of the Guadalupe Mountains, the northern Delaware Mountains, and the Gypsum Plain in the northwestern part of the Delaware Basin, showing position of the major sample localities from which the sponges were collected: D, Dark Canyon; C, Chinaberry Draw; S, Sponge Window and Bat Cave Draw localities; H, Hackberry Draw; and R, Rattlesnake Canyon (modified from P. B. King, 1942).

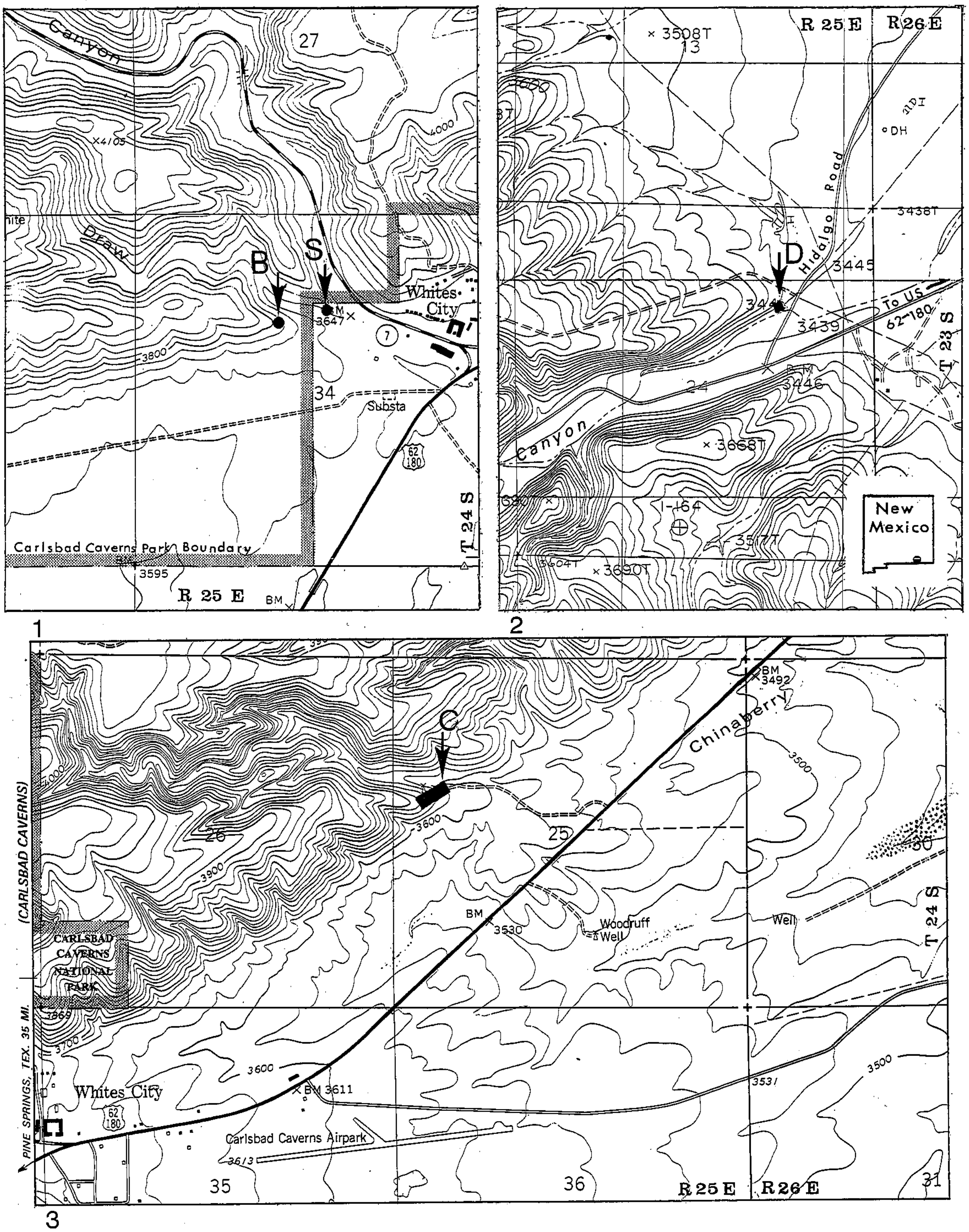

Figure 3. Locality maps showing positions of the sample grids and spot localilties where the fossil sponges for the study were collected. 1, *Position of the Bat Cave Draw (B) and Sponge Window (S) localities in the mouth of Bat Cave Draw, west of Whites City in the eastern part of the Carlsbad Caverns 7 1/2-minute Quadrangle, 1979. Samples UNSM 35246–35266 were collected in the canyon near the park boundary and in the Sponge Window area.* 2, *Dark Canyon Locality (D) showing position of the sample grid on the north edge of the mouth of Dark Canyon, in the central part of the Kitchen Cove Provisional 7 1/2-minute Quadrangle, 1985. Small inset of New Mexico in the southeast corner of the figure shows the general position of all 3 maps near the southern border of New Mexico.* 3, *Index map to the Chinaberry Draw sample grid in headwaters of the draw at the mouth of small canyon at the Guadalupe Escarpment, from the western part of the Black River Village 7 1/2-minute Quadrangle, 1979. All maps are at a scale of 1:24,000.*

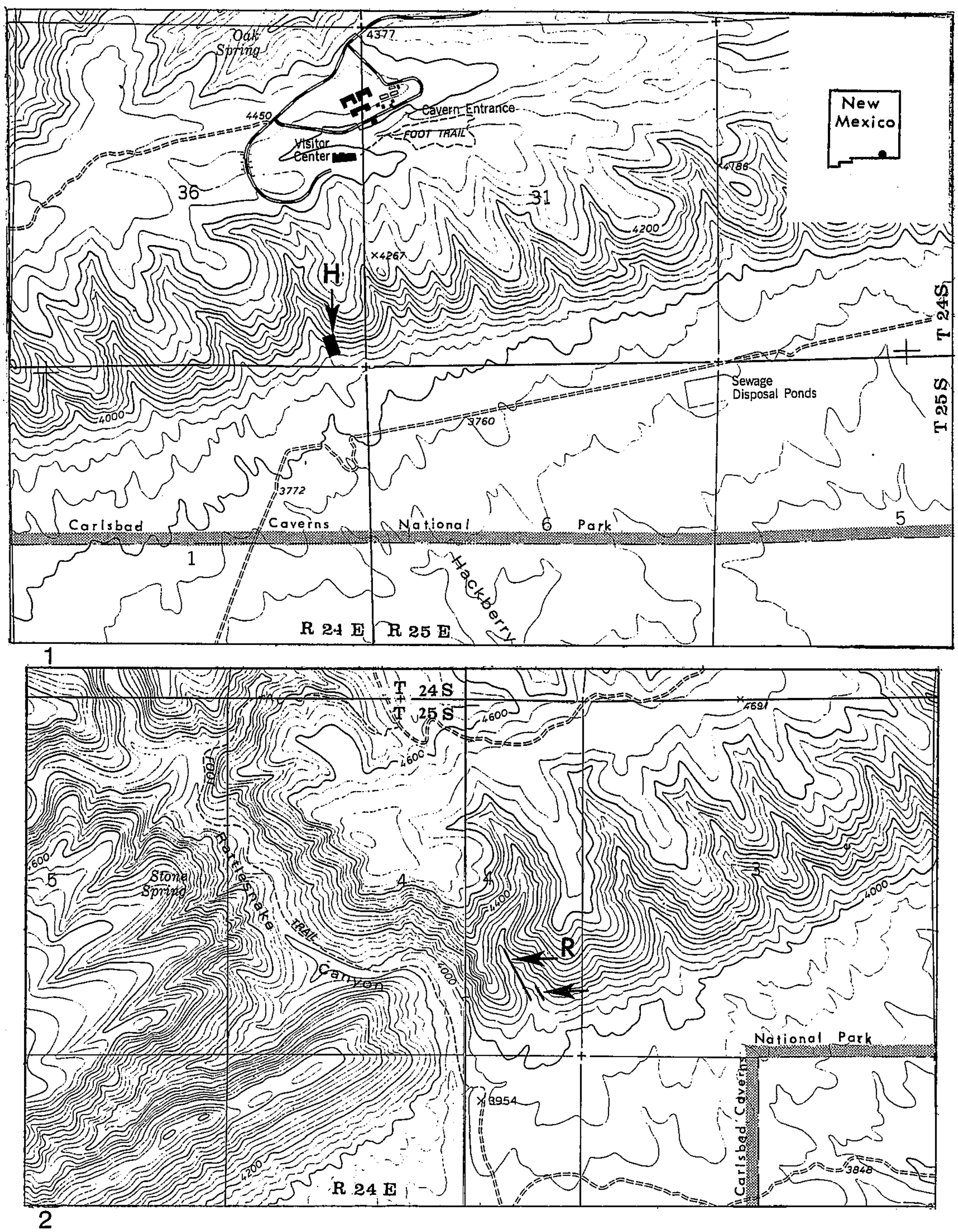

Figure 4. Locality maps to the Hackberry Draw and Rattlesnake Canyon sample localities from which the fossil sponges for the present study were collected. 1, *Position of the Hackberry Draw sample grid (H) in headwaters of the draw, south of the Carlsbad Caverns Visitors Center and Cavern entrance on the Carlsbad Caverns 7 1/2-minute Quadrangle, 1979. The sample grid is located at the base of the escarpment, on the eastern edge of the mouth of the small canyon near the headwaters of the draw. Inset map in the upper right shows the general position of both localities in southeastern New Mexico, near the southern border. Localities plotted on both maps are included in Carlsbad Caverns National Park.* 2, *Position of the two Rattlesnake Canyon traverses in the small canyon east of the mouth of Rattlesnake Canyon. The localities are in the westernmost part of the Carlsbad Caverns 7 1/2-minute Quadrangle, 1979. The left part of the map is part of the Serpentine Bends 7 1/2-minute Quadrangle, 1979. Scale of both maps is 1:24,000. Samples UNSM 35228–35245 were collected along the traverses.*

Northwestern Shelf to Delaware Basin sections (Figs. 1, 5). He (1969, p. 83) observed that the lower Tansill Formation is equivalent to the Lamar Member of the Bell Canyon Formation, in the co-occurrence of *Codonofusiella, Yabeina, Paradoxiella,* and *Reichelina* zones. These small fusulinids were described by Skinner and Wilde (1954, 1955) from the Lamar Member. *Reichelina* is common in the upper part of the Ocotilla Sandstone tongue of the Tansill Formation. Only *Paraboultonia* was reported from the upper Tansill Formation and from the post-Lamar limestone, a minor carbonate tongue above the post-Lamar sandstone at the top of the Bell Canyon Formation. The sponges described here are from the massive Capitan reef limestones equivalent to the upper Tansill beds characterized by *Paraboultonia.* These rocks are, thus, equivalent to the uppermost Wujiaping Formation or lower Changxing Formation in the upper Permian of China (Rigby, et al., 1989a,b).

Many of the controversies on interpretation of rocks and fossils of the Guadalupe Mountains focused on the relative importance of organisms, especially the algae and sponges; on the relative importance of marine and diagenetic cements; and on the topographic relief and shape-slope of the margin of the Northwestern Shelf and the Delaware Basin. Discussions revolved around the question of whether the margin was the site of an extensive barrier reef.

Newell, et al., (1953) interpreted the rocks exposed in the Guadalupe Mountains as part of a major reef complex (Fig. 5), and regarded the massive Capitan Limestone as a major reef intergrowth, dominated by sponges and algae, but with brachiopods, bryozoans, and other elements as accessories. Images and understanding of the carbonate complex by members of Newell's team were certainly influenced by their concurrent investigations of living reefs in the Bahama Islands and elsewhere in the Caribbean and Pacific regions (Newell and Rigby, 1957). Rigby and Millward (1988, p. 79), in discussion of the Newell project, noted that "the imagination-inspiring experience of modern reefs and carbonate deposits overprinted our interpretation of reefs in the Guadalupe Mountain complex, and influenced interpretations of possible topographic profiles and facies relationships in various studies of the reefs in the Guadalupe Mountains." Similarly, the steep escarpment at the front of the mountains and the transition to the thin-bedded basin facies were seen as forereef deposits (Fig. 5), in large part an accumulation of massive falls of reef talus and debris transported by turbidite currents. Those models still influence interpretation of basin facies rocks.

During the 1960s and 1970s other researchers presented quite different interpretations and conclusions about the Capitan Limestone and the nature of the topography at the basin margin. Dunham (1962, 1972) and Achauer (1969) described the Capitan Limestone as a sponge wackestone

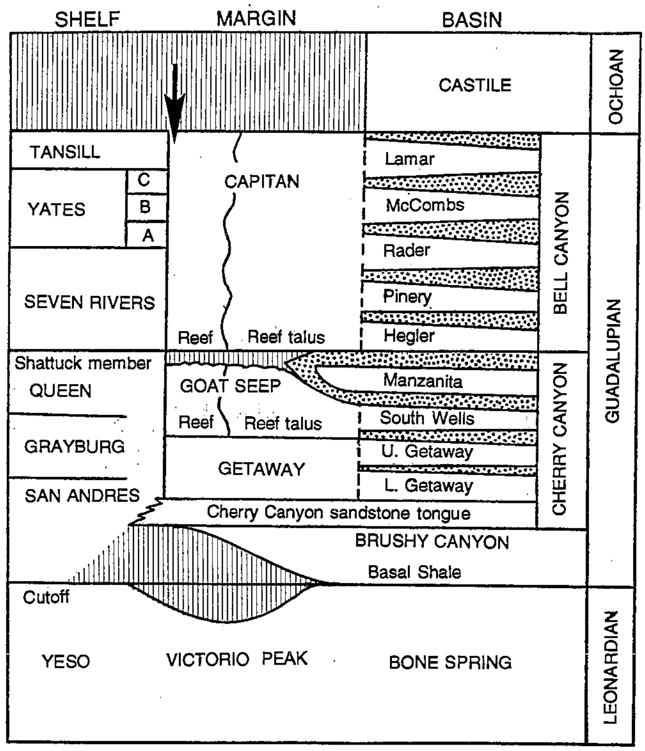

Figure 5. Stratigraphic nomenclature of Permian rocks exposed in the Guadalupe Mountains region of western Texas and southeastern New Mexico. Arrow in the upper part of the Capitan Reef Facies shows the approximate stratigraphic position of the sponges reported in this paper (modified from Newell, et al., 1953).

and emphasized its modification as a function of vadose exposure. They interpreted the Capitan Limestone largely as a bank deposit, with only minor amounts of boundstone that accumulated in deeper water than the model visualized by Newell, et al., (1953). Babcock (1974, 1977) and Yurewicz (1976, 1977) concluded that the massive Capitan Limestone is a sponge-algal boundstone, with large volumes of early marine cement.

The Capitan Limestone was subdivided into Lower, Middle, and Upper Members by Yurewicz (1977) and Babcock (1977) on the basis of petrology and fossil content. In the three members, sponge boundstones and sponges are most important in the Upper Capitan Member, which is the source of the sponges examined in the present study. Yurewicz noted that the lower members contain fewer algae than the Upper Capitan Limestone and interpreted them as shelf-edge reef deposits produced by the accumulation of calcareous sponges and other organisms that lived in moderately deep water. Similar conclusions were reached by Mazzulo and Cys (1978). Babcock (1977) studied the massive Upper Capitan Limestone and found an abundant and highly diverse biota of algae and sponges in intimate association with early cement. He concluded that Upper Capitan carbonates accumulated in more shallow water than the lower and older part of the formation and that the Upper Capitan carbonates accumulated as shallow-water organic reefs.

Wood, Dickson, and Kirkland-George (1994, 1996) recently interpreted the occurrences of calcareous sponges in the Capitan Limestone as "pendant cryptobionts inhabiting cavities, often in considerable abundance." We will discuss such occurrences and their interpretations, and general reef fabrics of the Capitan Limestone later in this and other papers.

PRESENT STUDY

Field work.—Three major localities and three additional supporting localities were sampled for the project, from the northeasternmost exposed sections of the Upper Capitan Limestone in the Guadalupe Mountains in New Mexico (Figs. 3, 4). H. Liu, C.J. Crow, and J.A. Fagerstrom, and other students of the University of Nebraska made detailed field collections from the localities during the summers of 1986 and 1987.

Additional collections were made by Rigby and Senowbari-Daryan in 1993. After discussion with representatives of the National Park Service and Bureau of Land Management, three large well-exposed and accessible localities along the outcrop belt were selected for intensive study by Liu, Crow and Fagerstrom. These include exposures in the headwaters of Hackberry Draw, Chinaberry Draw, and in the mouth of Dark Canyon (Figs. 3, 4). In addition, samples were collected by Liu and Crow along a traverse in the mouth of a small canyon east the mouth of Rattlesnake Canyon (Fig. 4.2). Rigby and Senowbari-Daryan also collected from what has been locally referred to as the "Sponge Window," along the east margin of the mouth of Bat Cave Draw, as well as from a separate locality in Upper Capitan beds on the west side of the mouth of Bat Cave Draw (Fig. 2.1) as part of the present study.

Sampling grids were established in the Hackberry Draw, Chinaberry Draw, and Dark Canyon localities (Figs. 6–8) to control quantitative sampling for Set A for paleoecology, as well as to provide a base for the additional Set B collections made for systematic paleontologic investigation. Grids were established by placing ropes around the outer boundaries of each grid, and each grid was then further subdivided by other ropes into sub-quadrangles, to create an XY coordinate system for detailed cm-by-cm location of each of the samples collected. XY coordinates of each sample were recorded on field maps and distances and orientations noted. Each cut fragment was marked with vertical and north arrows on the surface. Because biostratigraphic, biogeographic and paleoecologic research on

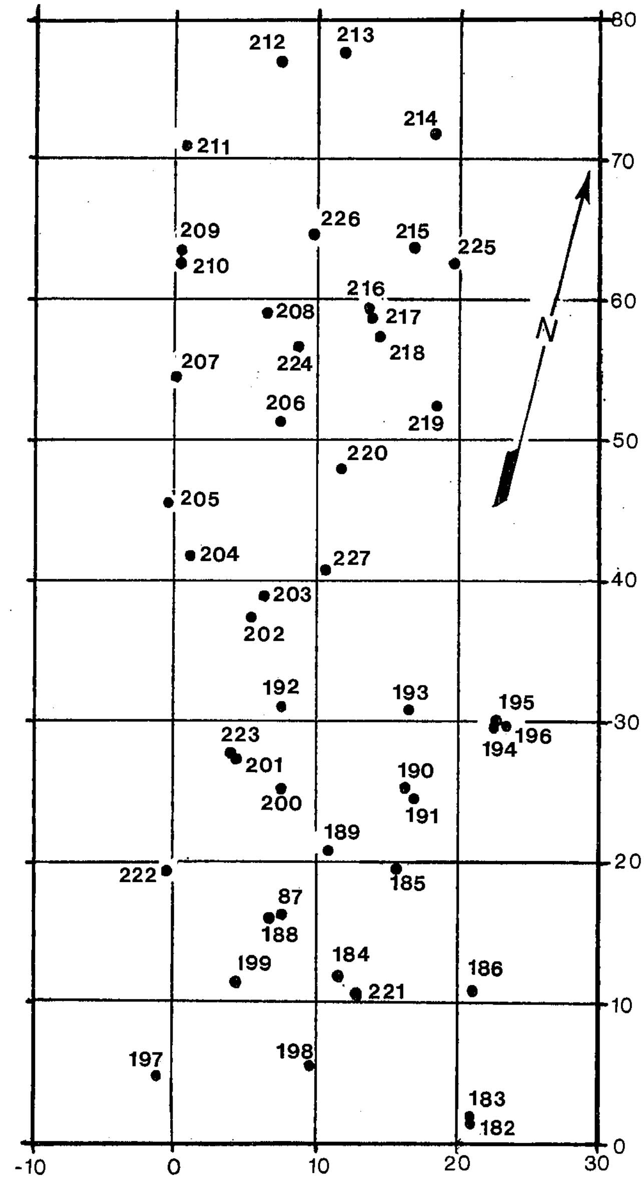

Figure 6. Detailed sample map and grid of the Hackberry Draw locality, in the southeastern part of section 36, T. 24 S., R. 24 E. (Figure 3.1), on the Carlsbad Caverns 7 1/2-minute Quadrangle, 1979. Numbered dots show positions of the samples of Set B. The grid has a 10-meter spacing. Samples from the Hackberry grid include UNSM 35182–35227, and those from the canyon floor above the grid include UNSM 35268–35285.

the sponge taxa is, of necessity, based on a large number of collections, as large a sample set as was feasible was obtained from each of the three localities.

In addition to the well-preserved sponges that were located within the grids, some samples in Set B were taken from outside the grids to provide as nearly a complete sampling as possible of sponges in the exposures. More

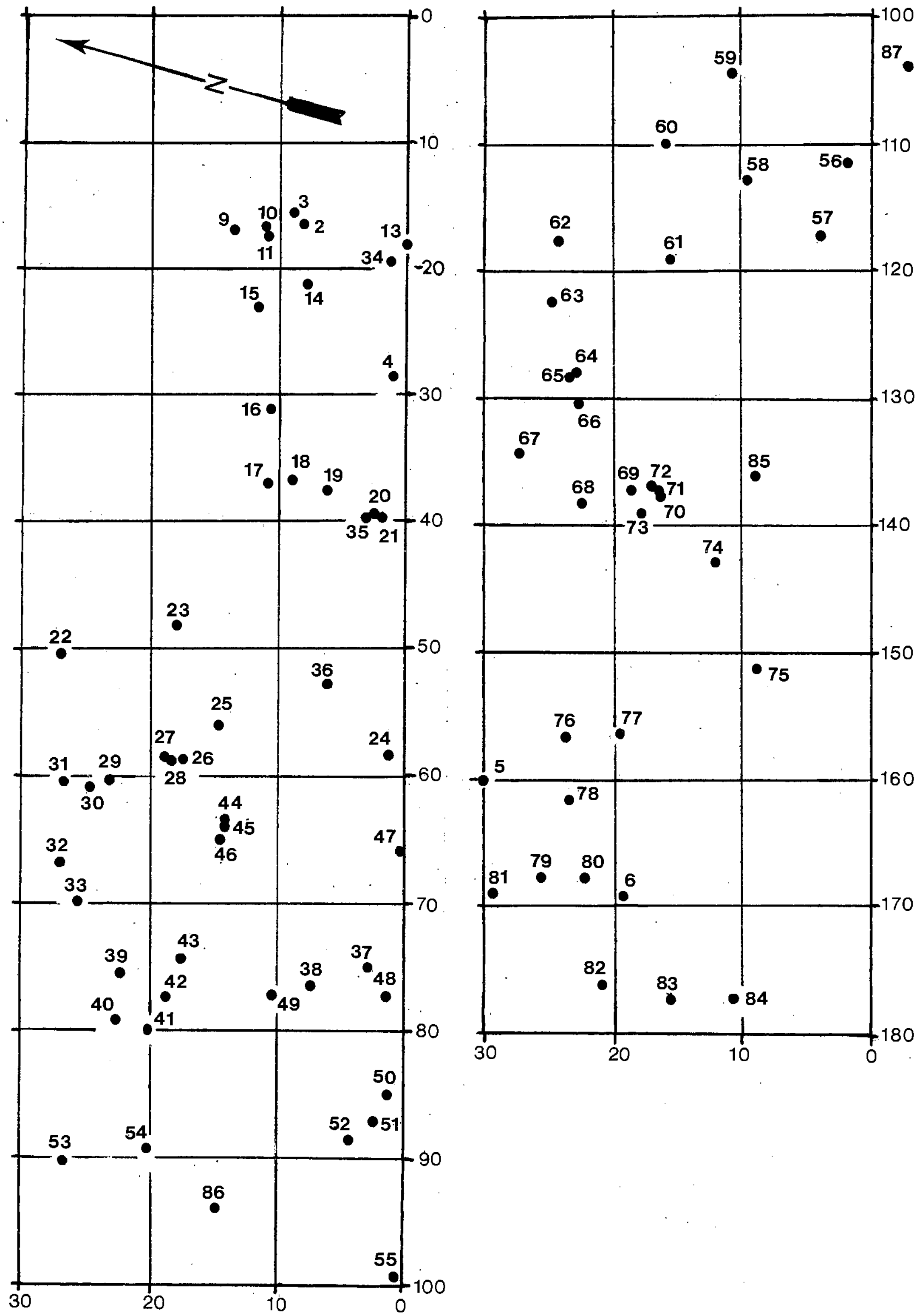

Figure 7. Detailed sample map and grid of the Chinaberry Draw locality (C, Figure 3.3) in the western part of section 25, T. 24 S., R. 25 E., from a short distance northeast of Whites City, in the Black River Village 7 1/2-minute Quadrangle, 1979. Position of each sample in Set B is shown plotted on the grid with 10 m squares; 1, northeastern part of the grid; 2, southwestern and adjoining part of the grid. Samples from the locality include UNSM 35002–35006, 35009–35087, and 35287–35289.

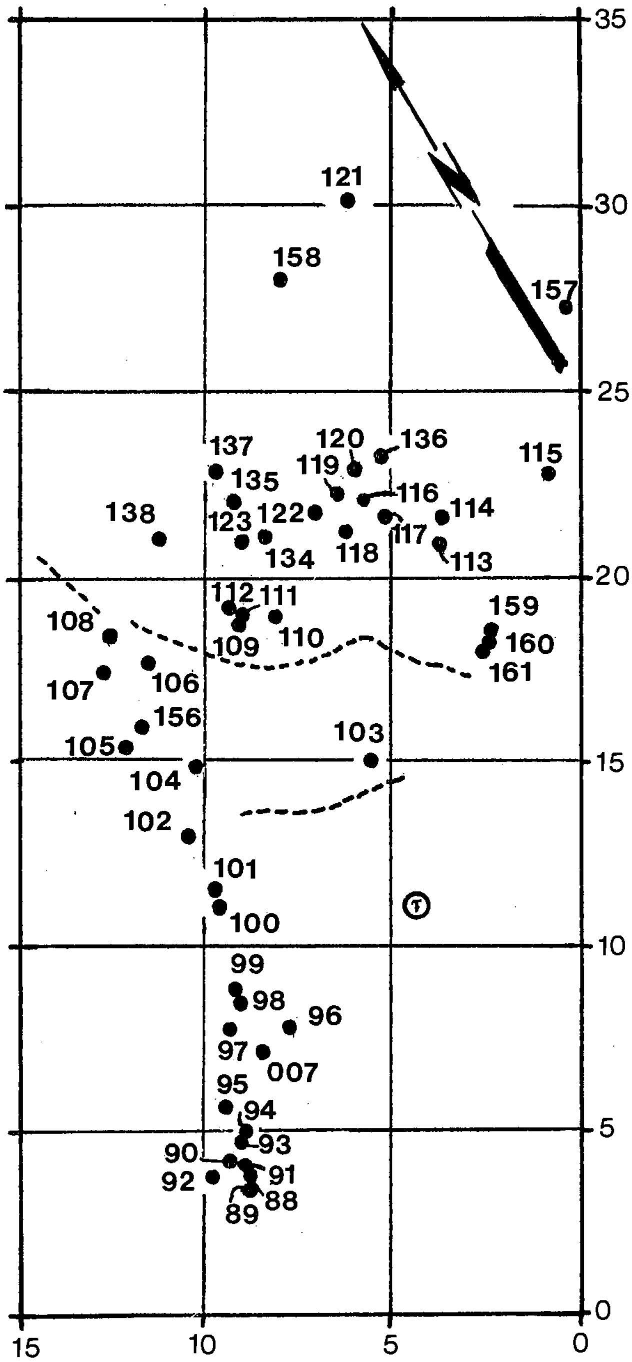

Figure 8. Distribution of samples of Set B collected along the north margin of the mouth of Dark Canyon (D, Figure 3.2) in the northeastern part of section 24, T. 23 S., R. 25 E., on the Kitchen Cove Provisional 7 1/2-minute Quadrangle, 1985. Samples collected from this locality include UNSM 35007, 35008, 35088–35181, from within the grid. Dashed lines are of fissure fillings in the outcrop, which is immediately above the gravelly canyon fill. The position of a small juniper tree (T) near the margin of the exposure and canyon fill is shown in the lower right of the figure.

than two hundred and fifty samples in sample set B were collected in limestone blocks, averaging about 10 cm by 10 cm. Distribution of those samples from the Hackberry, Chinaberry, and Dark Canyon localities are shown in figures 6–8 and Appendices 1 and 2.

Laboratory methods.—Polished sections, peels, and thick sections of sponges mounted on glass were prepared in Rigby's laboratory at Brigham Young University. Initial preparations were made by Liu and were followed up by preparation of other specimens by Rigby and Senowbari-Daryan. The most effective preparation was accomplished by sawing and subsequent polishing, through a series of silicon carbide grits to 1200-mesh powder, of longitudinal and transverse sections through sponges, where those sections could be properly oriented. Some experimentation showed that these surfaces etched in very dilute acetic acid, for from 15 to 30 minutes, increased contrast for photography, but produced microrelief thicker than useful for cellulose acetate peels. Such surfaces, however, are adequate for investigation of gross structures and microstructures within the sponges. The sponges in our collection are recrystallized so that primary microstructures have been largely destroyed, but the polished and etched surfaces provided adequate morphologic data for taxonomic and descriptive purposes.

We examined representatives of virtually all of the sponge taxa by SEM in an effort to determine original mineralogy and primary microstructure, but were unsuccessful because all are recrystallized. As a consequence, we focused on those features best preserved and most evident in the polished and weakly etched surfaces.

Etched surfaces were photographed both dry and wet with a thin film of water. The latter surfaces, in general, produced the most detailed and best expressed morphologic features. They also best show relationships of the sponges to enclosing matrix and encrusting organisms. Some time may have been saved in initial preparation if the cut surfaces had been prepared only to 600-mesh powder finish before etching in the dilute acetic acid solution.

In general, the calcareous microstructure of the sponges has been replaced by moderately crystalline coarse spar. Consequently, those sparry skeletal structures are etched into slight relief above the generally enclosing fine crystalline matrix. The coarse sparry skeletons appear very light grey, in contrast to the light brown and brownish grey matrix, even where the sponges are encrusted by *Archaeolithoporella* or other microbial- or algal-based crusts. Orientations, abundances, biological relationships, etc. of individuals or individual species and interpretations of community structures and relationships are being investigated as parallel projects by Fagerstrom and Weidlich (Fagerstrom, et al., 1995; Weidlich, et al., 1995).

DESCRIPTION OF LOCALITIES

Hackberry Draw.—The primary grid is approximately 20 m by 75 m, and is located in exposures along the east side of headwaters of the draw (Figs. 4.1, and 6). The southwest corner of the grid is at the base of the extensive, sheet-like, massive exposure which is approximately 45 meters (150 feet) north and 180 meters (600 feet) west of the southeast corner of section 36, T. 24 S., R. 24 E., at latitude 32°07′13″ north and longitude 104°26′47″ west, on the Carlsbad Caverns 7 1/2-minute Quadrangle, 1979. The exposure is in the base of the escarpment, in the gulley that heads directly southwest of the west end of the loop roads in the visitors parking area, west of the Visitors Center for Carlsbad Caverns. The locality is approximately 890 meters (2900 feet) south of the west end of the Visitors Center for Carlsbad Caverns Park Headquarters, and is within Carlsbad Caverns National Park. The locality is accessible by vehicle via the park access gravel or unpaved road that leads westward from south of Whites City (Fig. 4.1), past the power substation, and west-southwestward beyond the former sewage disposal ponds for the caverns headquarters area, along the power-telephone line approximately 4.2 miles west of U.S. Highway 62-180. A primitive road extends northeastward approximately 0.25 miles, to near the locality, from the poleline junction, which is 0.1 miles beyond the dugway crossing of Hackberry Draw. Sample sets A and B were collected largely within the grid but additional fossils were collected during field work in 1993 in the gully bottom, up to 100 m upstream from the grid.

Chinaberry Draw.—Samples from the Chinaberry Draw locality (Figs. 3.3 and 7) came essentially from the established grid of 30 meters by 180 meters. The southeast corner of the grid is approximately 275 meters (900 feet) east of the west line and 610 meters (2000 feet) south of the north line of section 25, T. 24 S., R. 25 E., at latitude 32°10′57″ north, longitude 104°20′51″ west, on the Black River Village 7 1/2-minute Quadrangle, 1979. The grid trends North 75° East, generally along the ridge crest, and on either side of the crest in what appears to be the youngest Upper Capitan reef limestone exposed in the immediate area. The length of the grid trends at approximately 20° to the major reef or escarpment trend. The locality is accessible along a primitive road which trends westward from US Highway 62-180, from 1.9 miles northeast of the junction of the major highway in Whites City and the Carlsbad Caverns National Park access road (Fig. 3.3). Additional samples were collected from the grid area during the 1993 field work.

Dark Canyon.—A relatively small grid, 15 meters by 30 meters, with the length oriented North 30° East, is located on the northwest side of the mouth of Dark Canyon (Figs. 3.2 and 8), northwest of Hidalgo Road and the paved main road. The southeast corner of the grid is 18 meters, at South 25° East, from a benchmark indicated by a pipe cemented into bedrock. The main outcrop in the eastern part of the grid is approximately 395 meters (1300 feet) west and 490 meters (1600 feet) south of the northeast corner of section 24, T. 23 S., R. 25 E., at latitude 32°17′33″ north, longitude 104°20′41″ west, on the Kitchen Cove Provisional 7 1/2-minute Quadrangle, 1985. The locality is near the Dark Canyon access road, approximately 3.9 miles west from the junction with US Highway 62-180. That junction is 4.4 miles southwest of the Carlsbad Airport entrance and roadside park area. The locality is west of the secondary Hidalgo Road and 0.2 miles north of the main Dark Canyon road (Fig. 3.2).

"Sponge Window."—The so-called "Sponge Window" exposure is approximately 3 by 5 meters across, on the massive face on the northeast side of the mouth of the gully of Bat Cave Draw (Locality S on Fig. 3.1), on private property owned by Jack White, Jr. The locality is approximately 140 meters (450 feet) southeast of a corner in the park fence boundary along Bat Cave Draw, or approximately 885 meters (2900 feet) east and 300 meters (1000 feet) south of the northeast corner of section 34, T. 34 S., R. 25 E., at approximately latitude 32°10′37″ north and longitude 104°22′56″ west, on the Carlsbad Caverns 7 1/2-minute Quadrangle, 1979 (Fig. 3.1).

Bat Cave Draw.—Samples were collected from the uppermost Capitan Limestone west and southwest of the corner of the park fence in the mouth of Bat Cave Draw (Locality B on Fig. 3.1). Samples were collected from exposures in the canyon bottom and to approximately 110 meters west of the corner and on the southwest wall, to an elevation of approximately 2800 feet and 150–180 meters from the fence corner. That fence corner is 802 meters (2630 feet) east and 401 meters (1315 feet) south of the northwest corner of section 34, T. 24 S., R. 25 E., within the National Park. Fossils were collected from exposures at approximately 32°10′33″ north latitude and 104°23′07″ west longitude, on the Carlsbad Caverns 7 1/2-minute Quadrangle, 1979. This is the general locality from which sponges described by Senowbari-Daryan (1990) were collected during an earlier investigation (Fig. 3.1).

Rattlesnake Canyon traverses.—Samples were collected from the Capitan Limestone along two traverses in the small canyon east of the mouth of Rattlesnake Canyon (Fig. 4.2), in the southeast part of section 4, T. 25 S., R. 25 E., on the Carlsbad Caverns 7 1/2-minute Quadrangle, 1979. The longer traverse, along which Set A was collected, is approximately 245 m (800 feet) long and continues essentially along the bottom of the canyon. It begins approximately 335 m (1100 feet) west and 460 m (1500 feet) north of the southeast corner of section 4 and terminates near the mouth of the canyon. The shorter traverse, along which samples of Set B were collected, centers approximately 180 m (600 feet) west and 275 m (900 feet) north of the southeast corner of section 24 and is parallel to the longer traverse, but on the northeast lower shoulder of the canyon near the mouth. Northern end of the long traverse locality is at approximately 32°09′13″ north latitude and 104°29′47″ west longitude; and that of the short traverse is at approximately 32°09′14″ north and 104°29′46″ west.

A primitive road that leads from Rattlesnake Springs Ranger Station toward the west, into the mouth of Rattlesnake Canyon, is the principal access route. Rattlesnake Springs is the source of water for Carlsbad Caverns National Park headquarters area. The road to the springs leads westward from US Highway 62-180 at 5.4 miles southwest of the intersection of the Carlsbad Caverns National Park access road and the highway in White City. This access road crosses the Black River in 0.2 miles, and 0.2 miles beyond the crossing the gravel road to the north leads to Rattlesnake Springs. The four-mile long road beyond Rattlesnake Springs to the mouth of Rattlesnake Canyon requires high-clearance vehicles and admittance through locked gates under Park Service control.

We consider the Capitan samples from Hackberry Draw to be equivalent in age to lower upper Tansill beds, immediately younger or partially equivalent to the post-Lamar sandstone, questionably exposed in Hackberry Draw southwest of our locality, and the upper Ocotillo Sandstone in the Tansill Formation. Sponges from Bat Cave Draw, including the Sponge Window, and from Chinaberry Draw we consider as from Capitan beds equivalent to the lower and middle upper Tansill-post-Lamar beds. Dark Canyon sponges we consider as from Capitan rocks equivalent to the upper part of the Tansill Formation and the youngest in our collections.

SPONGE ASSEMBLAGES OF THE UPPER CAPITAN REEF LIMESTONE

TAXONOMY, BIOSTRATIGRAPHY AND BIOGEOGRAPHY

Sponge faunas of the Permian reef limestones in the Guadalupe Mountains in Texas and New Mexico are represented mainly by sphinctozoid and inozoid sponges (Table 1). Demosponges, such as *Heliospongia*, sclerosponges ("chaetetids"), and hexactinellid sponges are rare and do not play important volumetric or paleoecologic roles in these carbonates.

The polyphyletic group of sphinctozoan sponges is represented most abundantly in the collection by the following genera: *Amblysiphonella* Steinmann, *Exaulipora* n. gen., *Girtyocoelia* Cossman, *Sollasia* Steinmann, *Parauvanella* Senowbari-Daryan, *Lemonea* Senowbari-Daryan, *Discosiphonella* Inai (=*Cystauletes* King), *Guadalupia* Girty, *Platythalamiella* Senowbari-Daryan and Rigby, and *Tristratocoelia* Senowbari-Daryan and Rigby.

The genus *Amblysiphonella* apparently marked the beginning of the sphictozoans in the Cambrian or Ordovician and has been reported in rocks up to the Upper Triassic (Senowbari-Daryan, 1990, p. 61). It is a cosmopolitan sponge and occurs in numerous localities throughout the world. Almost 60 species of *Amblysiphonella* have been described in the literature, about 70% of which have been described from the Permian. From North America, only two species of *Amblysiphonella* have been reported previously in the literature. *Amblysiphonella prosseri* was first described by Clarke (1897), and later by Beede (1900), Woodruff (1906), and King (1938), all from Carboniferous rocks. This species has not been reported from Permian deposits. The second reported species, *Amblysiphonella guadalupensis* is now considered to be a *Cystothalamia*. It was first described by Girty (1908a, p. 91–92) from the Permian reef rocks of the southern Guadalupe Mountains, but it has not been reported again until here.

The three additional species of *Amblysiphonella*, including *Amblysiphonella* cf. *A. merlai* Parona, 1933, and two other unnamed species described here, differ from the species described by Girty and represent additional forms occurring in the North American Permian. Generally speaking, *Amblysiphonella* is not an abundant sponge in the Capitan Limestone, but it has been reported from numerous other Permian reefs, for example from several localities in China (Fan and Zhang, 1985; Rigby, et al., 1989a).

The genus *Discosiphonella* Inai, 1936 includes as synonyms the genera *Cystauletes* King, 1943, *Ascosymplegma* Rauff, 1938, and *Lichuanospongia* Zhang, 1983, according to Senowbari-Daryan (1990, p. 56). *Discosiphonella* first appears in the Carboniferous and extends to the Permian-Triassic boundary. *Discosiphonella* has not been reported from Lower and Middle Triassic rocks, but sponges morphologically virtually identical to it appear again in Upper Triassic rocks.

Discosiphonella mammilosus (King, 1938) was first described from the Upper Carboniferous (Pennsylvanian) system. The genus also occurs in Middle Permian rocks of the Glass Mountains (Senowbari-Daryan, 1990, Pl. 20, Figs. 4–6). *Discosiphonella mammilosus* (King) is abundant in Upper Permian reefs in the Guadalupe Mountain, not only in our collections, but earlier collections as well (see Senowbari-Daryan, 1990).

The new genus *Exaulipora* is proposed here for relatively large, chambered, glomerately arranged to irregularly stratiform, sponges with prominent exaules, described as *Corymbospongia(?) permica* by Senowbari-Daryan (1990). Exaules of the sponge are moderately large and where cut in oblique or transverse cross-sections may be easily

Table 1. Occurrences of sponge species in samples of Sets A and B, Upper Capitan Limestone, Guadalupe Mountains, New Mexico.

UNSM Museum numbers	Amblysiphonella cf. A. merlai	Amblysiphonella sp. A.	Amblysiphonella sp. B.	Cystothalamia guadalupensis	Discosiphonella mammilosa	Tristratocoelia rhythmica	Exaulipora permica	Parauvanella minima	Platythalamiella (?) sp.	Preverticillites parva	Sollasia ostiolata	Girtyocoelia beedei	Guadalupia zitteliana	Guadalupia explanata	Lemonea cylindrica	Lemonea conica	Lemonea polysiphonata	Lemonea digitata	Lemonea exaulifera	Lemonea micra	Cavusonella caverna	Gigantospongia discoforma	Peronidella cf. P. rigbyi	Peronidella (?) delicata	Minispongia constricta	Bicoelia guadalupensis	Virgola neptunia	Virgola rigida	Grossotubinella parallela (?)	Pseudovirgula tenuis	Stellispongiella (?) sp.	Heliospongia ramosa	Heliospongia vokesi	Neoheliospongia cf. N. typica	Fossils of unkn. tax. form B	Fossils of unkn. tax. form A
Set A	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	aa	ab	ac	ad	ae	af	ag	ah	ai	aj
34602		x						x			x				x					x					x											
34603																				x					x											
34606							x	x															?													
34607							x				x									x						x								x		
34608							x				x				x					x						x										
34609							x																		x											
34610												x			x				x				x											x		
34611							x				x																									
34613							x				x									x					x											
34615							x				x	x							x	x					x											
34618																x	x								x									x		x
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34622											x					x	x								x											
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confused with other tube-like organisms, such as worm tubes. These exaules served as a favorable substrate for overgrowths of the small sponge *Parauvanella minima* Senowbari-Daryan, 1990.

Girtyocoelia is another cosmopolitan sphinctozoid sponge whose record appears first in the Ordovician (Rigby and Potter, 1986) and extends to the end of the Permian. Sponges described as species of *Girtyocoelia* from the Triassic do not belong to this genus (Senowbari-Daryan, 1990, p. 130).

The two Permian species of *Girtyocoelia, G. dunbari,* and *G. sphaerica* described by King (1932, 1943), were considered by Kügel (1987) and Senowbari-Daryan (1990) as synonyms of *Girtyocoelia beedei. Girtyocoelia beedei* (Girty) is one of the most abundant sponge species in exposures of late Paleozoic rocks in North America and throughout the world (Senowbari-Daryan, 1990, p. 131). It is not an abundant sponge species in the Guadalupe Mountains.

The large sheet-like sponge, *Guadalupia,* is perhaps the second-most abundant sphinctozoid sponge in Permian rocks in the Guadalupe Mountains, second only to the very abundant *Lemonea.* In our collections at least two species of *Guadalupia* can be recognized. *Guadalupia zitteliana* Girty, 1908, occurs in thin sheets of relatively small chambers; but specimens with thicker sheets and larger chambers are included in *Guadalupia explanata* (King, 1943). *Guadalupia explanata* is more abundant than the finer-textured *Guadalupia zitteliana* and is also easily recognizable in the field. *Guadalupia* is an endemic western Tethyan sponge, occurring only in the southwestern United States, Mexico, and Venezuela. It has been reported from the Guadalupe Mountains (Girty, 1908a; King, 1943; Finks, 1955, 1960; Senowbari-Daryan, 1990) and from Venezuela (Rigby, 1984). Both *Guadalupia zitteliana* and *Guadalupia explanata* are known only from this region.

Lemonea is the most abundant sphinctozoid sponge in the localities investigated. It includes at least five species, four of which are as yet unknown from other localities in the world. The only species which seems to be moderately cosmopolitan is *Lemonea cylindrica* (Girty, 1908a), which has been reported from several localities, such as Sicily, Tunisia, and China (Senowbari-Daryan, 1990, p. 151). The genus *Lemonea* is limited stratigraphically to rocks of Permian age.

Parauvanella was first described from Lower Permian reef limestones of Sicily by Senowbari-Daryan and Di Stefano (1988a). Only the small species, *Parauvanella minima* Senowbari-Daryan, 1990, is known from the Capitan Limestone. It was first described by Senowbari-Daryan from samples collected at or near the "sponge window," near Whites City, New Mexico, and has also been reported by Weidlich and Senowbari-Daryan (1996) from Oman. *Parauvanella minima* is an epifaunal element growing in moderate profusion on exaules of *Exaulipora permica* (Senowbari-Daryan, 1990).

Platythalamiella was first described from Upper Permian reef limestones of Djebel Tebaga, Tunisia, by Senowbari-Daryan and Rigby (1988). The sponge questionably identified as a *Platythalamiella* in this paper differs from the Tunisian type species in having much larger chambers. The sponge from the Guadalupe Mountains probably represents a new species.

Sollasia is another cosmopolitan sphinctozoid sponge and is known from almost all Permian reef localities and many level-bottom localities in the world. The most abundant species, *Sollasia ostiolata* Steinmann, 1882, occurs as numerous specimens in our collections from the Guadalupe Mountains, although it is only locally abundant and is not a major rock-forming sponge because of its small size.

Tristratocoelia was first described by Senowbari-Daryan and Rigby (1988) from Upper Permian reef limestones of Djebel Tebaga in Tunisia. Additional specimens were later found from the same locality and were reported by the same authors (1991). Occurrence of the genus in Upper Permian rock in the eastern part of the Tethyan realm, in Thailand, was documented by Senowbari-Daryan and Ingavat-Helmcke (1994). In both Tunisia and Thailand, *Tristratocoelia* is rare. The occurrence of *Tristratocoelia* in the Guadalupe Mountains documents a third occurrence of the genus, where it is also rare, but perhaps it is more common here than in either Tunisia or Thailand.

Most of the described species of sphinctozoid sponges from the Guadalupe Mountains are porate types. Only two genera, *Sollasia* and *Girtyocoelia*, are representatives of the aporate group. *Parauvanella*, a coarsely perforate large-chambered sponge, may be considered as of intermediate structure with relatively large pores.

It is surprising that *Cystothalamia* Girty does not occur in profusion in our collections. The genus was first described by Girty (1908a, p. 80–90) from the Capitan and lower Guadalupian Delaware Mountain Formations in the Guadalupe Mountains and Glass Mountains, from rocks somewhat older than the uppermost Capitan Limestone assemblages described here. *Cystothalamia* is a relatively abundant sponge in Middle Permian rocks of Sicily and in Upper Permian rocks of Tunisia in the Tethyan realm. In the Guadalupe Mountains, however, it appears to be limited to the Capitan Limestone and older Delaware Mountain facies.

Sphinctozoid sponges in our collections are represented by species that generally lack filling structures within chambers and which commonly have only minor vesiculae. Sponges with filling structures, as for example *Intrasporeocoelia,* were not found in the Guadalupe Mountains. It thus appears that the sphinctozoid sponge faunas of the Upper Capitan are structurally relatively primitive types. The progressive types, characterized by secretion of different filling structures, are not common in the Guadalupe Mountains collections.

Inozoid calcareous sponges play a secondary role to sphinctozoan sponges in reef faunas and in fabrics of the Capitan Limestone in the Guadalupe Mountains in Texas and New Mexico. With the exceptions of some large sponges like *Gigantospongia,* these inozoans are generally small sponges, only a few of which are numerically diverse. Most are known from only a few specimens in our collection.

The genus *Minispongia* is the smallest inozoan sponge and also the most abundant sponge in our collections from the Upper Capitan limestone. The genus was named by Rigby and Senowbari-Daryan (1996a) from Permian exposures in the Djebel Tebaga area of Tunisia. The sponge may occur in other Permian limestones but has not been reported, perhaps because of its small size. *Minispongia constricta* (Girty, 1908a) is widespread and common at each of the six major localities from which we have collections. These sponges were originally included in *Virgula rigida* var. *constricta* by Girty, but are recognized here as a separate species, having a spongocoel. *Peronidella* cf. *P. rigbyi* Senowbari-Daryan 1991 occurs in the collection, as do several specimens of the new species, *Peronidella delicata.*

Moderately common, but considerably less abundant than *Minispongia,* are sponges included here in the new genus *Bicoelia,* a small sponge with two spongocoels in the axial region of the cylindrical, twig-like form. The somewhat similar appearing *Bisiphonella* was described by Wu (1991, p. 60) from Permian carbonates of China, and more recently was reported by Dickson, et al., (1996) from the Pennsylvanian Holder Formation in New Mexico, but, as far as we can determine, *Bicoelia* is limited at present to the Guadalupe Mountain exposures.

Girty (1908a) described *Virgola neptunia, Pseudovirgula tenuis,* and the small, subcylindrical to branched inozoid *Virgola rigida* from the Capitan Limestone at the southern end of the Guadalupe Mountains, from rocks slightly older than represented by the Upper Capitan Limestone faunas described here. *Virgola neptunia* is locally common but *Vigola rigida* is moderately rare in the younger northern Guadalupe Mountains localities. *Pseudovirgula tenuis* is known only from the holotype.

Other inozoids in the New Mexico collections include the sponges *Grossotubenella parallela* Rigby, Fan, and Zhang, 1989b, which is known from a single specimen, and *Cavusonella caverna* Rigby, Fan, and Zhang, 1989b, known here from a few scattered samples. These are the first records of these genera outside of China, however, and the occurrence of *Grossotubenella* is somewhat questionable because we have only a single specimen.

Inozoid sponge faunas from the Guadalupe Mountains are considerably reduced from the very diverse assemblages from Middle and Upper Permian rocks and faunas from China described by Rigby, Fan, and Zhang (1988, 1989a, b), Rigby, Fan, Wang, and Zhang (1994), Fan and Zhang (1985), Fan, Rigby, and Zhang (1991), and Fan, Rigby, and Qi (1990), and from Tunisia by Senowbari-Daryan and Rigby (1988, 1991), and Rigby and Senowbari-Daryan (1996a).

The problematic organism *Permosoma* Jaekel, 1918 (H. W. Flügel, 1980) is also recorded in our collections as a moderately common fossil. This is the first time the genus has been reported outside of Tunisia and Sicily.

DIVERSITY

The Upper Capitan Limestone sponge fauna is only moderately diverse, with approximately 34 species of "calcareous" sponges and demosponges represented in the collections. This contrasts with the essentially contemporaneous exceedingly diverse sponge assemblages described from Tunisia (Senowbari-Daryan and Rigby, 1988; Rigby and Senowbari-Daryan, 1996a) and China (Fan and Zang, 1985; Rigby, et al., 1988, 1989a, b, 1994; Fan, et al., 1991), where assemblages of approximately 100–150 species have been reported. Whether this is a local stratigraphic gradient or a local geographic ecologic gradient must await additional investigations of sponge faunas from older parts of the Guadalupian series in the Guadalupe Mountains, as well as southward in the Glass Mountains, the Chinati Mountains, and into the Las Delicas area of Coahuila in northeastern Mexico (Fig. 1).

In China and Tunisia, the general tendency is for marked chronostratigraphic increase in diversity of calcareous sponges until almost the end of the Permian, when inozoid and sphinctozoid sponges underwent marked reduction. Whether that trend is reversed by a decrease in diversity vertically through the Guadalupian rocks in the Guadalupe and Glass Mountains must await completion of analyses of faunas begun in preliminary investigation by Finks (1960, 1983), for those faunas need to be worked in detail.

Upper Capitan exposures in the vicinity of Carlsbad Caverns are along the northwestern shelf margin at the northernmost end of a long, narrow embayment in Late Capitan time, at the north end of the major Delaware Basin (Fig. 1). That basin was restricted by the Hovey Channel, at the south entrance to the basin, that was probably limited both laterally and vertically by a sill that separated the basin from an open-sea embayment, represented by the general basin facies rocks of the Las Delicias exposures and those in the Marfa Basin. As a consequence of either restricted ecologic or time stratigraphic factors, the Late Capitan assemblages are characterized by abundant individuals of only a few endemic species, and by relatively primitive cosmopolitan genera and species that were able to persist, either stratigraphically or ecologically, beyond the ranges of other forms.

GENERALIZED MORPHOLOGY

Finks (1983) discussed the general morphology and geologic history of sphinctozoan and inozoan sponges and provided a general discussion on the general morphology of each of the two groups. Senowbari-Daryan (1990, p, 12–19) discussed the overall shapes, segmentation, sizes, and canal and pore structures of the sphinctozoid sponges in an extended treatment, and Rigby and Senowbari-Daryan (1996a) similarly discussed inozoid sponges as part of their treatment of the extensive sponge fauna from Permian deposits of Tunisia. Diagrams showing generalized morphologic features of the sponges are shown in figure 9, taken from Senowbari-Daryan (1990), and Rigby and Senowbari-Daryan (1996a).

DEPOSITORIES

Samples are deposited in the University of Nebraska State Museum (UNSM) and the U.S. National Museum (USNM).

SYSTEMATIC PALEONTOLOGY

Class DEMOSPONGEA Sollas, 1875
Subclass CERACTINOMORPHA Lévi, 1973
Order PERMOSPHINCTA Termier and Termier, 1977a
Suborder PORATA Seilacher, 1962
Family SEBARGASIIDAE Steinmann, 1882

(*pro* Sphaerosiphoniidae Steinmann, 1882, ascribed to Girty, 1908a, by De Laubenfels, 1955; Cystothalamiidae Girty, 1908a; Stromatocoeliidae Zhang and Fan, 1985, *in* Fan and Zhang, 1985)

Diagnosis.—"Porate "Permosphincta" ohne Füllskelett, aber in der Regel mit Vesiculae. Die catenulaten oder glomeraten Segmente ordnen sich um ein oder ein aus mehreren Tuben zusammengesetztes und axial gelegenes Spongocoel. Das Basalskelett, soweit dies bekannt ist,

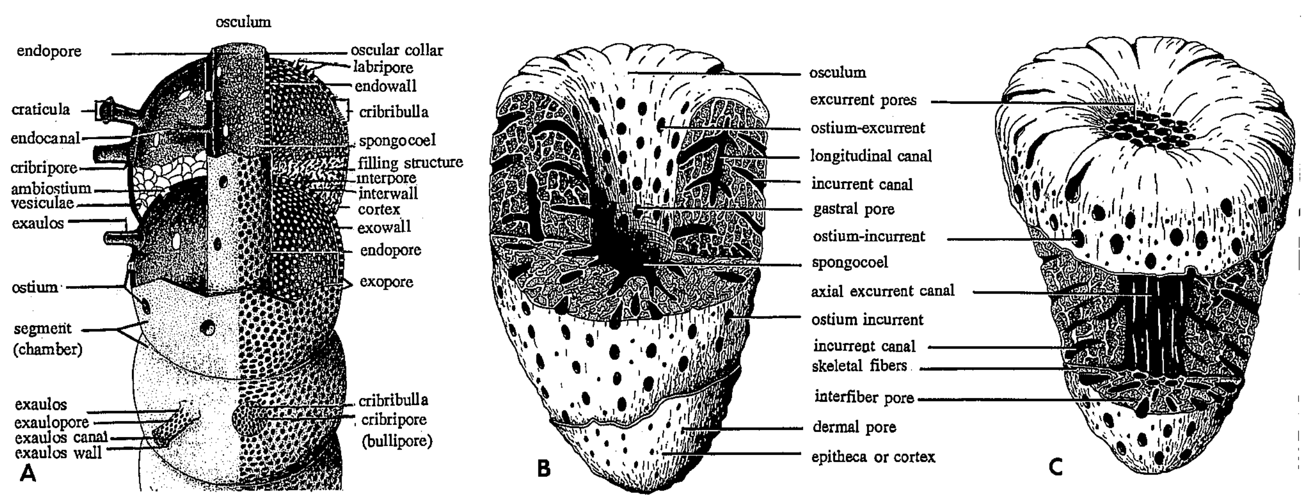

Figure 9. Generalized morphologic features of sphinctozoan (A) and inozoid (B, C) sponges showing terms used in their description (A from Senowbari-Daryan, 1990, and B and C from Rigby and Senowbari-Daryan, 1996a).

besteht aus Aragonit." (Porate "Permosphincta" without filling structures but as a rule with vesiculae. The catenulate or glomerate segments (chambers) are ordered around one or around more than one tube cluster and axially-lengthened spongocoel. The basal skeleton, as far as is known, is composed of aragonite.) Cambrian-Triassic, Cretaceous? (Senowbari-Daryan, 1990, p. 52–53).

Subfamily SEBARGASIINAE
Senowbari-Daryan, 1990

Diagnosis.—"Catenulate Anordnung der Segmente um ein oder mehrere Zentralkanäle." (Catenulate arrangement of the segments with one or more central canals) (Senowbari-Daryan 1990, p. 54).

Genus AMBLYSIPHONELLA
Steinmann, 1882

(=*Sebargassia* Steinmann, 1882; *Oligocoelia* Vinassa, 1901; *Tetroproctosia* Rauff, 1938; *Eurysiphonella* Haas, 1909; and *Laccosiphonella* Aleotti, Dieci and Russo, 1986)

Diagnosis.—"Single, rarely branched, porate sponges with one or more central tubes. Chambers are catenulate and ring-shaped. The endo- and exopores may be of the same size or different sizes. The pores may be simple or may branch dichotomously one or more times. Chambers lack filling structures but may contain vesiculae, particularly in early chambers. Skeleton consists of aragonite with a sphaerolitic microstructure. The retrosiphonate central tube may not always be recognizable." (Senowbari-Daryan and Rigby, 1988, p. 179)

Discussion.—More than 50 species of *Amblysiphonella* have been proposed. Those known up to 1990 were listed by Senowbari-Daryan (1990, p. 62). Since then several additional species have been described. They include: *A. benschae* Zhuravleva, 1991, *A. obichingouensis* Boiko, 1991 (in Bioko, et al., 1991, p. 65); *A. eleganta* Belyaeva, 1987 (cited in Boiko, et al., 1991, p. 86); *A. tenuiramosa* Boiko, 1991 (in Boiko, et al., 1991, p. 149); *A. sahajensis* Belyaeva, 1991 (in Boiko, et al., 1991, p. 163); *A. tubifera* Senowbari-Daryan, 1994, (1994, p. 68), and *A. omanica* Weidlich and Senowbari-Daryan, 1996 (1996, p. 29–31).

The genus *Amblysiphonella* is abundant in Permian reefs, especially in China, but the genus is generally a relatively rare sponge in the Upper Capitan Permian reefs in the Guadalupe Mountains (Table 3) but locally, as in some samples from Chinaberry Draw, it is moderately common. The genus seems to be relatively rare in the USA, not only in Permian rocks but also in Carboniferous strata where it seems to be somewhat more common than in Permian beds.

Two species of *Amblysiphonella* have been described from Paleozoic rocks of Texas and New Mexico. The first, *Amblysiphonella prosseri*, was originally described by Clarke (1897) from the Carboniferous (Pennsylvanian) of the Mississippi Valley. It was also later reported from other Carboniferous units by Beede (1900), Woodruff (1906), and King (1938, p. 500). This sponge has a stem diameter of up to 18 mm and a smooth axial spongocoel 3–6 mm in diameter. According to King (1938, p. 501), what would now be termed the exowall and endowall have different thicknesses, with exowalls 0.5 mm thick, and endowalls only 0.2 mm thick. Both types of walls are pierced by pores approximately 0.1 mm in diameter. Vesiculae are reported to occur within chamber interiors (King, 1938, p. 501).

The second species, *Amblysiphonella guadalupensis,* was described by Girty (1908a, p. 91) from Capitan Peak, at the south end of the Guadalupe Mountains, in Texas. This less well-documented species has stems up to 16 mm in diameter, according to Girty (1908a, p. 91), and a spongocoel 4 mm in diameter. In the type specimens illustrated by Girty (1908a, Pl. 7, Figs. 7, 8) the chambers are not complete ring-like structures around the spongoceol but are monoglomerate cystose in upper parts of the sponges. Hence assignment of the species to *Amblysiphonella* is not appropriate, as the genus is now interpreted. This species is placed in *Cystothalamia,* as discussed below.

Type species.—*Amblysiphonella barroisi* Steinmann, 1886.

AMBLYSIPHONELIA cf.
A. MERLAI Parona, 1933
Plate 1, fig. 8

Amblysiphonella merlai PARONA, 1933, p. 43, Pl. 8, fig. 9–11; SENOWBARI-DARYAN AND RIGBY, 1988, p. 179–180, Pl. 23, figs. 1–9, Pl. 25, figs. 3–5, text-fig. 4; SENOWBARI-DARYAN, 1990, Pl. 61, figs. 1, 2.

Thaumastocoelia permosicula PARONA, 1933, p. 38, Pl. 8, fig. 2.

Amblysiphonella cf. *vesiculosa* de Koninck, TERMIER AND TERMIER, 1955, p. 616, fig. 1a–1c.

Amblysiphonella protea n. sp. TERMIER AND TERMIER, 1977a, p. 42–43, Pl. 12, fig. 4; 1977b, TERMIER & TERMIER, p. 77, fig. 23, Pl. 8, fig. 6?, 7?.

Laccosiphonella merlai (Parona). ALEOTTI, DIECI AND RUSSO, 1986, p. 16, fig. 1c, Pl. 4, fig. 2–4.

Amblysiphonella? *permosicula* Parona. ALEOTTI, DIECI AND RUSSO, 1986, p. 18, Pl. 5, fig. 2a–2b.

Diagnosis.—*Amblysiphonella* 12–14 mm in diameter in adults, with ring-like chambers 2.0–3.5 mm high and 2.0–4.5 mm wide around central retrosiphonate spongocoel, commonly 2–3 mm across. Stems may be branched. Interpores and exopores numerous and commonly 0.2–0.3

mm in diameter. Cortex may be present and thin, pierced by numerous small pores; vesiculae may occur.

Description.—Oblique sublongitudinal section of stem at least 55 mm long and with widths or diameters of 12–14 mm, showing ring-like, uninterrupted, chambers characteristic of the genus around a tube-like walled spongocoel, 3.0 mm in outside diameter, with central opening 2.7 mm across and with walls approximately 0.3 mm thick. Ring-like chambers 2.0–3.5 mm high, as seen in vertical section, and up to 4.5 mm wide; individual rings slope downward from endowall or spongocoel margin and curve downward in outer part at 45° to trend of spongocoel. Interwalls approximately 0.3–0.4 mm thick and pierced by interpores, 0.2–0.3 mm in diameter, preserved where fine mudstone matrix forms interruptions in now coarsely crystalline skeletal structure. Interpores common and occupy up to one-half wall and appear essentially same size as exopores and endopores that even less evident in crystalline replacement. Vesiculae rare.

Discussion.—*Amblysiphonella* sp. A, described below, is a smaller species with stem diameters up to 8.6 mm around a spongocoel up to 3.0 mm in diameter (Table 2), and also has common lobate vesiculae in all chambers. Also included in our collections are two specimens identified only as *Amblysiphonella* sp. B, because they are fragmental, but these sponges are approximately 30 mm in diameter, with an axial spongocoel 10 mm in diameter, or a central tube of essentially the same size as the whole sponge stem in *Amblysiphonella merlai* Parona, 1933.

Material.—Figured reference specimen occurs on UNSM 34678 from Chinaberry Draw, and additional specimens occur on UNSM 35182 and 35217 from Hackberry Draw. The species is also questionally represented on UNSM 346591, and 34680 of Set A, also from Hackberry Draw.

AMBLYSIPHONELLA sp. A
Plate 1, figs. 1, 4, 5

Description.—Three transverse cross-sections, possibly two from single individual, in which chambers range 6.0–8.6 mm in diameter, as circular ring-like chambers around central axial spongocoel, 2.75–3.0 mm in diameter. Endowalls around central tube 0.2–0.4 mm thick, and exowalls 0.4–0.5 mm thick. Endopores in endowall 0.14–0.22 mm in diameter, generally as vague impressions, and most 0.16 mm in diameter as clear, spar-filled, perforations of somewhat denser skeletal structure; endopores separated by 0.1–0.5 mm of skeletal material. Exopores somewhat larger, 0.16–0.22 mm in diameter, with most approximately 0.2 mm across as interruptions in somewhat more dense walls. Both exowalls and endowalls appear with dense inner lining, 0.1 mm thick, that shows as light layer in reflected light, like structure of vesiculae which are common in all chambers. Vesiculae somewhat undulate and attached to endowall, but extend lobe-like into clear sparry fillings of chambers. All specimens microbial-encrusted and in erect growth position. Lengths of chambers unknown because only transverse sections available.

Discussion.—Many species of Carboniferous, Permian, and Triassic *Amblysiphonella* have been described, and measurements of these species were listed by Senowbari-Daryan, (1990, p. 62). None of those species have the proportions of chamber diameter to spongocoel diameter observed in these Capitan specimens, and most species appear significantly larger than our specimens. "*Amblysiphonella*" *guadalupensis* Girty, 1908a, is among those moderately close in size, but type specimens of Girty's specimens have multiple chambers around the spongocoel rather than a ring-like chamber, and that species is moved to the genus *Cystothalamia.*

Amblysiphonella merlai Parona, 1933, has chambers 12–16 mm in diameter around a spongocoel 3 mm across (Table 2), but apparently lacks vesiculae, and is almost double the size of our specimens. Similarly, *Amblysiphonella obliqua* Senowbari-Daryan and Rigby, 1988, has chambers 12–18 mm across, around a spongocoel 2.3 mm across, and has vesiculae, but in that species, the chambers are distinctly diagonally oriented, in contrast to what appear to be essentially horizontally oriented, though vertically stacked, chambers in the sponges observed here. *Amblysiphonella planorbis* Hayasaka, 1918, has chambers 11 mm across around a central spongocoel 3 mm across, but it too apparently lacks vesiculae. *Amblysiphonella prosseri* Clarke, 1897, is a sponge with chambers 18 mm in diameter, around a central spongocoel 3–6 mm in diameter and is, thus, somewhat larger and is probably not the species in our collections. The closest Permian species to measurements of the sponges described here is *Amblysiphonella yoshinoi* Akagi, 1958, which has chamber diameters of 8 mm and spongocoel diameters of 2.5 mm, but has large pores 0.6–1.0 mm in diameter, and it lacks vesiculae as well. Because measurements of our material fall outside the range of measurements given for species described from the Permian elsewhere and because our specimens are so incomplete, it seems best not to specifically identify this species of *Amblysiphonella* yet, although the specimens clearly are of that genus.

Material.—Figured specimens include two transverse cross sections on UNSM 34602W from Dark Canyon locality 2a of Sample Set A. What appears to be another section of one of those sponges is on UNSM 34602, cut from the same sample. Semilongitudinal and other diagonal subtransverse sections of the species occur in UNSM 34633 from the Dark Canyon locality, Sample Set A, and other sections occur in Sample Set B on UNSM 35239

Table 2. Dimensions of Amblysiphonella *species known from the Carboniferous and Permian of Texas and New Mexico. OW, outerwall; EW, wall of spongocel; C, Carboniferous; P, Permian; +, occurs; –, absent; measurements are in mm. Data from Girty (1908a), King (1938), and Senowbari-Daryan (1990), and new samples.*

Species\data	Diameter of stem	Diameter of spongocoel	Thickness of chamber walls	Diameter of pores	Vesiculae	Age	Height of sponge
A. prosseri	18	3-6	OW, 0.65 EW, 0.2	?	+	C	60
A. merlai	16	4	?	?	?	P	?
A. sp. A (this paper)	6-9	3	OW, 0.4-0.5 EW, 0.2-0.4	0.16-0.22	+	P	?
A. sp. B (this paper)	30	10	1	0.25-0.35	-	P	at least 60

Table 3. Comparison of species of Lemonea. *Measurements in mm.*

character	**stems**		**spongocoel**		**branched**	**chambers**	
species	**L**	**D**	**D**	**Number**	**yes/no?**	**L**	**D**
Lymonea cylindrica (G)	100+	10-25	3-10	one	yes	3-7	1
Lemonea digitata (G)	75	6-7.5	2-3.5	one per branch	yes	2-3	.05-.06
Lemonea conica (SD)	up to 17	25	3-5	several	yes	10	1.2
Lemonea polysiphonata (SD)	50+	15-25	5-6	one with multitubes	yes	3	.08-1.1
Lemonea exaulifera n. sp.	50+	4-6	.06-	one	yes	1.5-2.5	1.5-2.5
Lemonea micra n.sp.	62+	3-6	2	one	yes	2	2

(G), Girty 1908a; (SD) Senowbari-Daryan, 1990; L, length; D, Diameter from Rattlesnake Canyon, on UNSM 35255 from Bat Cave Draw, and on UNSM 35289 from Chinaberry Draw.

AMBLYSIPHONELLA sp. B
Plate 1, figs. 2, 3, 7

Description.—*Amblysiphonella* up to 30 mm in diameter, with height of at least 60 mm, but because large fragment broken, sponge could have been considerably taller, perhaps up to twice as tall. Chambers relatively low, with heights of 3–5 mm, arranged ring-like, in cateniform or catenulate arrangement, around axial spongoceol. Axial spongocoel 10 mm in diameter passes through whole sponge. Exowalls and interwalls of chambers, as well as endowall of spongocel, approximately same thickness, up to 1 mm thick, but locally appear thicker because of recrystallization. Walls pierced by equal-sized, unbranched, isolated pores 0.25–0.35 mm in diameter. Vesiculae do not occur.

Discussion.—Because of differences in size, these *Amblysiphonella* do not appear to belong to any of the previously described species, and are designated as of uncertain specific assignment. The species is compared to the other species previously described from New Mexico and Texas, to *Amblysiphonella merlai* Parona, 1933, and to *Amblysiphonella* sp. A in Table 2.

Material.—Two figured specimens occur on UNSM 35228, vertical and transverse sections, and one reference specimen on UNSM 35231, all from the Rattlesnake Canyon traverse, Sample Set B.

Subfamily CYSTOTHALAMIINAE
Girty, 1908a
Genus CYSTOTHALAMIA Girty, 1908a

Diagnosis.—"Kammern mehrschichtig (polyglomerat) um ein oder mehrere den Schwamm in der gesamten Länge durchziehendes Zentralrohr angeordnet. Zentralrohr retrosiphonat. Vesiculae fehlen oder sind selten. Aragonitisches Basalskelett mit sphärolithischer Mikrostruktur. Ein spiculäres Skelett ist bis jetzt nicht bekannt." (Chambers multilayered (polyglomerate) with one or more throughgoing spongocoels in each sponge. Spongocoel retrosiphonate, vesiculae common or rare, aragonitic basal skeleton with sphaerolitic microstructure; a spicular skeleton is not yet known.) (Senowbari-Daryan, 1990, p. 54)

Type species.—*Cystothalamia nodulifera* Girty, 1908a.

CYSTOTHALAMIA GUADALUPENSIS
(Girty, 1908a)
Plate 1, fig. 6

Amblysiphonella guadalupensis GIRTY, 1908a, p. 91–92, Pl. 7, figs. 7, 8, 8a.

Emended diagnosis.—Cylindrical sponges up to 16 mm in diameter, unbranched, with axial spongocoel 4 mm in diameter, around which multiple chambers arranged in monoglomerate layer, locally polyglomerate; exterior with ring-like expression, with chamberlets forming irregular cystose surface in low relief, with chambers 3–4 mm high and 2–4 mm wide. Endopores approximately 0.3 mm in diameter; other pores of uncertain dimensions in recrystallized species.

Description.—Holotype a, natural longitudinal section approximately 40 mm tall, of upward-expanding sponge, section 11 mm across at base, but expands upward to 18 mm near top of fragment, pierced by central spongocoel to 3–5 mm in diameter, surrounded by low chambers in monoglomerate or locally polyglomerate arrangements. Individual chambers to 3 mm high and 5 mm across, with endowalls to 1.5 mm thick and interwalls approximately 1 mm thick. Nature of pores uncertain because of irregular recrystallization.

Paratype fragment approximately 30 mm tall and 11–12 mm across at cut base, upper diagonal surface has been partially polished so that circular spongocoel, 4 mm across, shows both in base and in diagonal section in upper part of fragment. Exterior marked by irregular, coarse pustulose annulations, 3–4 mm high as exowalls of arched chamberlets, 3–4 mm high, and 2–4 mm wide. Outer ends rounded, inner ends terminate against endowall, 0.5–0.8 mm thick. Recrystallized so microstructure uncertain, but with indented, matrix-filled openings 0.3 mm across, spaced 0.5 mm apart, center-to-center, around periphery as openings of endopores. Interpores not well preserved but approximately 0.2–0.3 mm in diameter in the 2 or 3 indented preserved impressions, but no clear perforations through recrystallized walls of chambers. Interwalls to 0.4 mm thick, but with considerable variation. Chambers may contain vesiculae but most chambers partially matrix-filled in geopetal structure.

Discussion.—Girty (1908a) questioned whether the two sponges he selected as types, and which were figured, belonged to the same species, but this certainly appears to be the case. He included the species in *Amblysiphonella* because he interpreted the skeletal structure as made of ring-like chambers that extended unbroken around the spongocoel. The holotype (1908a, Pl. 7, Fig. 7) clearly shows chamberlets in the upper part of the tangential cut of the sponge. Such chamberlets are also evident in the transverse part of the section of the paratype, with these chamberlets having distinct pustulose exowalls similar to the chamberlets shown in the upper part of the paratype, where two pustolose chamberlets are clearly part of one "ring." Girty apparently interpreted walls between the chamberlets as vesiculae that interrupted the continuity of the torus-like chambers. Most of the sponge wall has only a single layer of chamberlets, but locally two layers are intermittently developed in the thick-walled sponge. Girty observed (1908a, p. 91) that "the interior of the structural ring is divided into simple cysts which are large and not very numerous," but the structure was so much simpler than the multiple-chambered *Cystothalamia nodulifera* Girty, 1908a, that he separated the two. Girty observed (1908a, p. 90) that *Cystothalamia* differs from sponges he included in the Sphaerosiphonidae Steinmann in not being made up of regular superposed chambers or systematic annular groups of chambers.

Cystothalamia is not common in the Guadalupe Mountains; only a few examples of the genus were observed in our collections. Girty's material came from somewhat older parts of the Capitan Formation exposed near El Capitan in the southern Guadalupe Mountains. Upper Capitan rocks, equivalent to those in the northern part of the Guadalupe Mountains, have been eroded and largely removed from the southern part of the range, where the upper part of the preserved Capitan Limestone is of approximately middle Bell Canyon Formation equivalent, generally in the range of the fusulinid *Polydiexodina.*

Material.—The holotype, USNM 118156, and the paratype, USNM 118150, were collected by G. B. Richardson from the top of Guadalupe Peak in the southern Guadalupe Mountains, from USGS locality 2966 and were described by Girty (1908a, p. 91–92). Other examples of the species occur in our collection in UNSM 35030, 35073 from Chinaberry Draw, UNSM 35262 from Bat Cave Draw, and UNSM 35246 and questionably UNSM 35273 from Hackberry Draw, all in Sample Set B.

Genus DISCOSIPHONELLA Inai, 1936

Diagnosis.—"The specimens consist of straight, bent, or branching cylindrical bodies traversed by a large smooth central cloaca. The body is divided into hollow cysts arranged in more or less regular diagonal rows forming a single layer of cells surrounding the cloaca. All walls are single and are perforated by numerous small pores. The external surface is nodular, each node corresponding in position with a cyst in the body. The spicular structure is unknown" (King, 1943, p. 31).

Discussion.—Senowbari-Daryan (1990, p. 56) placed the genera *Cystauletes* King, 1943, *Ascosymplegma* Rauff, 1938, and *Lichuanospongia* Zhang, 1983, into synonomy with *Discosiphonella* Inai, 1936. Skeletons of all of these genera are more or less cylindrical and composed of nodular, cyst-like, chambers arranged in one layer around the spongoceol, in a monoglomerate arrangement (see Senowbari-Daryan, 1990, p. 56–57). Rigby, Fan, and Han (1995) observed that *Discosiphonella* apparently has a relatively simple endowall, but were unable to examine the type specimens of *Discosiphonella* Inai, 1936, for both the holotype and paratype are missing from the collections. From figured specimens, these sponges appear to have relatively simple endowalls and a structure much less complex than the canalled pattern in *Cystauletes mammilosus,* King, 1943 from the Upper Carboniferous of Oklahoma. Consequently Rigby, Fan, and Han (1995) maintained *Cystauletes* as a separate and valid genus.

Lichuanospongia Zhang, 1983, was intrepreted to have a two-layered outer wall and, hence, was separated from *Cystauletes* and *Discosiphonella,* but that outer layer is like the outer cortex noted in *Cystauletes lercarensis* Senowbari-Daryan and Di Stephano, 1988a. Senowbari-Daryan (1990, p. 57) observed that such a cortex-blanketed wall is known in other discosiphonellids and is probably not of generic importance.

Wu (1991, p. 87) and Belyeava (1991, p. 102) both proposed establishment of the new family "Cystauletidae." The priority and justification of those proposals were discussed by Senowbari-Daryan and Ingavat-Helmcke (1994, p. 16). For discussion concerning establishment of the family Cystauletidae and its membership, see Senowbari-Daryan, (1990) and Belyeava (1991).

The new genus *Squamella* proposed by Belyeava (1991, p. 106) seems to be identical with the genus *Imbricatocoelia* Rigby, et al., 1989a. We think that relationships of genera within the families Sebargasiidae and "Cystauletidae" (*sensu* Belyaeva) are very close and that they should be included in a single family. The classification of Senowbari-Daryan (1990) is used in this paper.

Discosiphonella is a cosmopolitian genus, appearing first in the Carboniferous and ranging commonly into the Permian, but locally into the Upper Triassic (Norian-Rhaetian). Senowbari-Daryan (1990, p.58) tabulated occurrences of *Discosiphonella,* known to 1990. The genus *Lichuanospongia* was reported recently from the former Soviet Union (Belyaeva, 1991, p. 103) and it probably occurs in China (Wu, 1991) and Thailand (Senowbari-Daryan and Ingavat-Helmcke, (1994, p. 444).

Type species.—*Discosiphonella manchuriensis* Inai, 1936.

DISCOSIPHONELLA MAMMILOSA (King, 1943)
Plate 1, figs. 9, 10; Plate 2, figs. 2, 3; Plate 3, figs. 2–4; Plate 7, fig. 8

Cystauletes mammilosus KING, 1943, p. 32, Pl. 1, figs. 3–5; VAN DE GRAAFF, 1969, p. 243, Pl. 1, figs. 3–4, 7, Pl. 2, fig. 8, Pl. 3, figs. 2, 5, Pl. 4, figs. 2, 3, 5, 7, 8, Pl. 5, figs. 1, 2; TOOMEY, 1979, p. 846, Pl. 1, fig. 5, Pl. 2, figs. 1–9; SENOWBARI-DARYAN AND RIGBY, 1988, p. 191, Pl. 33, figs. 1, 3, 5, Pl. 35, fig. 19.

Cystothalamia insolita TERMIER AND TERMIER (in TERMIER, et al.), 1977a, p. 43, Pl. 10, fig. 7; TERMIER AND TERMIER, 1977b, text-fig. 24.

Cystothalamia sp., ALEOTTI, DIECI, AND RUSSO, 1986, p. 15, Pl. 4, figs. 1a, 1b.

Cystothalamia sp., RIGBY (in BOARDMAN, et al.), 1987, text-fig. 10.18.G.

Discosiphonella mammilosa (King), SENOWBARI-DARYAN, 1990, p. 57–58, Pl. 20, figs. 4–6, Pl. 59, figs. 4–6.

Emended diagnosis.—Straight cylindrical to branching stems up to 20 mm in diameter, with chambers 3–8 mm high wide, radially from central tubular spongocoel up to 6 mm in diameter and one-eighth to one-third total stem diameter. Chambers arranged in single cyst-like layer in monoglomerate arrangement around spongocoel. Pores in segment walls not usually numerous, but with common diameters of 0.1–0.2 mm and rarely up to 0.5 mm. Cyst-like chambers may be arranged in horizontal rings or in somewhat diagonally stacked patterns. Interwall and exowalls 0.2–0.4 mm thick, endowall to 0.5 mm thick with endopores to 0.25 mm in diamter. Vesiculae common in chambers.

Description.—Stems cylindrical, straight or bent and branched, commonly with diameters of 15 mm, but ranging up to 20 mm. Large specimens up to 28 mm in diameter have been reported from the Carboniferous of Spain (Van de Graaff, 1969, p. 243).

Cyst-like chambers range 2–8 mm across, with sizes proportional to sizes of specimens. Chambers arranged in one monoglomerate layer around axial spongocoel 3–8 mm in diameter (King, 1943, p. 32). Van de Graaff (1969) observed diameters of spongocoel to range from about one-eighth (6–8 mm) to one-third (10 mm or more), of entire sponge diameter. In longitudinal sections, cyst-like chambers may appear as ring-like, or in diagonal sections, skeleton may appear composed of more than monoglomerate layer. Where chambers appear ring-like, *Discosiphonella* may be confused with representatives of *Amblysiphonella,* where chambers are complete rings around spongoceol.

On UNSM 34701, a slab 15 mm thick, both surfaces show sections of moderately good preservation, subtransverse section on upper surface 15 X 20 mm in diameter. Chambers in irregular moniliform arrangement around irregular spongocoel 2–4 mm across. Chambers generally 3–4 mm long and wide, appear subcircular in transverse sections and upward crescentic in longitudinal ones. Diagonal part of sections give false impression of more than one layer because of arcuate chamber development where parts of two or three vertically and diagonally stacked chambers intersected.

Interwalls and exowalls 0.2–0.4 mm thick, pierced by numerous coarser pores, 0.18–0.20 mm in diameter, only irregularly preserved. Endowall with pores or canals up to 0.25 mm diameter appears somewhat vermiculate in diagonal sections, although structure not clearly defined, in layer up to 0.5 mm thick.

Vesiculae common as bubble-like in single and multiple layers and plate-like; most subhorizontal but some at high angles. Vesiculae nearly fill many chambers.

Sections on lower surface of slab partly longitudinal, show arcuate chambers 1.4–1.2 mm high and up to 3.5 mm long, radially, in moniliform layer around spongocoel which is open central tube 2 mm across. Spongocoel wall irregularly canalled and locally up to 0.8 mm thick, but with simple porous walls, like interwalls, where chambers bulge toward spongocoel.

King (1943 p. 32), observed that "elevations (cysts) are disposed in more or less regular diagonal lines," but such packing observable only in specimens weathered free of matrix. Chamber walls range approximately 0.2–0.3 mm thick, but our specimens may have walls appearing somewhat thicker because of recrystallization.

Specimen sectioned long-diagonally on UNSM 34718, 30 mm long and 9–10 mm in diameter, shows chambers and single central canal. Chambers up to 6–7 mm wide and 3–4 mm high, with upwardly arcuate, locally arranged in scale-like sections in monoglomerate layer up to 4–5 mm thick around tube-like spongocoel up to 2 mm in diameter. Interwalls and exowall 0.4–0.5 mm thick, endowalls obscure but probably 0.5–0.6 mm thick. Diagenesis has obscured pores and microstructure, as well as details of structure in endowalls. Exterior pustulose or nodular caused by bulges of individual chambers.

Several aligned specimens on UNSM 34650 show cylindrical structure of species well, in long-diagonal and transverse sections sponges are at least 40–60 mm tall and 15–18 mm in diameter. Monoglomerate layer of subspherical cyst-like chambers up to 6 mm high and 4–5 mm wide, around central spongocoel 3–5 mm in diameter; up to 10 chambers in "ring" at one level around spongocoel. Chambers commonly filled with bubbly vesiculae and with sparry cement or preserved as voids. Diagonal sections or transverse sections cut through parts of several chambers give false impression of polyglomerate arrangements, particularly confusing where differences of chamber walls and vesiculae obscure. Microstructure and pores of walls largely destroyed by diagenesis.

Discussion.—*Discosiphonella mammilosa* (King), has been reported from Carboniferous and Permian rocks (see Senowbari-Daryan and Rigby, 1988, p. 191).

Material.—The species is abundant in UNSM 34650 in Sample Set A, where at least 9 stems, apparently fallen and aligned, occur in bafflestone associated with *Guadalupia zitteliana* and *Lemonea conica.* The species occurs in Sample Set B in UNSM 35002, 35003, 35010, 35011, 35013, 35014, 35020, 35022, 35028, 35029, 35637, 35043, 35051, 35064, 35065?, 35067, 35072, 35092, 35083?, 35084, and 35286 from Chinaberry Draw. It also occurs in UNSM 35107, and 35159 from Dark Canyon; and in UNSM 35182, 35183, 35195, 35213, 35222, 35275, 35277, and 35285 from Hackberry Draw, and in Sample Set A in UNSM 34650 from Chinaberry Draw, and 34693, 34701 and 34718 from the Hackberry Draw. Figured specimens include UNSM 35011, 35013, 35020 and 35028 from Chinaberry Draw, and UNSM 34701 and 34718, from Hackberry Draw, and UNSM 35281, from an uncertain locality.

Family COLOSPONGIIDAE
Senowbari-Daryan, 1990

(=Colospongiidae Boiko and Belyaeva, 1991, in Boiko, et al., 1991) (see Senowbari-Daryan and Ingavat-Helmcke, 1994)

Diagnosis.—"In dieser Familtie werden alle poraten Vertreter der thalamiden Schwämme ohne Füllskelett und ohne Zentralrohr zusammengefaßt. Die Poren der Segmentwände sind entweder unverzweigt oder nur dichotom verzweigt. Das Basalskelett ist/war primär aragonitisch. Je nach der Anordnung der Segmente werden zwei Subfamilien unterschieden." (In this family will be placed all porate representatives of the thalamid sponges without filling skeletons and without central tubes (spongocoels). The pores of the segment walls are either unbranched or dichotomously branched. Because of differences in arrangements of segments two subfamilies are recognized.) (Senowbari-Daryan, 1990, p. 63)

Subfamily COLOSPONGIINAE
Senowbari-Daryan, 1990

Diagnosis.—"Moniliforme Anordnung der Segmente." (Moniliform arrangement of the segments.) (Senowbari-Daryan, 1990, p. 63)

Genus TRISTRATOCOELIA
Senowbari-Daryan and Rigby, 1988

Diagnosis.—"Porate sponge consisting of several rhythmically repeated chambers. The external view shows of three repeated parts: the first and major chamber is barrelshaped and about twice the height of the other parts. The second part corresponds to an expanded dense ringlike element above the first one and is situated below the bottom of the third part. The third part of the skeleton is part of the regular chamber wall and is higher than the ringlike elements. It is constantly more strongly weathered than the other two. Internally the barrel-shaped chamber has a thin wall and is clearly set off from the ring-like chamber, which is thick-walled. Both are porous, but the lower part of the barrel-shaped chamber exowall is more coarsely perforate. Large openings pierce the chamber interwalls. Ostia may occur." (Senowbari-Daryan and Rigby, 1988, p. 189)

Type species.—*Tristratocoelia rhythmica* Senowbari-Daryan and Rigby, 1988

TRISTRATOCOELIA RHYTHMICA
Senowbari-Daryan and Rigby, 1988
Plate 4, figs. 1–4; Figure 10

Tristratocoelia rhythmica SENOWBARI-DARYAN AND RIGBY, 1988, p. 189–190, Pl. 25, figs. 5, 6, 9, text-fig. 10; SENOWBARI-DARYAN AND RIGBY, 1991, p. 625, figs. 3.6, 3.7; SENOWBARI-DARYAN AND INGAVAT-HELMCKE, 1993, fig. 5a; SENOWBARI-DARYAN AND INGAVAT-HELMCKE, 1994, p. 13–14, Pl. 10, figs. 1, 2, text-fig. 5.

Diagnosis.—Same as for genus.

Description.—Four specimens occur in our collections; largest composed of nine chambers with preserved height of 92 mm, on UNSM 35063. Individual chambers relatively high, with heights ranging between 6 and 13 mm. Diameter of sponge stem and of chambers up to 7 mm. Chamber interwalls (called "ring chambers" by Senowbari-Daryan and Rigby, 1988, p. 189–190), very thick, reaching thicknesses up to 5 mm. Exowalls thin and pierced by isolated, unbranched, small individual pores. Interwalls pierced by relatively large branched pores, but because of relatively poor preservation of skeleton, sizes of pores cannot be precisely determined. Large ostia described in holotype and paratype from Tunisia, but not observed in Capitan Limestone specimens. Some vesiculae present.

Smallest specimen represented by only 3 1/2 chambers, is 30 mm high, and reaches diameter of 6 mm. Chamber heights, and other features, are like those in larger specimen.

Fragment of 2 chambers, 6–7 mm tall and 3.5–4 mm in diameter, on UNSM 34701, poorly preserved and somewhat questionable representatives of species. Sublongitudinal section of well-preserved specimen on UNSM 34623 irregularly bent sponge showing most of 10 chambers, although 4 of these are separated from six that show characteristic structure of genus and species. Sponge at least 45 mm tall, with best preserved chambers in center of sponge; chambers range 4.0–5.7 mm high and 3.0–5.0 mm in diameter; thickened chamber roofs range 1.5–1.8 mm thick and appear as relatively massive interruptions in growth of sponges. Major chambers only 4.0 mm tall in tangential sections in upper and lower part of sponge, but

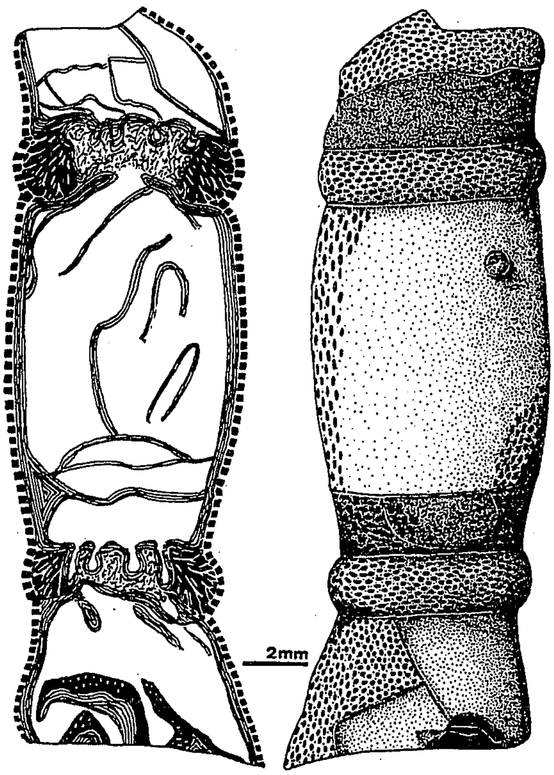

Figure 10. Longitudinal section of the interior (A) and external surface (B) of Tristratocoelia rhythmica *Senowbari-Daryan and Rigby, 1988. The barrel-shaped chambers are subdivided by thick complex interwalls (modified from Senowbari-Daryan and Rigby, 1988).*

range 5.0–5.7 mm tall and up to 4.8 mm in diameter in best longitudinal sections.

Fourth section, on UNSM 34627, essentially longitudinal section of slightly bent sponge, 55 mm tall, of 6 plus chambers. Chambers increase in diameter from 4.5 mm in lower small chamber, to 6.3 mm in upper two chambers, and increase in height from 3.0 mm tall in smallest lower chamber to 6.8 mm in intermediate one, but upper chambers only 6.0 mm tall. Chambers separated by dense chamber roofs, somewhat narrower than maximum diameters of barrel-shaped chambers, but appearing as slightly annulate rings between them, ranging from 2.2 to 3.0 mm thick, as relatively massive chamber separations and forming rings that range from 3.8 mm in diameter, between lower two rings, to 5.4 mm in diameter at top. Recrystallization has largely destroyed details of wall, so pore distribution and diameter in exowall obscured, but in two interwalls, moderately large openings 0.7 mm across preserved as matrix fill. These openings suggest structure of so-called "ring chambers" like that in type specimen from Tunisia, with interwalls perforated by osculi and outer parts with more dense, organic-rich skeleton that contains small branching pores, but details obscure in our largely recrystallized sponges, seen here only in polished sections.

Discussion.—Heights of individual chambers in specimens from the Guadalupe Mountains are almost twice that of the holotype from Djebel Tebaga, Tunisia. Specimens with intermediate heights of chambers, up to 10 millimeters, have been described by Senowbari-Daryan and Ingavat-Helmcke (1993,1994) from Permian deposits of Thailand and suggest that variation in chamber height may be a response to ecological factors rather than being genetically controlled. General structural relationships appear essentially identical in specimens from all three collections.

Tristratocoelia in UNSM 34623 appears fallen and approximately horizontal. Most associated species of *Lemonea micra* n. sp., which are abundant in the sample, and *Lemonea cylindrica*, which are somewhat less abundant, are approximately vertical and in normal upright growth position.

Tristratocoelia permica was intially described from Upper Permian reef limestones of Djebel Tebaga, Tunisia, by Senowbari-Daryan and Rigby (1988, 1991). It was later reported from uppermost Permian rocks of Phrae Province, northern Thailand (Senowbari-Daryan and Ingavat-Helmcke, 1993, 1994). *Tristratocoelia* seems to be a cosmopolitan sponge, but in Tunisia and Thailand, as well as in the Guadalupe Mountains, it appears to be a relatively rare thalamid genus and species.

Material.—The species occurs on UNSM 34623, and 34627 from Dark Canyon, and 34701 from Hackberry Draw in Sample Set A, and on UNSM 35004, 35013?, 35035, 35039, 35055?, 35063, 35085, 35086, and 35087? from Chinaberry Draw, and on UNSM 35099 and 35158 from Dark Canyon; and UNSM 35202 from Hackberry Draw. Figured specimens are USNM 34623 and 34627 from Dark Canyon, 35004, and 35063 from Chinaberry Draw.

Subfamily CORYMBOSPONGIINAE
Senowbari-Daryan, 1990

Diagnosis.—"Glomerate bzw. stratiforme Anordnung der Segmente." (Glomerate to stratiform arrangement of segments.) (Senowbari-Daryan, 1990, p. 64)

Genus EXAULIPORA new genus

Diagnosis.—Thalamid sponges composed of clusters of spherical to subspherical, occasionally egg-shaped, chambers arranged glomerately in clusters or locally tending to grow with moniliform parts. Coarse exaules, tubular, perforate, only one, or rarely two, per chamber, extend from porous chamber walls. All chamber walls, walls of exaules, and walls that form sieve-like plate at inner base of exaules perforated. Chamber interiors contain vesiculate.

Discussion.—Sections of *Exaulipora*, especially moniliform specimens, may be confused with the genus *Colospongia* Laube, which also has moniliform chambers with perforated walls. *Colospongia*, however, lacks the prominent coarse exaules. Some glomerate, porate, thalamid sponges, like *Parauvanella* Senowbari-Daryan and Di Stephano, 1988, or *Platythalamiella* Senowbari-Daryan and Rigby, 1988 (see Senowbari-Daryan, 1990) may be confused with *Exaulipora*. However, presence of the distinctive coarse exaules that are usually large and longer than the chamber diameter would clearly differentiate *Exaulipora*.

Such exaules were also described in the Ordovician genus *Corymbospongia* by Rigby and Potter (1986, p. 28) from the eastern Klamath Mountains of northern California. However, exaules in the type species of *Corymbospongia* are aporate and, in general, are much shorter and smaller than in *Exaulipora*. In addition, the exaules in *Exaulipora* appear situated over porous basal plates, which are continuations of the perforated wall, and thus appear perched on the more or less original continous wall, in contrast to the structure in *Corymbospongia*. The presence of perforate plates in *Corymbospongia* was not documented in the silicified specimens described by Rigby and Potter (1986, Figs. 10.1–10.6, 10.7–10.11), but such a porous base seems unlikely.

Corymbospongia(?) *perforata* Rigby and Potter (1986, p. 31–32, Fig. 10.7) has perforated exaules. This species was placed, with question, into the genus *Corymbospongia* by Rigby and Potter and should probably be moved to the new genus *Exaulipora*, if the chamber walls at bases of the exaules are also perforated like in the type species *Exaulipora permica* (Senowbari-Daryan, 1990).

Type species.—*Corymbospongia*(?) *permica* Senowbari-Daryan, 1990, p. 69–70.

Etymology.—*Ex*, Greek, out of, or from; *aulos*, pipe or tube; *porus*; pore; named for the distinctly perforated outer exaulos tubes characteristic of the genus.

EXAULIPORA PERMICA
(Senowbari-Daryan, 1990),
Plate 2, figs. 4–7, Figure 11

"Sheet-like and cateniform Sphinctozoa" FAGERSTROM, 1987, Pl. 48a.

Corymbospongia(?) *permica* SENOWBARI-DARYAN, 1990, p. 69–70, Pl. 22, figs. 1–5; text-fig. 22.

Diagnosis.—"Segmentierter Schwamm, bestehend aus glomeraten, kugeligen bis eiförmigen Segmenten, ohne Zentralkanal. Jedes Segment enthält einen (selten zwei) Exaulos. Die Segmentwände und die Wand des Exaulos besitzen zahlreiche Poren. Ein Cribribulla (Siebplatte) ist an der Basis des Exaulos ausgebildet. Kein Füllskelett, aber mit Vesiculae." (Thalamid sponge composed of glomerate spherical to egg-shaped chambers, without an axial tube. Each chamber has one (rarely two) exaulos. The wall of the chambers and exaules possess numerous pores. A cribribulla (sieveplate) is developed at the base of each exaulos. Without filling structures, but with vesiculae.) (Senowbari-Daryan, 1990, p. 70)

Description.—Clusters of numerous spherical or subspherical to egg-shaped chambers reach diameters, or widths, of more than 8 cm. Each chamber is up to 20 mm in diameter. Chambers glomerately arranged, occasionally moniliform or perhaps locally stratiform. Chamber walls relatively thick, generally of less than 1 mm, commonly 0.4–0.7 mm. Wall pierced by numerous small unbranched, pores 0.2–0.3 mm in diameter. Each chamber usually possesses one exaulos, as that term was proposed by Finks (1983), rarely two but never three. Exaules usually longer than diameter of chamber and lengths may reach up to 40 mm. Diameters of exaules larger at base and narrow distally to outer open end. Basal diameters of flared attachment base commonly 5 or 6 mm but range up to 8 mm. Walls of all exaules pierced by pores of generally same size as those in chamber walls, or perhaps somewhat smaller. Exaules usually not overlapped by younger chambers but locally such overlap does occur and mutually overlapping exaules were observed.

Porous plate present as continuation of chamber wall within base of each exaulos, like sieveplate or cribribulla, as that term was proposed by Finks (1983). Pores in these elements have same general diameters as those in adjacent chamber walls. Exaules generally irregularly located on chamber walls and commonly do not show any preferred orientation. One specimen, however, shows exaules of four successive chambers located on same side of their chambers, pointing in same direction.

Chamber interiors usually empty but may contain minor vesiculae in rare cases. Vesiculae also may occur in the interior of exaules and basically seal them as functional units.

Discussion.—In the field, as well as in hand samples, the exaules may be confused with other organisms if the exaules are cut in tranverse cross-sections and isolated from the chambers. Such sections may be confused with porous worm tubes or other circular-looking skeletal elements (see Senowbari-Daryan, 1990, Pl. 22, Figs. 1, 2, 6; Pl. 57, Fig. 3).

As pointed out by Senowbari-Daryan (1990, p. 70), exaules of *Exaulipora* may often be encrusted by the small glomerate sponge *Parauvanella minima* Senowbari-Daryan. Such encrustation commonly occurs on specimens exposed in the "Sponge Window" locality, perhaps more abundantly

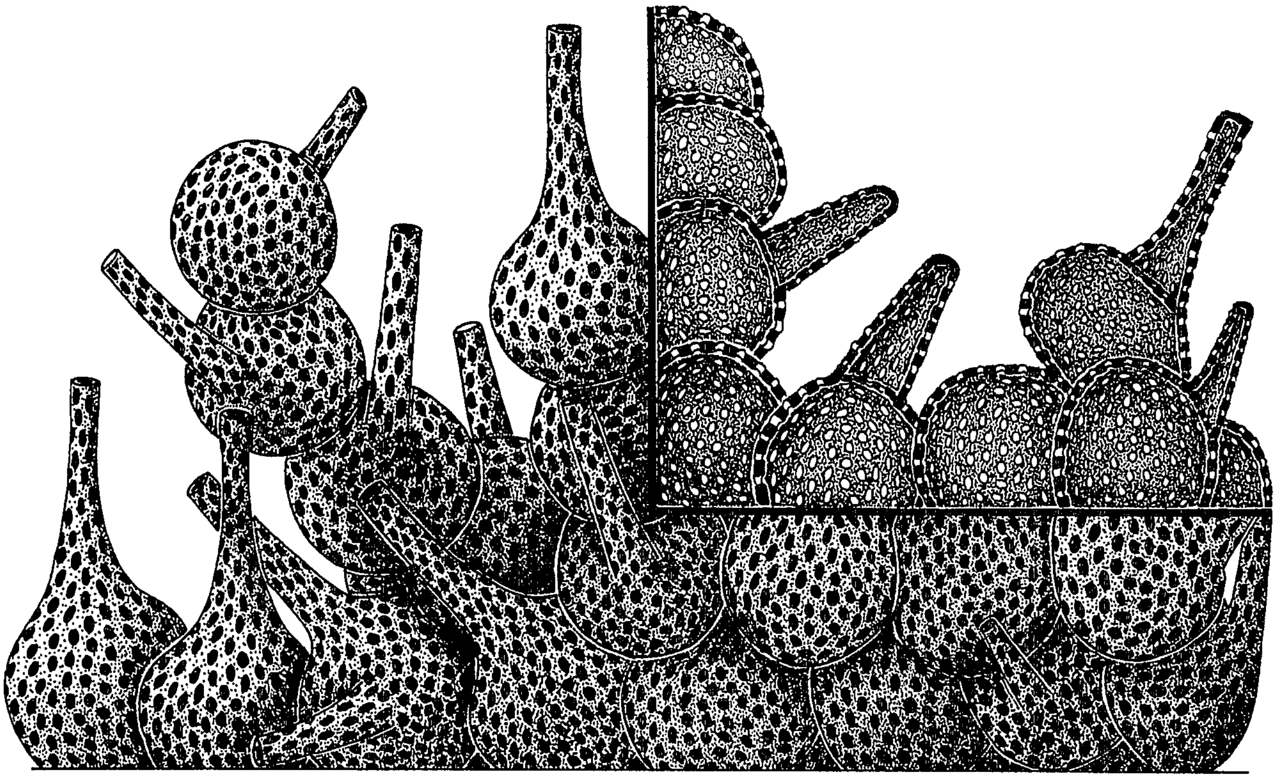

Figure 11. Reconstruction of Exaulipora permica *(Senowbari-Daryan, 1990), showing the generalized exterior of the clustered chambers with prominent long exaules and a section through associated chambers showing their porous walls; the porous-walled exaules are separated by a basal wall from the chamberlets, not to scale (from Senowbari-Daryan, 1990).*

than from other localities (Senowbari-Daryan, 1990, Pl. 22, Fig. 6; Pl. 57, Fig. 3; Pl. 58, Fig. 6; Pl. 59, Fig. 3).

Sponges with long imperforate exaules were described from the Ordovician of northern California as *Corymbospongia* by Rigby and Potter (1986). In these sponges, the chamber walls are perforate and water probably passed throught those pores into the chamber interiors, but left the chambers through the coarse unperforated tubular exaules. On the other hand, walls of exaules in *Exaulipora* are perforated, in contrast to the dense walls of exaules in *Corymbospongia.* The functions of pores in exaules in *Exaulipora* are, thus, open to some interpretation. We believe that water passed through the sponge in essentially the same manner as in *Corymbospongia.* Inhalant water passed through pores in the chamber walls, into the chamber interiors, and left partially or wholly by the exaules. Pores on the exaules were, therefore, exhalant. Porous exaules many have developed from the nonperforated structures seen in the Ordovician sponge, to discourage attachment of other organisms such as bryozoans or algae (e.g., *Archaeolithoporella*) and to discourage use of the exaules as a substrate. The perforated exaules and the outflowing current could hinder encrustation by keeping the surface swept clean of attaching larvae.

A notable exception, however, is the encrustation of the outer ends of exaules by the small glomerate sponge *Parauvanella minima* Senowbari-Daryan, 1990. It might be possible that *Parauvanella* was a "comfortable" guest and allowed exhalant water from *Exaulipora* to leave through the small sponge body. Such a relationship may not have been a particular disadvantage to *Exaulipora*, but apparently it was distinctly advantageous for *Parauvanella*, which could profit by the exhalant current produced by the larger sponge.

Nature and relationship of the seiveplate or cribribulla to water circulation is also uncertain. Pores of the cribribulla would have no apparent function if the exaules were only exhalant tubes. Perhaps exaules were added secondarily during evolution and the sieveplates were of primary construction. The sieveplates, thus, appear to be remains of the original chamber walls which were possibly reduced during the next step of evolution.

On one specimen, exaules occur consistently on one side of the aligned chambers. Such an alignment might indicate that water movement was essentially horizontal and the leeward-facing exaules functioned chimney-like for removal of wastes to some distance from inhalant canals or pores of the chambers. The exaules appear tilted slightly upward, which could indicate that water movement was essentially horizontal through the chambers, but then slightly upward as it exited in the exhalant system.

The genus *Exaulipora* is questionably present in the Ordovician of the Eastern Klamath Mountains, as suggested by the species *E.*(?) *perforata* Rigby and Potter, 1986. The type species, *E. permica* (Senowbari-Daryan, 1990), is known only from the Permian Upper Capitan Limestone of the Guadalupe Mountains.

Material.—Figured specimens occur on UNSM 35114. Reference specimens occur on UNSM 35091, 35097, 35101, 35103–35105, 35110, 35114, 35116, 35146, 35151, 35157, 35165, 35166, 35168, 35169 and 35177 from Dark Canyon, as well as on USNM 35257, 35261, 35262 and 35263? from Bat Cave Draw; and UNSM 35003, 35073, 35086? from Chinaberry Draw, UNSM 35277 from Hackberry Draw, and UNSM 35228 from Rattlesnake Canyon, all from Sample Set B. The species also occurs in samples of Set A on UNSM 34606, 34607, 35608, 34609, 34611, 34613, 34615, 34625, 34626, 34629, from the Dark Canyon locality, and on UNSM 34680, from the Chinaberry Draw locality, and UNSM 34701 from the Hackberry Draw locality.

Genus PARAUVANELLA
Senowbari-Daryan and Di Stefano, 1988

Diagnosis.—"Nodular aggregates consisting of numerous small and irregular chambers. Central canal missing. Chamber walls sparitic to microsparitic (most probably primary aragonite?); imperforate to coarsely perforate, without filling tissue and vesiculae." (Senowbari-Daryan and Di Stefano, 1988a, p. 18)

Type species.—*Parauvanella paronai* Senowbari-Daryan and Di Stefano, 1988a.

PARAUVANELLA MINIMA
Senowbari-Daryan, 1990
Plate 4, fig. 5; Plate 9, fig. 7

Parauvanella sp. REINHARDT, 1988, p. 258, Pl. 33, fig. 6, Pl. 35, fig. 1 (*non* Pl. 34, fig. 6).

Parauvanella minima Senowbari-Daryan, FLÜGEL AND REINHARDT, 1989, p. 511, fig. 10A (*nom. nud.*); SENOWBARI-DARYAN, 1990, p. 70–71, Pl. 22, figs. 1, 2, 6, Pl. 57, fig. 3, Pl. 58, figs. 5–8, Pl. 59, figs. 2, 3; WEIDLICH AND SENOWBARI-DARYAN, 1996, p. 32, fig. 6.10.

Diagnosis.—"Aggregate, bestehend aus kleinen und runden Kammern. Uviforme Anordnung der Segmente. Segmentwände grob perforiert. Vesiculae kommen vor." (Aggregate composed of small spherical chambers. Uviform arrangement of the chambers. Chamber wall coarsely perforated. Vesiculae may occur.) (Senowbari-Daryan, 1990, p. 70)

Description.—Small aggregates, characteristic of species, generally 5–20 mm in diameter, and composed of numerous spherical to crescent chambers, arranged in grape-like clusters. Individual chambers small, generally with diameters of only 0.5–0.8 mm, but locally up to 1.2 mm. Chamber walls 0.04–0.06 mm thick, pierced by small pores, 0.05–0.10 mm in diameter (Senowbari-Daryan, 1990, p. 71). Chamber interiors contain rare vesiculae.

Discussion.—*Parauvanella minima* Senowbari-Daryan, 1990, seems to be most abundant in the vicinity of the "Sponge Window" at the mouth of Bat Cave Canyon, near Whites City (Locality S of Fig. 3.1). Senowbari-Daryan (1990, p. 71) observed that *Parauvanella minima* commonly occurs growing epifaunally, preferentially, on exaules of *Exaulipora permica* (Senowbari-Daryan, 1990), rather than growing over other organisms (see discussion of *Exaulipora permica* above). Relatively rare examples of *Parauvanella* also occur attached to *Peronidella*(?) cf. *P. rigbyi* Senowbari-Daryan, 1991, in UNSM 34633 from Dark Canyon (Locality D, Fig. 3.2). Moderately common small clusters occur in UNSM 34718 from Hackberry Draw, associated in sponge-algal boundstone with *Sollasia*, *Minispongia*, rare *Discosiphonella* and the bryozoan *Acanthocladia.*

Parauvanella minima is known from Upper Permian reef limestones on the Island of Skyros, Greece (Flügel and Reinhardt, 1989), and in China (Fan and Zhang, 1985; Rigby, et al., 1994), there described as *Uvanella* (Flügel and Reinhardt, 1989). *Parauvanella* is also known from Oman (Weidlich and Senowbari-Daryan, 1996). *Parauvanella minima* is limited to rocks of Permian age.

Material.—The species is widespread in the Upper Capitan Limestone. Its occurrences in our samples are shown in Table 1. It has been observed in at least 86 samples in the collections and occurs in all the sample grids and sets. Figured specimens occur on UNSM 35109 and 35155 of Sample Set B from Dark Canyon; and UNSM 34701, in Sample Set A from Hackberry Draw.

Genus PLATYTHALAMIELLA
Senowbari-Daryan and Rigby, 1988

Diagnosis.—"Tabular or plate-like sponge composed of numerous flattened chambers arranged in several layers (2–4). The chambers have crescent-like shapes in sections perpendicular to the plane of the plates. Walls of the chambers are perforated by numerous small pores. A central tube, filling tissue or vesiculae are lacking." (Senowbari-Daryan and Rigby, 1988, p. 184)

Type species.—Platythalamiella newelli Senowbari-Daryan and Rigby, 1988.

PLATYTHALAMIELLA? sp. (n. sp.?)
Plate 2, fig. 1, Figure 12D

Description.—Only one incompletely preserved specimen of this species available in our collections, so reconstruction of style of construction and arrangement of individual chambers not possible. It appears, however, that the sponge is composed of clusters of chambers in stratiform or layered glomerate arrangement. Individual chambers range in diameter up to 25 mm, with heights up to 10 mm. Relatively thin chamber walls approximately 0.8 mm thick and pierced by small pores. Because of recrystallization, diameters of pores cannot be accurately determined.

Interiors of chambers filled with many vesiculae, making clear differentiation of chamber walls and vesicular structures difficult. Neither spongocoel nor other large exhalant canals present.

Discussion.—Arrangement of the chambers in a moniliform, stratiform, or glomerate structure, without an axial spongocoel, suggests the affiliation of the sponge to the family Colospongiidae and the type genus *Colospongia* (Figure 12A). The probable glomerate arrangement of chambers in the skeleton is the principal reason for including the sponge in the subfamily Corymbospongiinae, which was proposed by Senowbari-Daryan (1990, p. 64) to include perforate sponges with stratiform or glomerate chamber arrangements. At that time, the genera *Corymbospongia* Rigby and Potter, 1986; *Parauvanella* Senowbari-Daryan and Di Stefano, 1988; *Neoguadalupia* Zhang, 1987; and *Platythalamiella* Senowbari-Daryan and Rigby, 1988, and somewhat questionably *Imbricatocoelia* Rigby, Fan, and Zhang, 1989, were included in the Corymbospongiidae.

Platythalamiella differs from *Corymbospongia* and *Exaulipora* by lacking exaules, and from *Neoguadalupia* (Figure 12.3) which is characterized by circular or arched chambers arranged in one stratiform layer. The sponge described here shows at least two layers of chambers, if they are indeed arranged in stratiform fashion. Arrangement of chambers in two or more layers is typical of the genus *Platythalamiella* (Figure 12.4). *Cinnabaria* Senowbari-Daryan, 1991 (Figure 12.2), is also a plate-like sponge that may appear similar in cross-section but it is composed of long tubular chambers rather than oval or crescentic ones.

Of the known species of *Platythalamiella* described from the Permian, the sponge described here differs from *Platythalamiella newelli* Senowbari-Daryan and Rigby, 1988, by its extremely large chambers. That species may be a synonym of *P. guanguaensis* Fan, et al., 1987. The Guadalupe Permian specimen appears similar to the Triassic species, *Platythalamiella siciliana* (Senowbari-Daryan, 1990 p. 72–73), but that Triassic species has crescentic chambers. The Guadalupe Mountains sponge probably represents a new species, but because there is so little of the skeleton preserved, and what is available has recrystallized, it seems best to leave it unnamed until more adequate collections are available and relationships to *Platythalamiella* are clearly documented.

Material.—The figured specimen is only one known in the collection and it is incompletely preserved, on UNSM 35225, Sample Set B from Hackberry Draw.

Family SOLENOLMIIDAE Engeser, 1986
Subfamily SOLENOLMIINAE
Senowbari-Daryan, 1990
Genus PREVERTICILLITES Parona, 1933

Diagnosis.—"Cylindrical stems without recognizable, only poorly recognizable, outer segmentation. Chambers are low and filled by reticular-trabecular (pillar-like) filling tissue. A central pseudosiphonate tube extends through the sponge. The chamber roofs or interwalls are very thin and appear as points in a line of sections. Skeleton with sphaerolitic microstructure." (Senowbari-Daryan and Rigby, 1988, p. 195)

Type species.—Preverticillites columnella Parona, 1933.

PREVERTICILLITES
PARVA new species
Plate 4, figs. 5; Plate 5, fig. 6

Diagnosis.—Small branched sphinctozoans with ring-like chambers around pseudosiphonate spongocoel and with coarse, reticular to trabecular filling structures in each chamber. Chambers up to 1.4 mm high, with interwalls 0.2 mm thick of thickened segments of trabecular net. Exowalls, 0.5 mm thick, continuous porous structure with exopores 0.4 mm in diameter. Spongocoel approximately one-fifth stem diameter, may be weakly annulated, lacks well-defined endowall. Filling structure composed of upward radial elements in lower parts but more net-like in upper parts of chambers.

Description.—Small branched sphinctozoans with low, ring-like chambers around tubular pseudosiphonate spongocoel in each branch; chambers with coarse reticular to trabecular-reticular filling structures. Stems 3.0–3.7 mm in diameter, with annulae formed by outward bulged walls of low chambers that bend inward 0.2–0.3 mm at bases of chambers to form narrow rings and annulations. Spongocoel 0.6–0.7 mm in diameter, weakly and irregularly annulate, with some sections broader and others narrower at or

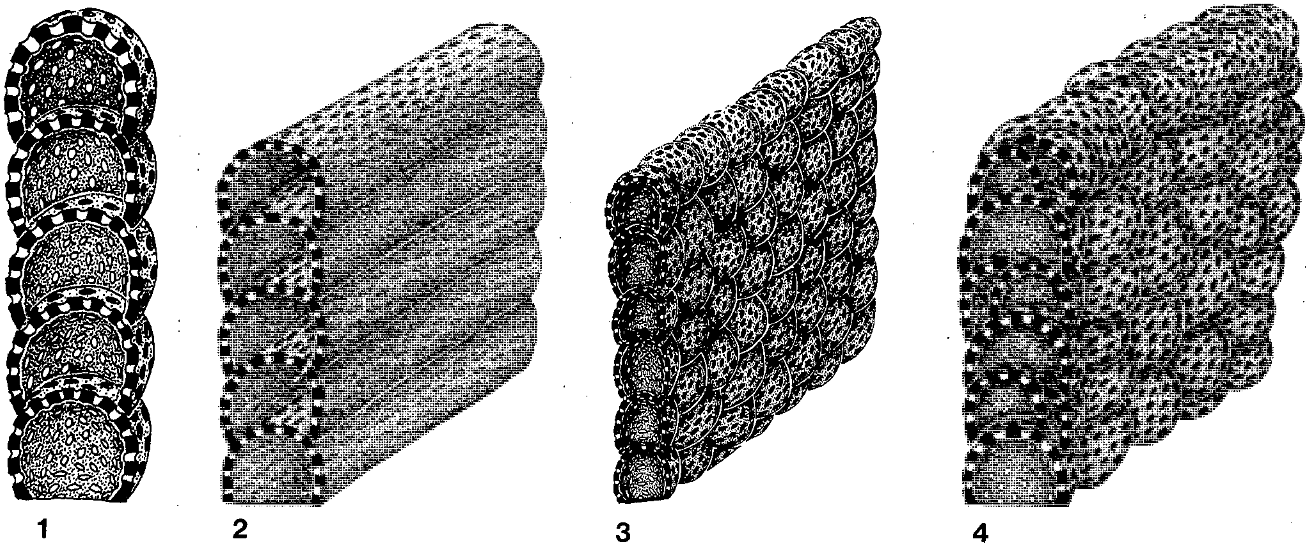

Figure 12. Generalized reconstructions of some thalamid sponges that, in cross section, might be confused with Platythalamiella *Senowbari-Daryan and Rigby, 1988, showing chamber arrangements and growth forms.* 1, Colospongia *Laube, 1865, showing a longitudinal section of the stem or bead-like sponge with linear series of spherical or crescentic chambers.* 2, Cinnabaria *Senowbari-Daryan, 1990, a plate-like or tabular sponge with long tubular chambers.* 3, Neoguadalupia *Zhang, 1987, a tabular sponge composed of a single layer of spherical or crescentic chambers.* 4, Platythalamiella *Senowbari-Daryan and Rigby, 1988, a tabular sponge with spherical or crescentic chambers arranged in two or more layers. In longitudinal sections these genera could appear similar, particularly in poorly preserved specimens (not to scale). (Modified from Senowbari-Daryan and Stanley, 1992)*

near intersections of interwall and spongocoel margins. Spongocoel lacks well-defined endowall.

Chambers ring-like, 1.1–1.4 mm high, most evident on exterior, but also in coarsely reticulate interior. Interwalls largely defined by lineation of horizontally aligned and thickened segments of trabecular net, in layers 0.1–0.2 mm thick, or as series of points of intersections of interwall elements. Individual tracts in interwalls mostly 0.10 mm in diameter and to 0.3 mm long, but commonly half that. Interpores in reticulate net 0.04–0.12 mm in diameter, mostly 0.10 mm in diameter.

Exowalls thin, 0.03–0.5 mm thick, as most continuous porous structure in skeleton, pierced by exopores generally 0.03–0.04 mm in diameter, spaced 0.1 mm apart, as suggested by "dimples" of ostia and openings in skeleton. Structure of "endowall" clearly shown in tangential section of rectangularly arranged tracts, each 0.06–0.08 mm in diameter, expanded to 0.08–0.10 mm in diameter at junctions between rounded quadrate to subcircular exopores 0.08–0.10 mm in diameter. Such pores spaced 6–7 pores per millimeter vertically and horizontally in moderately regular part of skeleton.

Chamber filling structure coarse reticulate to trabecular-reticulate, with vertical trabecular-like irregular elements mostly 0.1 mm in diameter, but irregularly up to 0.15–0.20 mm in diameter, particularly at junctions. Shorter, more discontinuous, horizontal cross-connecting, elements of generally similar diameters. Vertical to upward-outward radial elements 0.2–0.5 mm apart in lower parts of chambers and locally cross-connected there. More reticulate net-like structure developed in upper part of chambers, with more common horizontal segments producing regular pores or openings 0.2–0.3 mm across in reticulate net and somewhat radially (horizontally) elongate as seen in transverse sections.

Paratype on upper surface branched, cut almost at point of branching, with 2 closely adjacent spongocoels and with characteristic trabecular-reticular filling structure. Moderately well-defined exowall in diagonal sections of sponge overgrown by small clump of *Parauvanella.*

Discussion.—Solenolmia Pomel, 1872 (= *Dictyocoelia* Ott, 1967) resembles *Preverticillities,* but has a clearly differentiated retrosiphonate central tube, in contrast to *Preverticillites* which has a pseudosiphonate central tube. Other genera in the family listed by Senowbari-Daryan (1990, p. 89) are from the Triassic, except for the Devonian *Hormospongia* Rigby and Blodgett, 1983. These forms have considerably more irregular and finer-textured reticulate filling structures than seen in *Preverticillites.*

Parona (1933) described *Preverticillites columnella* from the Permian of Sicily. Senowbari-Daryan and Rigby (1988, p. 195) described additional specimens of the species from

Djebel Tebaga, Tunisia. Those sponges, however, are considerably larger and have irregular annulations that do not correspond to the internal segmentation, in a pattern different from that seen in the small sponge here. Except for having chambers of approximately the same height as *P. columnella,* the other dimensions in *P.* parva are considerably greater, as for example, a central spongocoel that is about 6 mm in diameter. Because of these differences, we have chosen to separate the Capitan sponges as a distinct species.

Material.—The holotype of the species occurs on the lower surface, and a paratype occurs on the upper surface of UNSM 34701, of Sample Set A from the Hackberry Draw locality. The third specimen occurs on UNSM 35216, and a fourth questionable specimen occur on UNSM 35220, both from Hackberry Draw. The species also occurs on UNSM 35172 from Dark Canyon. All the latter sponges are in Sample Set B. The sponges occur in association with moderately well-preserved *Discosiphonella mammilosa* (King, 1943) and species of *Parauvanella, Girtyocoelia, Minispongia,* and the new genus *Exaulipora,* in a sponge-algal boundstone, with most elements in growth position. Figured specimen, holotype, on UNSM 34701, compared with other Permian species of the genus.

Suborder APORATA Seilacher, 1962

Diagnosis.—"Segmentwände imperforat, nur mit vereinzelten Ostien. (Segment walls imperforate, only with isolated ostia.) (Senowbari-Daryan, 1990, p. 113)

Family THAUMASTOCOELIIDAE Ott, 1967

Diagnosis.—"Die Familie wurde für die imperforaten Gattungen ohne Füllskelett, aber mit sphärolithischer Wandstruktur aufgestellt." (The family was established for the imperforate genera without filling structures, but with sphaerolitic wall structure.) (Ott, 1967, p. 15, *per* Senowbari-Daryan, 1990, p. 126)

Subfamily THAUMASTOCOELIINAE Senowbari-Daryan, 1990

Diagnosis.—"Moniliforme Anordnung der Segmente, ohne Spongocoel." (Moniliform arrangement of segments, without spongocoel.) (Senowbari-Daryan, 1990, p. 126)

Genus SOLLASIA Steinmann, 1882

Diagnosis.—"Aporate moniliform stems with a single large cryptosiphonate opening in the chamber interwalls, without a central tube. Chamber exowalls contain one or more ostia. Interwalls are normally two layered. Vesiculae may occur. The skeleton was composed of aragonite with sphaerolitic microstructure." (Senowbari-Daryan and Rigby, 1988, p. 197)

Type species.—*Sollasia ostiolata* Steinmann, 1882.

SOLLASIA OSTIOLATA Steinmann, 1882
Plate 1, fig. 1; Plate 4, figs. 11–14;
Plate 5, figs. 1, 2; Plate 7, fig. 1; Figure 13

Sollasia ostiolata STEINMANN, 1882, p. 151–152, Pl. 7, fig. 3; VAN DE GRAFF, 1969, p. 240, Pl. 1, fig. 2, Pl. 2, figs. 5–7, Pl. 4, fig. 4; KÜGEL, 1987, p. 144, Pl. 33, fig. 1–3; SENOWBARI-DARYAN AND DI STEPHANO, 1988, p. 19, Pl. 2, fig. 5, Pl. 3, figs. 6, 8, 9, Pl. 5, fig. 7, Pl. 7, figs. 1, 5, 6, Pl. 8, fig. 4d; SENOWBARI-DARYAN AND RIGBY, 1988, p. 197– 198, Pl. 39, figs. 1–13; SENOWBARI-DARYAN, 1990, p. 128, Pl. 43, fig. 7, Pl. 45, figs. 4, 8, Pl. 56, fig. 9, text-fig. 47; SENOWBARI-DARYAN AND INGAVAT-HELMCKE, 1994, p. 19, Pl. 3, fig. 1c, Pl. 4, fig. 1b, Pl. 6, fig. 4a, 6, Pl. 12, fig. 1b; WEIDLICH AND SENOWBARI-DARYAN, 1996, p. 40–42, figs. 12.6, 12.7.

Sollasia dussaulti MANSUY, 1914, p. 9, Pl. 1, fig. 2a, b; TERMIER AND TERMIER, 1955, p. 617, fig. 1i–a; TERMIER AND TERMIER, 1977a, p. 39, Pl. 10, figs. 1–2; TERMIER AND TERMIER, 1977b, p. 75, fig. 19; ALEOTTI, DIECI, AND RUSSO, 1986, p. 8, Pl. 1, fig. 1a, b.

Heterocoelia beedei Girty, 1908b, PARONA, 1933, p. 42, Pl. 8, fig. 1.

Sollasia aff. *S. ostiolata* Steinmann, DENG, 1982a, p. 710, Pl. 1, fig. 1.

Sollasia cf. *S. ostiolata* Steinmann, DENG, 1982b, p. 251, Pl. 6, fig. 10.

Sollasia n. sp., FAN AND ZHANG, 1985, p. 8, text-figs, 7, 9.

For a complete listing of synonomy to 1990, see Senowbari-Daryan (1990, p. 128), and for later publications see Senowbari-Daryan and Ingavat-Helmcke (1994, p. 19).

Diagnosis.—Small to moderate size, moniliform sponges with spherical to barrel-shaped chambers generally 2–6 mm high but rarely up to 10 mm. Chamber walls pierced laterally by ostia generally small in small specimens and larger in larger specimens, openings up to 1 mm in diameter. Interwalls with central cryptosiphonate openings up to 2.5 mm in diameter. Vesiculae rare. Lateral ostia up to 5 per chamber.

Description.—Skeletons of small to moderate-size sponges composed of numerous moniliformly arranged chambers. Individual chambers spherical or barrel-shaped, with diameters ranging 3–7 mm, and maximum heights to 7 mm. Heights of sponges variable, dependent upon numbers of chambers and with great variation, for example, specimen with 20 chambers 70 mm tall and another with 6 chambers only 21 mm tall.

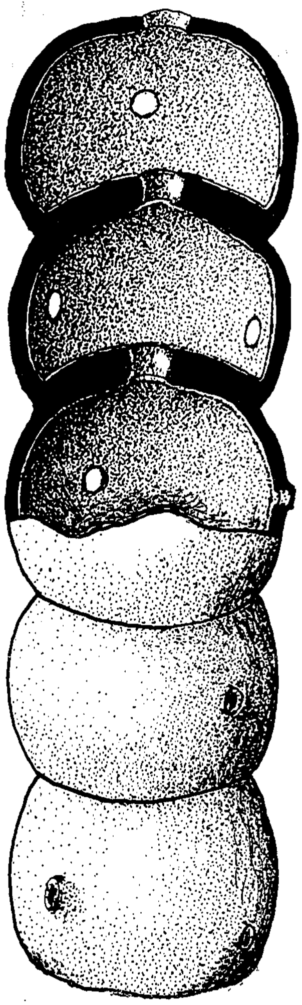

Figure 13. Generalized illustration of Sollasia ostiolata *Steinmann, 1882, showing the appearance of the stacked bead-like chambers from the outside, in the lower part, and in vertical longitudinal section, in the upper part, with the pseudosiphonate central openings in the interwalls, not to scale (from Senowbari-Daryan, 1990).*

Exowalls of chambers pierced by rare and commonly large ostia. Chambers usually interconnected with single moderately large ostium up to 1 mm in diameter. Walls between chambers, interwalls or chamber roofs, 0.3–1.3 mm thick, thicker than exowalls 0.3–0.7 mm, because younger chambers characteristically with additional basal layer that coats interwalls of previous chambers, 0.2–0.5 mm thick in example on UNSM 34602w. Chamber interiors usually hollow. Only in rare cases were vesiculae observed.

Discussion.—Sollasia ostiolata Steinmann, 1882, is a cosmopolitian sphinctozoid sponge known from numerous Carboniferous localities, as for example from Spain (Steinmann, 1882; Van de Graff, 1969), and Austria (Kügel, 1987), and from a variety of Permian localities including China (Deng, 1982a, 1982b), Pamir (Zhuravleva, 1991), USA, (Senowbari-Daryan, 1990), Tunisia (Termier and Termier, 1977a; Senowbari-Daryan and Rigby, 1988), Sicily (Senowbari-Daryan and Di Stefano 1988; Aleotti, et al., 1986), Thailand (Senowbari-Daryan and Ingavat-Helmcke, 1994) and Oman (Weidlich and Senowbari-Daryan, 1994).

Sollasia is a typical Carbonferous and Permian sponge. Reports of its occurrence in Triassic rocks (*Sollasia*(?) *baloghi* Kovacs, 1978) is questionable and not confirmed. *Sollasia ostiolata* is not an abundant sponge in the Guadalupe Mountains, but does occur widely in our samples (Table 1). It is also known elsewhere from the western part of the Tethys (see Senowbari-Daryan and Di Stefano, 1988; Senowbari-Daryan and Rigby, 1988).

Material.—The species is one of the most common sponges in our collections. The species has been documented in approximately 135 sample localities (Table 1). Figured specimens include UNSM 35045, and 35077 from Chinaberry Draw, UNSM 35197, and 35220 from Hackberry Draw, and UNSM 35291–35293, etched specimens, from uncertain localities, all from Sample Set B.

Subfamily ENOPLOCOELIINAE
Senowbari-Daryan, 1990

Diagnosis.—"Thaumastocoeliidae mit catenulater Anordnung der Segmente und mit durchgehendem Spongocoel." (Thaumastocoeliidae with catenulate arrangement of the segments and with a through-going spongocoel.) (Senowbari-Daryan, 1990, p. 129)

Genus GIRTYOCOELIA Cossman, 1909
(pro *Heterocoelia* Girty, 1908b,
non Dahlbom, 1854)

Diagnosis.—"Sponges of the genus *Girtyocoelia* comprise straight or bent stems composed of a series of spherical chambers slightly overlapping, just in contact, or separated by a space bridged only by the central cloaca, which transverses the entire stem. The outer wall of each chamber is perforated by a few large openings, the margins of which may be extended outward as spouts. There seems to be no communication between cells except through the cloaca; pores open into the cloaca from each chamber. The whole sponge body resembles somewhat a string of beads." (King, 1943, p. 33)

Discussion.—All of the previously described and revised species of *Girtyocoelia* proposed until 1990 were listed by Senowbari-Daryan (1990, p. 130–131). Since that time, only one new species, *Girtyocoelia gracilis*, has been described and it was proposed by Weidlich and Senowbari-Daryan (1994) from Permian reef limestones of Oman.

Girtyocoelia is represented by at least two species from Ordovician rocks of the Eastern Klamath Mountains, in northern California (Rigby and Potter, 1986). No representatives of the genus have been reported from rocks of Silurian or Devonian ages, but the genus has been reported from several Carboniferous and Permian localities. *Girtyocoelia* is apparently limited to rocks of Paleozoic age. The report of *Girtyocoelia* in Triassic reefs of Europe cannot be confirmed, for both *Girtyocoelia oenipontana* Ott, 1967, and *G. carnica* Senowbari-Daryan, 1981, do not belong to *Girtyocoelia* (see Senowbari-Daryan, 1990, 1. 130.)

Type species.—*Heterocoelia beedei* Girty, 1908b.

GIRTYOCOELIA BEEDEI (Girty, 1908b)
Plate 3, fig. 3; Plate 4, figs. 6–10; Figure 14

Heterocoelia beedei GIRTY, 1908b, p. 248, Pl. 14, figs. 1–8; KING, 1932, p. 78, Pl. 14, figs. 1–8; *non* PARONA, 1933, p. 42, Pl. 8, fig. 1.

Heterocoelia sphaerica KING, 1932, p. 79, Pl. 7, figs. 7, 8.

Girtyocoelia beedei ZHURAVLEVA, 1962, p. 76, fig. 110; KÜGEL, 1987, p. 144, Pl. 33, figs. 4–8; SENOWBARI-DARYAN & DI STEFANO, 1988a, p. 16–17, Pl. 1, figs. 2, 3, 5b, Pl. 3, figs. 1–4, Pl. 7, fig. 7; SENOWBARI-DARYAN AND RIGBY, 1988, p. 200, Pl. 39, figs. 14–17; SENOWBARI-DARYAN, 1990, p. 130–131, Pl. 45, figs. 1–3, 5–7, text-fig. 48; SENOWBARI-DARYAN AND INGAVAT-HELMCKE, 1994, p. 24, Pl. 7, fig. 1, Pl. 8, fig. 3?, Pl. 9, fig. 2; WEIDLICH AND SENOWBARI-DARYAN, 1996 p. 42, fig. 9.6.

Girtyocoelia cf. G. *beedei* TOOMEY, p. 248, fig. 4b.

Girtyocoelia dunbari KING, 1943, p. 33–34, Pl. 3, fig. 6; ZHURAVLEVA, 1962, p. 76, fig. 111; RIGBY, 1984, p. 1452, fig. 31.

Girtyocoelia sp., TERMIER AND TERMIER (in TERMIER, et al.), 1977a, p. 40, Pl. 10, fig. 8; TERMIER AND TERMIER, 1977b, fig. 20, Pl. 9, fig. 1–2.

Girtyocoelia sp., RIGBY (in BOARDMAN, et al., 1987) fig. 10.18E.

Diagnosis.—Straight or bent stems of spherical to barrel-shaped chambers overlapping, in contact, or separated and connected by prominent, walled central tube; chambers commonly 6–7 mm in diameter, ranging up to 10 mm in diameter. Exowalls and interwalls thick, pierced by distinct large ostia commonly extended to form exaules to several millimeters long. Prominent axial tube prosiphonate and one-quarter to one-third diameter of chambers. Chambers and central tube increase in diameter upward. Endowall of spongocoel or central tube pierced by endopores smaller than ostia.

Description.—Bead-like sponges in which individual chambers are spherical to barrel-shaped, with chamber heights of 3–5 mm. Chambers appear strung on prominent central tube, and chambers may be touching or separated along height of sponge. Heights of sponges variable but largest specimen in our collection is 40 mm tall and composed of 9 chambers. Chambers range 4 to 7 mm in diameter, and become slightly larger in upper, more mature, parts of sponge. However, large specimens, with diameters

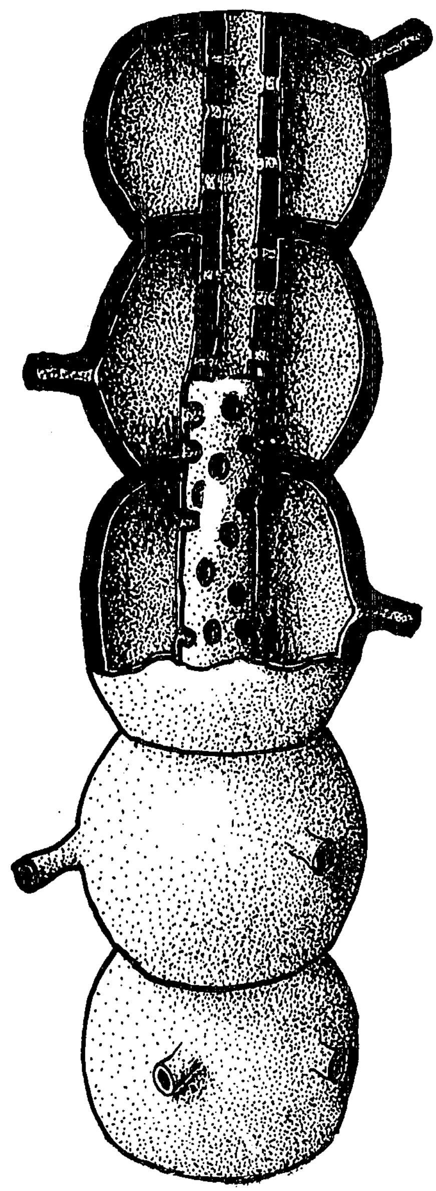

Figure 14. Reconstruction of Girtyocoelia beedei *(Girty, 1908b) showing the generalized exterior, below, and a vertical longitudinal section in the upper part, with prominent tubular exaules to the bead-like chambers, which are pierced by a porous central spongocoel, shown three dimensionally in the middle part of the illustration of the figure, and in longitudinal section in the upper part, not to scale (from Senowbari-Daryan, 1990).*

up to 12 mm, have been reported from other localities, as for example from Permian of Tunisia (Senowbari-Daryan and Rigby, 1988, p. 200).

Individual chamber exowalls and interwalls relatively thick, up to approximately 1 mm, and pierced by large ostia 0.8 mm in diameter. These ostia commonly extend from exterior as tubes, termed exaules by Finks (1983). Exaules not observed in our specimens, but probably broken off or not intersected in sections available. Lengths of exaules range to several mm (for examples, see Girty, 1908b, Pl. 14, fig. 5; Senowbari-Daryan, 1990, Pl. 45, figs. 2, 5–6; text-fig. 48).

Silicified specimens from Glass Mountains show some chambers connected not only by prominent axial tube, but by additional exaules. Such connnections of chambers by exaules may be represented in specimen illustrated by Girty (1908b, Pl. 14, fig. 1).

Prominent cylindrical axial tube prosiphonate, as defined by Seilacher (1962), and tube passes completely through chambers and entire sponge. Diameters of spongocoel or central tube one-quarter to one-third diameter of chambers. Endowall or spongocoel wall pierced by relatively small openings, much smaller than diameters of ostia (see Girty, 1908b, Pl. 14, fig. 3; Senowbari-Daryan, 1990, Pl. 45, figs. 1–3, text-fig. 48). Because of recrystallization, these characteristics not observable in detail in our specimens and chambers appear interconnected only by spongocoel tubes, if not adnate with touching mutual interwalls. In several specimens, chambers arranged loosely, in part, but elsewhere on same adjacent specimen chambers in contact; where distant, interconnected only by spongocoel tube. Where chambers in contact, interwalls with double thickness because of duplication of chamber tops and bottoms. Interiors of chambers without filling structures and generally without vesiculae.

One small specimen, on UNSM 34627, only 2 distant, bead-like chambers, 2.6–2.9 mm high, and 4 mm in diameter, separated by 1 mm on cylindrical central tube, 1.3–1.5 mm in diameter; tube extends as naked tube additional 5 mm beyond chambers. Chambers and tube cement-lined but hollow. Additional smaller, similarly preserved, specimens also occur in sample. A broken specimen of 3 chambers, 2 adnate and one at distance of 3 mm but connected by tube-like spongocoel. Chambers subspherical and 3.0 mm in diameter and high, spongocoel 1.0 mm in diameter, sponge is accessory organism in boundstone in UNSM 34669.

Discussion.—*Girtyocoelia beedei* (Girty) is a cosmopolitan sponge and has been reported from several Carboniferous and Permian localities around the world (Senowbari-Daryan, 1990, p. 131). Within the reef limestones of the Upper Capitan Limestone of the Guadalupe Mountains, *Girtyocoelia beedei* occurs in approximately the same abundance as the small associated *Sollasia ostiolata* Steinmann, 1882.

Material.—The species occurs on UNSM 34627, 34701, and 34717, and 15 additional samples in Sample Set A. The species also occurs in an additional 52 samples from the major grid localities and in Bat Cave Draw samples in Sample Set B. Figured specimens include UNSM 34627, 34717, and 35011 from the Chinaberry Draw; and UNSM 35115, and 35120 from the Dark Canyon, and UNSM 35267 from the Capitan Limestone in the northern Guadalupe Mountains.

Subclass SCLEROSPONGEA
Hartman and Goreau, 1970
Order GUADALUPIIDA
Termier and Termier, 1977a
Family GUADALUPIIDAE Girty, 1908a

(=Polyphymaspongiidae Wu, 1991
p. 78; Lemoneidae Wu, 1991, p. 80)

Diagnosis.—"Porate, schüssel- bzw. pilzförmige, plattige, dendroide oder zylindrische Schwämme ohne Füllskelett. Kammern röhren- bis eiförmig. Mit Astrorhizen. Spicula und Skelettmineralogie unbekannt." (Porate, bowl-like to mushroom-shaped, plate-like, dendroid or cylindrical sponge without filling structure. Segments are tube-like or extended egg-shaped. Spicules and skeletal mineralogy are not known.) (Senowbari-Daryan, 1990, p. 148)

Additional genus in family.—*Lemonea* Senowbari-Daryan, 1990

Discussion.—Wu (1991, p. 78) proposed a new family Polyphymaspongiidae, with the type genus *Polyphymaspongia* King, 1943. Investigation of *Polyphymaspongia* by Senowbari-Daryan (1990) has shown that *Polyphymaspongia explanata* King, 1943, is a *Guadalupia zitteliana*, the type species of *Guadalupia* Girty (1908a), in terms of priority. The species have identical features: a plate-like growth morphology, tube-like or egg-shaped chambers, astrorhizal canal systems on one side of the plate and perforated chamber walls on the other side and between chambers. We consider the genera as synonyms (see Senowbari-Daryan 1990, p. 139–140, for more discussion), and consequently the family Polyphymaspongiidae Wu (1991), which was based only on the genus *Polyphymaspongia*, and the Guadalupiidae Girty (1908a) are synonyms, with the Polyphymaspongiidae as the junior synonym.

Wu (1991, p. 80) also proposed a new family Lemoneidae, with *Lemonea* designated as the type genus. Differentiation of the family was based on the presumed nature of the exhalant canal system, called lemosiphonate by Wu (1991, p. 75–77), and is very theoretical. The genera *Guadalupia* (including *Polyphymaspongia*) and *Lemonea* cooccur in the Guadalupe Mountains and are phylogenetically very close to each other. They belong to the same group and should not be separated at a family level, as was done by Wu. We also do not agree that these closely-related organisms belong to different suborders, as was proposed by Wu. The families Guadalupiidae and Lemoneidae Wu are synonyms and the family name Guadalupiidae has priority. We would like to emphasize here that the systematic scheme of Wu (1991, p. 78–80) is theoretical and does not correspond to natural relationships in the sphinctozoan sponges. Individual families, genera, as well as species, proposed by him should be carefully reexamined and revised. Such a revision should not only concern the sphinctozoan sponges, but also other groups, including the inozoans, bryozoans, hydrozoans, algae, and other problematic organisms. All are in need of careful review and revision (see Rigby and Senowbari-Daryan, 1995).

Type genus.—*Guadalupia* Girty, 1908a.

Genus GUADALUPIA Girty, 1908a

(=*Polyphymaspongia* King, 1943, see Senowbari-Daryan, 1990, p. 148)

Emended diagnosis.—"Plattige, schüsselförmige oder dendroide Schwämme, bestehend aus röhrenförmigen oder eiförmigen Segmenten, die nebeneinander angeordnet sind (stratiform, FINKS 1983). Die Oberflächen der Platten tragen Astrorhizen, die in Erhebungen (Mamelonen) an der Schwammoberfläche lokalisiert sein können (ähnlich wie bei Stromatoporen oder manchen Sclerospongien). Die Unterseite des Schwammes, sowie die Wand zwischen den Röhren, sind von zahlreichen Poren durchbohrt. Ein Zentralrohr fehlt. Vesiculae können auftreten. Primäre Skelettmineralogie sowie Spicula sind unbekannt. Nach FINKS (1983) soll die Mikrostruktur sphärolithisch sein, was wir allerdings (aufgrund der Diagenese) nicht bestätigen können." (Platter-like, bowl-like or dendroid sponges composed of tubular or oval segments that are arranged next to one another (stratiform, Finks, 1983). Upper surfaces of platters contain astrorhizae, which may be localized on elevations (mamelons) on the upper suface of the sponge (as in stromatoporoids and many sclerosponges). Lower sides of sponges, as well as walls between tubes, pierced by numerous pores. Spongocoel rarely developed. Vesiculae may occur. Primary skeletal mineralogy, as well as spicules are unknown. Finks (1983) concluded the microstructure was sphaerolitic, but our specimens are diagenetically altered and we cannot confirm that.) (Senowbari-Daryan, 1990, p. 148)

Discussion.—Girty (1908a) described several species of *Guadalupia* that differ in their growth forms and by possession or lack of astrorhizal systems. Based on these differences and on whether there is a lack of, or development of several exhalant canals (spongocoels), Senowbari-Daryan (1990, p. 148–149) subdivided the genus *Guadalupia* into two genera: *Guadalupia* Girty, 1908a, and *Lemonea* Senowbari-Daryan, 1990. For more information about the revision of the genus *Guadalupia* see Senowbari-Daryan (1990, p. 148–149).

Paleobiology and growth strategy of the genus Guadalupia *Girty.*—Representatives of the genus *Guadalupia*, especially *Guadalupia explanata* (King), are among the largest segmented sponges found in the Permian reefs in the Guadalupe Mountains. It is interesting to speculate on the life style and original position of these peculiar sheet-like sponges, which appear limited to Permian deposits in the Guadalupe and Glass Mountains. The skeleton provides some information about its growth orientation. Uniform perforation of the expanded chamber walls of the sponge skeleton occur on one side of the sheets and astrorhizal systems of exhalant canals occur on the other side, indicating a living position in which both sides of the sheets were essentially "free." This means the sponge was not uniformly and solidly attached by either the pore- or astrorhizal-bearing surface.

As in other sponges, water probably passed through small pores on one side of the sheet into the tube- or egg-shaped chambers, which were occupied by the soft body of the sponge. After circulation through the choanocyte-bearing chambers, the water probably left the sponge body through the astrorhizal canals. Two possibilities of living position are suggested:

a) The sponge may have grown upward, blade-like, that is the sheets were oriented perpendicular to the substrate. This would allow the perforate surface of the sheets to be oriented into the water current as an aid to passive pumping of water and nutrients through the sponge and out the exhalant astrorhizal canal system. In such cases, the sponge could not have been stable and would have been easily toppled and broken by intensified water currents.

b) The sheets may have grown horizontally, from a vertical substrate like a cavity wall or reef front, extending into the direction of water currents. Some geopetal structures hint that this is a possibility. These geopetal structures also point to an orientation in which the astrorhizal-bearing exhalant surface was located on the upper surface of the sheets, in which case water movement through the sponge body and skeleton was directed upward. This would have allowed the inhalant surface with small pores to have remained relatively sediment free, and allowed the upper surface to have been swept free by the exhalant currents. Similar horizontally expanded growths of modern scleractinian corals in reef environments suggest *Guadalupia* may have grown in moderately quiet environments a few meters deep.

The partial vertical blade of *Guuadalupia* in UNSM 34658 is in growth position, as are associated and intergrown *Acanthocladia* fronds. *Minispongia* stems are also intergrown with the bryozoans as clearly contemporaneous organisms in the structure. Preservation and abundance of vesiculae makes the sectioned sponge appear like a *Platythalamia* blade but separation of vesiculae and interwalls indicate the correct generic placement of the sponge.

Type species.—Guadalupia zitteliana Girty, 1908a.

GUADALUPIA ZITTELIANA
Girty, 1908a
Plate 3, fig. 1; Plate 5, figs. 3–5, 7–9;
Figure 15

Guadalupia zitteliana GIRTY, 1908a, p. 80, Pl. 6, figs. 1a–1d, 2a–2b; SENOWBARI-DARYAN, 1990, p. 149–150, Pl. 53, figs. 1–10, Pl. 54, figs. 1–6, text-fig. 50.
Guadalupia zitteliana var. GIRTY, 1908a, p. 81.
Guadalupia williamsi KING, 1943, p. 23, Pl. 2, fig. 10, Pl. 3, figs. 7, 11 (not fig. 12 as indicated by KING, 1943, p. 14 and 23).

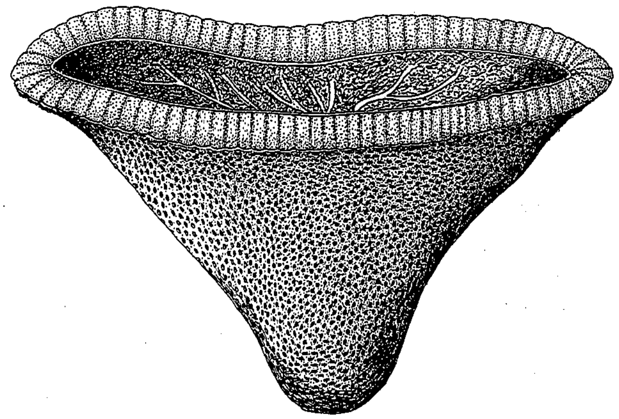

Figure 15. Reconstruction of an obconical example of Guadalupia zitteliana *(Girty, 1908a), showing the moderately dense dermal layer, chamberlets of the honeycomb-like intermediate layer and astrorhizal canal structure of the somewhat more complex thickened gastral layer in the interior, not to scale (modified from Senowbari-Daryan, 1990).*

Diagnosis.—"Pilz- bzw. schüsselförmiger, oder unregelmäßig bis plattiger Schwamm, bestehend aus röhrenförmigen Segmenten. An der rauhen Oberseite des Schwammes sind die sternförmigen Ausfuhrkanäle (Astrorhizen) entwickelt. Die Unterseite des Schwammes, sowie die Tubenwände enthalten zahlreiche Poren. Vesiculae fehlend bis rudimentär." (Mushroom to irregularly bowl-shaped or plate-like sponges composed of tube-like segments. Rough upper surface of the sponge bears star-like exhalant canals (astrorhizae). The surface below, as well as the walls between the tubes (segments), contains numerous pores. Vesiculae are lacking or very rudimentary.) (Senowbari-Daryan, 1990, p. 149)

Description.—Holotype fragment of undulate plate 82 X 44 mm and 6–8 mm thick. Lower exterior marked by weak annulate ridges suggesting fragment from sponge approximately twice size of present specimen, although indefinite because rounded growing edge preserved near what appears as center of expansion of the arcuate growth lines.

Plate composed of tubular chambers, with round to oval cross sections and long dimensions of chambers normal to major dimensions of plate of sponge; outwardly crescentic, with rounded ends top and bottom. Individual chambers 0.7–1.1 mm wide, with most 1.0 mm wide, measured radially in direction of growth, spaced such that 6–7 chambers occur per 5 mm, measured radially. Individual chambers 6–7 mm high, with outward arcuate or radially arcuate interwalls 0.15–0.22 mm thick.

Upper surface rough, produced by layer 1–2 mm thick, that blankets upper rounded pustulose ends of chamberlets; inner part of upper layer with pillars 0.9–1.3 mm in diameter, with most 1.0 mm in diameter, and circular, extending upward from exowalls of chambers and expanded to form a prominent thick dermal layer in which astrorhizal canals and circular exhalant canals occur. Skeletal elements of outer layer approximately 0.25 mm wide, merge to form irregular vermiform layer pierced by pores mainly 0.75 mm across, but ranging 0.35–1.0 mm across, as irregular subcircular to subpolygonal openings in outer layer.

Transverse section normal to long dimensions of chamberlets show them to be round to oval in cross-section, with smaller ones more commonly round, and larger ones oval-shaped to curved, sagging bean-like in cross section, because interwalls arched, and 0.65–0.75 mm high in the direction of sponge expansion and to 1.3 mm wide normal to that. Interwalls 0.10–0.17 mm thick in thinnest parts located near center of each chamber innerwall.

Chambers in stacked radial series, with adjacent chamber series in alternating positions, in an echelon fashion, so 6 chambers occur per 5 mm, measured radially in direction of growth. Interpores only moderately well-preserved in transverse section but more evident in vertical sections where interpores 0.08–0.12 mm in diameter, with most approximately 0.08 mm in diameter, as common openings now preserved as dark matrix fill or as dark fine-grained microspar resulting from recrystallization. Walls are up to 50 percent pores, which occur 6–7 per millimeter along a single wall seen in vertical section, but dimensions of pores only moderately well-defined because of recrystallization.

Flat, plate-like, vesiculae moderately common in upper half of tube-like chamberlets and occur 2 or 3 per chamber as thin plates mostly 0.05 mm thick, but irregular and expanding to several times that thickness near chamber interwalls.

Prominent matrix fills of probable pores surrounded by light gray skeletal material in lower or outer wall. These pores range 0.08–0.22 mm in diameter with most 0.15–0.20 mm across, as moderately, uniformly spread but not particularly defining chamberlets in principal part of the skeleton, but locally aligned parallel to growth lines in dermal layer. These pores presumed inhalant openings in water circulation of sponge.

Shapes of sponges in species may range considerably. One of better preserved specimens of species, on UNSM 34717, sheet-like and 8 cm long or wide, and 6–8 mm thick. Specimen with rippled surface, in which ripples gently arcuate, laterally, suggesting fragment part of much larger sponge tens of centimeters in diameter. Numerous tube-like or cell-like chambers up to 1 mm high, measured perpendicular to long dimensions of sheets. In sections cut parallel to upper and lower surfaces, chambers polygonal in cross section with honeycomb-like appearance. Vesiculae occur very rarely in chamber interiors. Because of recrystallization, pores in chamber walls barely recognizable or totally destroyed. Other features correspond to those for specimens described by Senowbari-Daryan (1990, p. 149–150). Several plate- to cup-shaped sponges occur in cluster 8 X 15 cm, with individual sponges 3–4 cm across and up to 6 cm long with chamberlets of same sizes, arrangements and packing as other specimens described above.

Erect blade 17 mm long, cut in UNSM 34715, shows double-layered skeleton characteristic of species. Fine, irregular astrorhizae-bearing upper layer on gently concave side, only intermittently preserved in sponge now largely eroded away. Arcuate chambers moderately well preserved, 4–5 mm high and 1–1.2 mm wide, radially.

Additional, only moderately well-preserved section of species as bent plate, more or less on end, with vertical cross section of plate 3 mm thick. Characteristic outward arcuate chambers 0.5 mm wide in direction of growth, and 2.7–2.8 mm long, vertically. Encrusted or coated on upper or convex side by astrorhizae-bearing irregular layer approximately 0.5 mm thick. Because of irregular flexure of plate, part of section shows subhorizontal cross-section across small spatulate chambers with maximum heights of 0.5–0.6 mm in radial direction of growth, and 0.5–0.6 mm wide normal to that direction.

Microstructure and pores in skeleton poorly preserved.

Discussion.—Descriptions and appearance of *Guadalupia zitteliana* Girty, 1908a, and *Guadalupia williamsi* King, 1943 (p. 23–24), are almost identical. According to King (1943, p. 24), "*Guadalupia williamsi* differs from the former (*G. zitteliana*) in being only 3 or 4 mm thick instead of 6 or 7 mm." Taking into consideration the variations in chamber size and thicknesses of sponges, these two specimens seem to be variants of a single species. In our opinion, the sponge described as *Guadalupia zitteliana* var. by Girty (1908a, p. 81) and *Guadalupia williamsi* King are synonyms and should be included within *Guadalupia zitteliana* Girty.

These relatively rare sponges occur in an algal-worm-tube boundstone, in UNSM 34669 from Chinaberry Draw, a sample in which sponges are relatively accessory, but include moderately common small to large *Sollasia ostiolata,* along with several examples of *Lemonea cylindrica* and *Lemonea micra* n. sp., relatively rare *Girtyocoelia,* and moderately common small clusters of *Parauvanella.* Small specimens of *Minispongia* are essentially vertical in growth direction and are small, thin-walled, sponges with large spongocoels inside a reticulate skeletal net. Clusters of chambers of *Parauvanella* form columnar structures up to 1 cm across and 2 cm tall, attached to algal crusts and stems of *Lemonea.* Two separate segments of *Sollasia ostiolata* show in the polished surface, but are probably part of a single, tall sponge at least 5 cm tall. The specimen has fallen and is not in growth position. The entire structure forms a sponge-algal boundstone in which the many sponges are bound by algae and by small encrusting vermiform tubes, and the entire structure is overgrown by thick, irregularly encrusting, algal layers of *Aporella.*

Guadalupia zitteliana Girty is endemic, known only in Permian deposits in the Guadalupe and Glass Mountains in Texas and New Mexico. In the Guadalupe Mountains it is a relatively rare sponge, and it appears to be more abundant in the Glass Mountains than in the Guadalupe Mountains.

Material.—Holotype, USNM 118135, from Capitan Limestone, 1000 feet below top of Guadalupe Peak, in a prominent knob in the long northeast spur, on the south side of the entrance of Pine Spring Canyon, Guadalupe Mountains, Texas, USGS locality 2926, collected by Hill and Girty. Two thin sections from USNM 118135 also occur in the collection as sections of fragments figured by Girty (1908, Plate 6, figures 1a, 1c, 1d). One section of the species occurs in UNSM 34669 from Chinaberry Draw, and the species also occurs in a specimen of 35211 in three polished slabs. It also occurs in Sample Set A in UNSM 35009, 35003, 35035, 35068, 35086 from Chinaberry Draw; in UNSM 35183, 35186, 35188, 35192, 35199, 35202, 35204, 35205, 35209, 35211, 35217, 35218, 35221?, 35224, 35227?, 35269, 35270, 35273, 35275, 35277, 35278, 35280, 35281 and 35282 from Hackberry Draw; in UNSM 35092?, 35095, 35121, 35140, 35158 from Dark Canyon. The species also occurs in UNSM 35229?, 35233, 35237, 35239 from Rattlesnake Canyon, and on UNSM 35246, 35247, 35257, and 35262 from Bat Cave Draw. It also occurs in Set A Samples UNSM 34688, 34694, 34697, 34702, 34704, 34715, and 34717 from Hackberry Draw, and in UNSM 34650 and 34669 from Chinaberry Draw. Question marks indicate that the species questionably occurs in the sample. Figured specimens include USNM 118135, UNSM 34717, 35009, 35211 and 35275.

GUADALUPIA EXPLANATA (King, 1943)
Plate 6, figs. 1–4; Figure 16

Polyphymaspongia explanata KING, 1943, p. 25–26, Pl. 1, fig. 8, text-fig. 2.
Guadalupia explanata (King) SENOWBARI-DARYAN, 1990, p. 150–151, Pl. 55, fig, 1, Pl. 56, figs. 1–7, text-fig. 51.

Diagnosis.—"Plattenförmiger Schwamm bestehend aus mehreren, in einer Reihe angeordneten, kugeligen bis eiförmigen Segmenten. Platten können verzweigt sein. An der Oberseite des Schwammes sind mehrere Astrorhizen entwickelt. Unterseite des Schwammes und die Segmentwände sind porat. Vesiculae kommen vor." (Sheet-like sponge composed of numerous spherical to egg-shaped chambers which are arranged in one layer. The sheets may branch. On upper surface of sponge several astrohizae are developed. Wall of the lower surface and the chamber walls are porate. Vesiculae occur.) (Senowbari-Daryan 1990, p. 150)

Description.—Sheet-like or bowl-like, occasionally branched, sponges form plates more than 50 x 50 cm wide, easily recognized in field by numerous oval to subspherical chambers arranged in a single layer, stratiform, beside one another. In bowl-like specimens inner part of bowls represents upper or probably dermal surface, with astrorhizal canals and outer or lower surface formal by domed gastral or probably inhalant walls of chambers. In sheet-like specimen, concave side presumed dermal surface usually upper side and convex side or lower side inhalant surface with distinct chambers. Thicknesses of sheets relatively constant, ranging between 9 and 11 mm. King (1943, p. 25) noted thickness of 12 mm for holotype. Thicknesses of sheets up to 20 mm observed by Senowbari-Daryan (1990, p. 150).

Sections perpendicular to long dimensions of sheets exhibit two layers in skeleton: lower layer (upper layer of King, 1943, p. 25) composed of subspherical or egg-shaped to crescentic, tube-like or vertically elongate honeycomb-like chambers. Individual chambers usually 6–9 mm but range to 10 mm long, with heights or diameters of 2–5 mm parallel to long dimensions of sheet. Walls of chambers mostly 0.2 mm thick but commonly appear thicker because of recrystallization. Chamber walls pierced by small and equal unbranched pores with diameters of 0.2 mm. Chamber interiors mostly hollow although vesiculae also occur within some chambers.

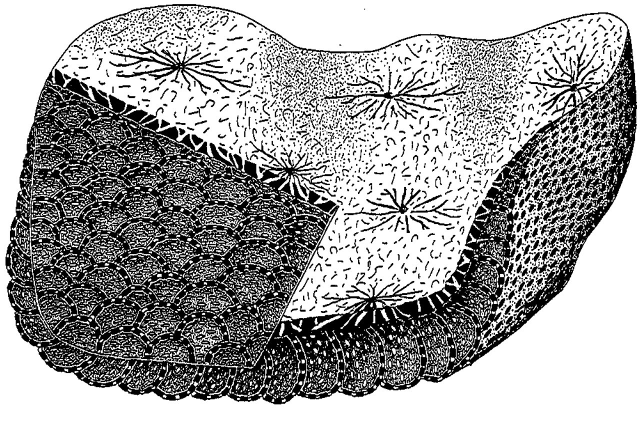

Figure 16. Reconstruction of a plate-like example of Guadalupia explanata *(King, 1943), showing the prominent astrorhizal canal system of the moderately thick upper gastral layer; the arcuate chamberlets of the honeycomb-like layer, and the thin dermal layer on the right, and a transverse section showing the arcuate nature of the chamberlets in the honeycomb-like layer on the lower left, not to scale (from Senowbari-Daryan, 1990).*

Upper or astrorhizal-bearing layer ("lower layer of smaller cells," King 1943, p. 25) usually much thinner than lower layer of coarser chambers. In some specimens, however, upper layer may have same thickness or may be thicker than lower layer (see Senowbari-Daryan 1990, p. 150). Upper layer pierced by labyrinthine canal system that connects chambers of lower layer with exhalant astrorhizal canals of upper layer. Boundary between layers diffuse.

Vertical blade part of sponge with major thickness 9–12 mm with crescentic chambers 7–9 mm long and 1–2 mm high; moderately well preserved on UNSM 34650, in *Acanthocladia* bafflestone, with intergrowths of bryozoans interfering with sponge skeleton regularity. Vesiculae common, walls up to 0.5 mm thick but diagenetically altered so microstructure obscure.

Discussion.—A detailed description of *Guadalupia explanata* was given by Senowbari-Daryan (1990, p. 150–151). *Guadalupia explanata* (King, 1943), represents an endemic sponge known only from the Permian rocks of the Glass and Guadalupe Mountain regions in Texas and New Mexico. In both areas it is abundant.

Guadalupia explanata (King, 1943), has larger chamberlets than *Guadalupia zitteliana* Girty, 1908a, and has a coarser textured skeleton. Some sections of the species might appear similar to the plate-like *Platythalamiella* Senowbari-Daryan and Rigby, 1988, but that sponge is composed of 2–4 layers of flattened crescentic chambers, rather than just one such layer, and lacks the thin gastral layer characteristic of species of *Guadalupia.*

Material.—The species occurs in UNSM 34652 and 34658 of sample set A, and in UNSM 35004, 35021?, 35026, 35041, 35046, 35050–052, 35055, 35061, 35069, 35087 from Chinaberry Draw; in UNSM 35092 from Dark Canyon, and in UNSM 35233 and 35234 from Rattlesnake Canyon, and in UNSM 35265 from Bat Cave Draw in Sample Set B. Figured specimens include UNSM 35004 and 35050 from Chinaberry Draw.

Genus LEMONEA
Senowbari-Daryan, 1990

Diagnosis.—"Porate, zylindrische oder konische Schwämme mit einem oder mehreren den Schwamm in seiner Länge durchziehenden Spongocoels, um welches die röhrenförmigen Segmente radial angeordnet sind. Astrorhizen-Systeme fehlen. Vesiculae können auftreten, sind jedoch nicht häufig. Solitar oder koloniebildend." (Porate, cylindrical, or conical sponges with one or several spongocoels passing essentially through the sponge. Around the spongocoel(s), the tube-like chambers are oriented radially. Astrorhizal system lacking. Vesiculae may occur but are not abundant. Solitary or colonial forms.) (Senowbari-Daryan, 1990, p. 151)

Discussion.—Girty (1908a) described several species of his new genus, *Guadalupia,* based on differences in their growth forms, and whether or not they possess an astrorhizal system and one or several spongocoels. These different features justify subdivision of the species and grouping them into two different genera. The genus *Lemonea* was established by Senowbari-Daryan (1990, p. 151) for those sponges with tube-like chambers regularly arranged around one or several spongocoels, and sponges that are without an astrorhizal system. Species described by Girty (1908a) and later workers now grouped into *Lemonea* were listed by Senowbari-Daryan (1990, p. 148, Table 17). In addition to tabulating species previously described, the new species *L. conica* and *L. polysiphonata* were described by Senowbari-Daryan (1990). Additional specimens of the species of *Lemonea* are described below.

Type species.—*Guadalupia cylindrica* Girty, 1908a.

LEMONEA CYLINDRICA
(Girty, 1908a)
Plate 3, fig. 1; Plate 7, figs. 1–4, 7;
Plate 13, figs. 3, 6

Guadalupia cylindrica GIRTY, 1908a, p. 81, Pl. 6, figs. 3–3c; PARONA, 1933, p. 47, Pl. 9, figs. 10–12; TERMIER AND TERMIER, 1977a, p. 45, Pl. 10, fig. 10; TERMIER AND TERMIER, 1977b, Pl. 9, figs. 4–5, text-fig. 16; DENG, 1982a, p. 250, Pl. 2, fig. 1; FLÜGEL, in FLÜGEL, ET AL., 1984, p. 202, Pl. 37, figs. 2B, 3; ALEOTTI, DIECI AND RUSSO, 1986, p. 11, Pl. 2, figs. 2–4; SENOWBARI-DARYAN AND RIGBY, 1988, p. 203, Pl. 34, figs. 10, 11; SENOWBARI-DARYAN AND DI STEFANO, p. 14, Pl. 6, fig. 1.

Guadalupia neijiawanensis DENG, 1982a, p. 250, Pl. 2, fig. 2.

Lemonea cylindrica (Girty), SENOWBARI-DARYAN, 1990, p. 151, Pl. 54, figs. 7, 8, Pl. 57, figs. 2, 4–6.

Diagnosis.—"Zylindrischer Schwamm, bestehend aus mehrerer, in einer Reihe radial angeordneten und röhrenförmigen Segmenten. Ein Spongocoel vom retrosiphonaten Type zieht sich durch den Schwamm hindurch. Die Segmentwände sind porat. Vesiculae sind rudimentär." (Cylindrical sponges composed of numerous tube-like chambers which are arranged radially around the axial spongocoel of retrosiphonate type. The chamber walls are porate. Vesiculae rudimentary.) (Senowbari-Daryan, 1990, p. 151)

Description.—Cylindrical and usually unbranched stems of species commonly reach heights of more than 100 mm with common diameters of 15 mm, but ranging up to approximately 25 mm in diameter. However, branched specimen in our collections attains height of 170 mm. Stems usually smooth or slightly pustulose because of irregular swollen chamber surfaces, but specimens may also be annulate with parallel wall margins, so spongocoel, as well as exterior, shows ring-like wavy annulations.

Axial spongocoels pass essentially through full length of stems and range 3–10 mm in diameter, with variation dependent upon size of entire sponge.

Tube-like, horizontal, radial chambers arranged around spongocoel in monoglomerate series. Individual chambers have polygonal to rounded polygonal cross-sections with diameters of approximately 1 mm, lengths of chambers dependent upon diameter of entire sponge and generally range between 3 and 7 mm. Tube or chamber walls perforated by small unbranched pores. Radial arrangement of chambers shows prominently in transverse cross-sections; in longitudinal sections chambers usually upward arched or crescentic, with convex side oriented upward in direction of growth.

Rare vesiculae occur within some chamber.

Discussion.—In addition to widespread and abundant occurrence in the Guadalupe Mountains, *Lemonea cylindrica* (Girty) had been reported from Lower and Middle Permian rocks of Sicily (Senowbari-Daryan and Di Stefano, 1988; Parona, 1933; Aleotti, et al., 1986; Senowbari-Daryan, 1990; Flügel, et al., 1991), Upper Permian rocks of Tunisia (Termier and Termier, in Termier, et al., 1977a; Senowbari-Daryan and Rigby, 1988) and from China (Deng, 1982). *Lemonea cylindrica* (Girty) has almost the same geographic distribution as the genus *Guadalupia* (see Senowbari-Daryan, 1990, p. 151).

Materials.—The species is common in our collections. Occurrences are compiled in Table 1. Figured specimens include UNSM 34623 from Dark Canyon in Sample Set A; and UNSM 35009, 35019, 35035, and 35077 from Chinaberry Draw; and UNSM 35186 from Hackberry Draw from Sample Set B.

LEMONEA CONICA
Senowbari-Daryan, 1990
Plate 3, fig. 3, Plate 6, figs. 5–7,
Plate 9, fig. 8; Figure 17

Lemonea conica SENOWBARI-DARYAN, 1990, p. 151–153, Pl. 57, fig. 1A, Pl. 58, figs. 1A, 2, 3?, 4?, Pl. 59, fig. 1, text-fig. 52.

Diagnosis.—"Konische Schwämme, bestehend aus mehreren zusammenhängenden Individuen. Jedes Individuen besteht aus einen axialen Kanalbündel, um welches die röhrenförmigen Kammern radial angeordnet werden. Kammerwände porat. Vesiculae kommen vor." (Conical sponges composed of several individuals growing together. Each individual contains an axial bundle of canals around which the tube-like chambers are radially arranged. Chamber walls are porate. Vesiculae occur.) (Senowbari-Daryan, 1990, p. 152)

Description.—Except for *Guadalupia explanata* (King, 1943), species is largest thalamid sponge in the Guadalupe Mountains, with generally obconical shape, but locally hemispherical to irregular. Sponge composed of several individual stems, growing adjacent to one another. Each stem includes a cluster or bundle of exhalant tubes, around which radial, horizontal, tube-like chambers are arranged in honeycomb-like fashion. Each stem within cluster corresponds, structurally, more or less to stem of *Lemonea polysiphonata* Senowbari-Daryan, 1990.

Several large conical to conico-cylindrical sponges occur in UNSM 34618, in intergrowths almost as major stems of branching form, ranging from well-defined conical to irregular growth, forming cluster approximately 10 X 12 cm across on polished surface. Largest, most clearly defined, sponge in cluster approximately 6 cm in diameter and at least 4 cm tall extending full thickness of cut slab. Sponges all with upward arcuate, radially arranged, chambers typical of genus, arranged around several long clusters of exhalant tubes. Those clusters 5–8 mm in diameter, with some irregularity, are composed of numerous tubes 0.7–1.2 mm in diameter as circular to irregular openings.

Individual chambers to 4–5 mm long, radially, and 0.8–1.2 mm wide and high, stacked ovoid to slightly spatulate-appearing in cross-section. Chamber walls 0.15–0.2 mm thick, as preserved in somewhat diagenetically altered carbonate, locally appearing 0.08–0.12 mm thick where encrusted by light colored, possible dolomitic cement, latter areas to 2 or 3 times thickness of what appears to be original walls. Both interwalls and exowalls of same general dimensions.

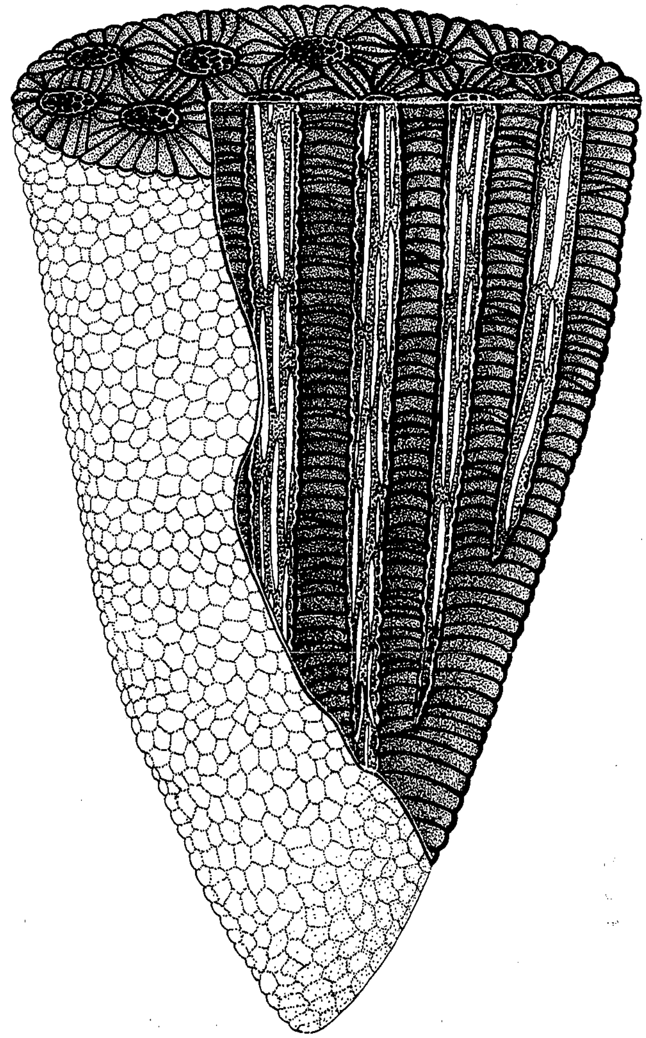

Figure 17. Reconstruction of Lemonea conica *Senowbari-Daryan, 1990, showing the distinctive clusters of vertical exhalant tubules separated by honeycomb-like layered chamberlets between, not to scale (from Senowbari-Daryan, 1990).*

Vesiculae plate-like, common in some chambers, but not developed in others; most commonly diaphragm-like, extending straight across tubular chambers. Pores obscured by diagenesis in only moderately well-preserved sponges.

Discussion.—Specimens of *Lemonea conica* occupy considerable volume in UNSM 34618, for 5 or 6 moderately clearly defined examples occur in the sponge-algal boundstone. They are associated with moderately common *Lemonea polysiphonata* Senowbari Daryan, 1990, relatively rare *Minispongia,* and several specimens of a large hydrozoan(?) in irregular branching, finger-like structures.

Abundant cryptostome bryozoans, mainly *Acanthocladia*, occur in the algal boundstone, apparently as accessory organisms around the sponges and adjacent to the sponges. All the organisms appear in growth position, except the hydrozoans(?), two of which may be fallen or with irregular sub-horizontal growing bases.

Material.—The species is widespread, occurring in 70 samples. Its distribution in our samples is shown in Table 1. Figured specimens include UNSM 34623, in Sample Set A from Dark Canyon; and UNSM 35009, 35019, 35077 from Chinaberry Draw; UNSM 35158 and 35225 from Hackberry Draw, and etched sample UNSM 35296 from an uncertain locality, all in Sample Set B.

LEMONEA POLYSIPHONATA
Senowbari-Daryan, 1990
Plate 3, fig. 4; Plate 7, figs. 5, 6, 8

Lemonea polysiphonata SENOWBARI-DARYAN, 1990, p. 153, Pl. 22, figs. 1A, 2A, 7, Pl. 56, fig. 8, Pl. 58, fig. 1E.

Diagnosis.—"Zylindrische und unverzweigte Art der Gattung *Lemonea* mit gleichen Dimensionen wie die des Genotypes. Das axiale Kanalbündel besteht aus mehreren (ca. 10) Tubuli, die den Schwamm in seiner gesamten Länge durchziehen." (Cylindrical, unbranched sponges of the genus *Lemonea* with the same dimension as the genotype (*Lemonea cylindrica*). The axial canal composed of several (approximately 10) tubes which pass through the length of the whole sponge.) (Senowbari-Daryan, 1990, p. 153)

Description.—Cylindrical stems of species usually 15 mm in diameter, but some reach diameters up to 25 mm. Outer surface of sponge sometimes annulate, but tube-like cylindrical spongocoel does not reflect annulation. Roughly horizontally arranged, tube-like or crescentic, chambers radially arranged around spongocoel composed of axial cluster of several (approximately 10) individual exhalant tubes that pass virtually through whole sponge. Large specimens with large spongocoel, with numerous parallel undivided tubes and smaller specimens with smaller spongocoels and fewer tubes. Generally spongocoel tubes occupy up to 50 percent of whole stem. Individual tubes of spongocoel approximately 1 mm in diameter and each with distinct wall.

Horizontal chambers of wall with prismatic to circular cross-sections and generally with diameters of 1 mm. Radial lengths of chambers and diameter of spongocoel directly dependent upon size of whole sponge.

Interwalls and exowalls of horizontal chambers pierced by small pores, but because of poor preservation and recrystallization of chamber walls, original pore diameters and distribution cannot be determined.

Two individual sponges, cut in transverse section in Sample 34618, show characteristic development of structures. Both stems approximately 15 mm in diameter and composed of more or less monoglomerate or unilaminate layer of radially-arranged chambers around axial cluster of exhalant tubes. Axial clusters 5–6 mm in diameter, of round cylindrical tubes 0.8–1.0 mm in diameter, each with walls 0.1 mm thick, essentially same thickness as interwalls between radially-arranged chambers. Those chambers upwardly arcuate and up to 3 mm long, radially. Individual chambers 0.8–1.1 mm wide and high, most with ovoid cross sections apparently in en echelon stacked series.

Discussion.—*Lemonea polysiphonata* Senowbari-Daryan, 1990, may be confused with *Lemonea cylindrica*, the type species, because both have essentially the same dimensions of unit elements in the wall and the external appearance of both species is strikingly similar. The species are differentiated, however, based on the exhalant axial tube complex of the central spongocoel, for there is only a single long opening in *Lemonea cylindrica* but a bundle of tubes in *Lemonea polysiphonata* (see Senowbari-Daryan, 1990, p. 153).

The two sponges in UNSM 34618 appear vertical, in place, in the sponge-algal boundstone. They are associated with large, in situ, examples of *Lemonea conica* Senowbari-Daryan, 1990, common cryptostomous bryozoans, mainly *Acanthocladia*, and common, large, finger-like to irregularly branching, dense, hydrozoans(?), and isolated examples of *Permosoma* and *Minispongia*, in a good example of *Archaeolithoporella*-bound sponge and bryozoan communities.

Lemonea polysiphonata Senowbari-Daryan, 1990, is known only from Permian reefs in the Guadalupe Mountains in Texas and New Mexico.

Material.—The common species occurs in the Chinaberry Draw samples in UNSM 35009, 35010, 35015, 35020, 35023, 35028, 35035, 35048, 35052, 35057, 35063, 35072, and 35073. It also occurs in UNSM 35088, 35096, 35108, 35117, 35120, 35138 and 35149 from Dark Canyon, in the Hackberry Draw samples in UNSM 35193, 35206, 35279 and 35283?, and in Bat Cave Draw sample UNSM 35254 in Sample Set B. It also occurs in Sample Set A in UNSM 34704 from Hackberry Draw; 34663, and 34674 from Chinaberry Draw; and 34618, 34619, 34622 and 34627 from Dark Canyon. Figured specimens include UNSM 35020, 35028, 35108, and 35117.

LEMONEA DIGITATA (Girty, 1908a)
Plate 13, fig. 2

Guadalupia digitata GIRTY, 1908a, p. 84, Pl. 5, fig. 13.

Emended diagnosis.—Cylindrical or palmate to branching digitate *Lemonea* with axial spongocoels 2–3.4 mm in diameter surrounded by radially-arranged, tubelike, chambers, essentially horizontal or upward-arched in monoglomerate series. Individual chambers 0.5–0.6 mm in diameter, compactly arranged in honeycomb-like fabric, with porous exowalls and endowalls, outer surface micronodose with rounded chamber ends but lacking exaules.

Description.—Only holotype, USNM 118140, known of species. Specimen 75 mm high from truncated base to tips of multiple branches, four of which show along one side of slightly palmate or oval cross-sectioned sponge. Sponge expands upward from diameter of 6–7 mm, from possibly branched base, through unbranched part 50 mm tall, and shifts from subcylindrical to oval cross-section to digitate with short branches, each with basal diameter of 3–4 mm, but each expands upward to 7–7.5 mm in diameter at preserved crest. Sponge approximately 21 mm across and perhaps 8–10 mm thick immediately below where branches diverge, but lower in sponge, cross-section oval and 11 X 8 mm across.

Surface smooth lacking exaules, but with low micronodose surface formed of rounded tips of exowalls of radially arranged chamberlets; chamberlets in monoglomerate series, compactly stacked, around central opening, dimensions of chamberlets in lower part of the sponge unknown but in branches range 2.2 mm across in one branch to 3.0–3.4 mm across in another. Possible irregular spongocoel poorly expressed in recrystallized base and perhaps 1.5–2.0 mm in diameter, as defined by thickened carbonate layer that may represent endowall.

Individual chamberlets horizontal to upwardly arcuate and 0.4–0.6 mm in diameter, with most 0.5 mm across, and with interwalls 0.15–0.2 mm thick where seen in coarsely recrystallized, partially weathered surfaces of upper branches. Possible endopores in the upper right branch, as figured by Girty (1908a, Pl. 5, fig. 13), 0.10–0.15 mm in diameter. Similarly sized impressions of exopores locally preserved along left margin, although such pores uncertain because only about sizes of crystals in some parts of wall. Nodose gobular outer ends of chambers rise as much as 0.1–0.2 mm out from depressed areas that mark walls between chambers, in arrangement typical of other species of genus.

Discussion.—*Lemonea digitata* (Girty, 1908a), is perhaps most similar to *Lemonea exaulifera* new species, in being composed of small-stemmed, multibranched sponges with small chamberlets arranged around the central open spongocoel. The chamberlets in both species are essentially of the same diameter, 0.6 mm. However, *Lemonea digitata* lacks the prominent tubular exaules so characteristic of *Lemonea exaulifera* and differs somewhat in growth form, for in the latter species the tiny slender stems are long and often straight. In addition *L. exaulifera* has axial spongocoels only 0.6–0.8 mm in diameter, rather than the considerably more robust opening developed in the short branches of *Lemonea digitata.*

Lemonea micra new species is also a small sponge but is generally unbranched, though occasionally branched, but, more significantly, is composed of horizontal chambers that are approximately 1.0 mm in diameter. Pores and chamber filling structure are unknown in both of the species and cannot be used for comparison.

Material.—The holotype and figured specimen, USNM 118140, is the only known example of the species. It was collected by Hill and Girty from USNM locality 2902, from the Permian Capitan Limestone, probably the lower part of the upper third, on the peak on the north side of Pine Spring Canyon, Guadalupe Mountains, Texas. The sponge is, thus, probably slightly older than any of the sponges in our collection from the northern Guadalupe Mountains.

LEMONEA EXAULIFERA new species
Plate 8, figs. 7, 8; Plate 9, figs. 1–3

Diagnosis.—Small-stemmed to multibranched sponges, with small axial tube or spongocoel, and with tube-like chambers arranged essentially horizontally and radially around spongocoel in monoglomerate series. Short exaules to 1 mm long extend from chamber exowalls or from between chambers to exterior of sponge.

Description.—Tiny slender stems to multibranched stems of species reach diameters of 4–6 mm and heights up to more than 50 mm. Stems up to approximately 10 mm in diameter at points of branching. In typical specimens several stems intergrown or multibranched and grown together so several may occur in clusters.

Axial spongocoel, with internal diameter of 0.6–0.8 mm, passes through whole sponge as smooth simple tube. Radiating cell-like chambers, with diameters of approximately 0.6 mm, radially and horizontally arranged, perpendicular to axial spongocoel.

Holotype 50 mm tall, now cut longitudinally. Sponge appears to rise from segment, which was probably fallen and broken but which continued to grow upward. Near mid-height, spongocoel 0.6 mm in diameter where cut by section.

Small tubular exaules extend normal to surface of sponge as most diagnostic feature of species. These small pipelike elements, approximately 1 mm long, produce almost spinose appearance to exterior, and appear irregularly distributed on sponge surface. Outer diameters of exaules approximately 0.4 mm, with inner pore diameters of 0.2–0.3 mm. It is not certain whether exaules extend only from single chamber or perhaps may belong to two or more chambers, in all likelihood each chamber has at least one exaulos.

Outer exowall of sponge chambers, interwalls between chambers, and endowall of spongocoel appear as light-gray lines composed of small crystalline calcite. Because of poor preservation, dimensions and distributions of skeletal pores cannot be determined.

Discussion.—*Lemonea exaulifera* is one of the smallest species of the genus, with stems generally only 3–6 mm in diameter. Girty (1908a) described several species or varieties of the genus as *Guadalupia.* All species of *Lemonea* that were initially described as species of *Guadalupia* by Girty (1908a), and by other authors, are listed with their specific characters in Table 3. The new species is differentiated from all other species of the genus by its small dimensions, and particularly by having prominent small tubular exaules, which do not occur in other species of the genus.

Etymology.—*Exaulos,* Gr., *Ex,* out, away from; *aulos,* tube or pipe; *ferra,* bearing. The species is named for the numerous small tube-like exaules which extend from the chambers and from between chambers to the exterior of the sponge.

Material.—Figured holotype and paratypes are on UNSM 35215. The species occurs in 24 samples including UNSM 35017, 35032, and 35033 from Chinaberry Draw; UNSM 35108 from Dark Canyon; UNSM 35205, 35206, 35208, 35210, 35215, 35220 and 35273 from Hackberry Draw, from Sample Set B. The species also occurs on UNSM 34782 from Chinaberry Draw; 34610 and 34615 from Dark Canyon, and 34682, 34687, 34691, 34703, 34704, 34705, 34706, 34712, 34715, 34719, and 34720 from Hackberry Draw in Sample Set A.

LEMONEA MICRA new species
Plate 1, figs. 3, 7; Plate 3, fig. 3; Plate 6, fig. 6;
Plate 7, figs. 5, 7; Plate 8, figs. 1–6, Plate 9, figs. 4, 5

Diagnosis.—Small unbranched to occasionally branched species of *Lemonea* with broad axial spongocoel almost one-third to one-half stem diameter. Chambers relatively short, horizontally arranged around spongocoel, interior of spongocoel contains bubblelike vesicular structures, exaules absent.

Description.—Sponges with stem diameters 3–6 mm and, except for *Lemonea exaulifera* new species, includes some of smallest *Lemonea* found in Guadalupe Mountains. Specimens, as in *Lemonea exaulifera,* occur as distinct individual sponges and in clusters. Holotype represents relatively large specimen, with height of at least 62 millimeters, part of which weathered away, and with diameter of almost 6 millimeters. Holotype cut in longitudinal section exhibits broad spongocoel 2 millimeters in diameter, which passes through whole sponge. Vesicular structures may partly fill interior of spongocoel.

Egg-shaped, regularly arranged, horizontal chambers generally range approximately 2 mm long and 1.0 mm in diameter. Chambers tube-like or upward crescentic in longitudinal sections, but radially tube-like or cylindrical in cross section, forming monoglomerate layer around relatively large spongocoel. Because of poor preservation, pores in walls destroyed and dimensions and distributions cannot be determined accurately in Guadalupe Mountains specimens.

Discussion.—The small size and stem diameters of this species are essentially identical to *Lemonea exaulifera,* described above, but the two species are relatively easy to differentiate. Exaules are abundant in *Lemonea exaulifera,* but are lacking in *Lemonea micra.* The spongocoel in *Lemonea micra* is 2–3 millimeters in diameter, comparatively much larger than the relatively narrow tube-like opening in *Lemonea exaulifera,* where the central opening is 0.6–0.8 mm in diameter. In addition, vesicular structures occur within the spongocoel of *Lemonea micra,* but have not been observed in the spongocoel of *Lemonea exaulifera. Lemonea exaulifera* is a multibranched species, but *Lemonea micra* was observed to branch only occasionally.

Lemonea micra new species is known to date only from the Guadalupe Mountains in the Upper Capitan Limestone.

Material.—Holotype, on UNSM 35022, of Sample Set B and paratypes on UNSM 34628 of Sample Set A, both from Chinaberry Draw, from the Upper Capitan Limestone, and UNSM 35138 from Dark Canyon in Sample Set B. Other paratypes occur on UNSM 35028 and 35037. The species is also figured as reference specimen on UNSM 35002 and 35019 from Chinaberry Draw, and UNSM 35108 from Dark Canyon, also from Sample Set B. The widespread sponge occurs in 69 samples in Set B. It also occurs in 37 samples in Set A. Distribution of occurrences is shown in Table 1.

Etymology.—*Micros,* Greek, small, little; referring to the small size of the species among those of *Lemonea.*

Class CALCAREA Bowerbank, 1864
Artificial Key to Genera and Species of
Upper Capitan Inozoid Sponges

I. Sponges massive, irregular to mushroom-shaped
   A. With scattered large canals or shallow spongocoels in coarse reticulate skeleton
      Virgola neptunia (Girty, 1908a)
II. Sponges cylindrical or steeply obconical
   A. Lacks axial spongocoel
      1. Lacks prominent canals
         Virgola rigida (Girty, 1908a)
      2. Has prominent canals
         a. Coarse canals mainly sublongitudinal

Grossotubinella parallela Rigby, Fan and Zhang, 1989b
b. Coarse canals irregular, generally not sublongitudinal
Cavusonella caverna Rigby, Fan and Zhang, 1989b
c. Lacks coarse axial canals
1) Upward-outward divergent canals convergent to lateral ocular clusters
Stellispongiella (?) sp.
2) Horizontal canals extend as exaules in small sponges
Pseudovirgula tenuis Girty, 1908a
B. Has one or more axial spongocoels
1. Has one spongocoel
a. Prominent unwalled spongocoel, lacks canals or with rare horizontal to uparched canals
1). Nonannulate, up to 6 mm in diameter with gastral and dermal layers locally developed
Peronidella cf. *P. rigbyi* Senowbari-Daryan, 1991
2). Annulate, up to 7 or 8 mm in diameter
Minispongia constricta (Girty, 1908a)
b. Irregular narrow, perhaps discontinuous unwalled spongocoel
1). Prominent dermal layer and stems to 8 mm in diameter
Peronidella (?) *delicata* new species
2. Has 2 or more spongocoels
a. Has 2 distinct, walled, spongocoels
Bicoelia guadalupensis new species
b. Has 1–3 unwalled tiny spongocoels, prominent annulae
Minispongia carinata Rigby and Senowbari-Daryan, 1996a
III. Sponges discoidal, platter-like
Gigantospondia discoforma Rigby and Senowbari-Daryan, 1996a

Superorder ASPICULATA
Rigby and Senowbari-Daryan, 1996a

Diagnosis.—"Calcareous sponges lacking spicules but with rigid skeletons composed of aragonite or possibly calcite; usually unsegmented but rarely segmented." (Rigby and Senowbari-Daryan, 1996a, p.26)

Order INOZOIDA
Rigby and Senowbari-Daryan, 1996a

Diagnosis.—"Rigid skeleton not segmented, usually composed of aragonite but may include calcite; lacks spicules." (Rigby and Senowbari-Daryan, 1996a, p. 26)

Family AURICULOSPONGIIDE
Termier and Termier, 1977a

Original diagnosis.—"Nous rangeons dans cette famille la genre *Auriculospongia* caractérisé par sa structure 'foliacée,' le squelette épais offrant d'un côté une surface inhalante et de l'autre une surface exhalante. Ce type écologique est connu chez de nombreux Calcisponges et Démosponges plus récents." (We include in this family the genus *Auriculospongia,* which is characterized by its "foliate" structure, a thick skeleton, and with one side as the inhalant surface and the other as an exhalant surface. This ecologic type is known from numerous examples in recent calcisponges and demosponges.) (Termier and Termier, 1977a, p. 29)

Subfamily AURICULOSPONGIINAE
Rigby and Senowbari-Daryan, 1996a

Diagnosis.—"Auriculospongiidae with exhalant canals on one side; without inhalant canals; interfiber spaces serving as inhalant openings." (Rigby and Senowbari-Daryan, 1996a, p. 26)

Genus CAVUSONELLA
Rigby, Fan, and Zhang, 1989b

Diagnosis.—"Cylindrical sponges with uneven to undulating exteriors, interiors pierced by coarse irregular openings, which may bifurcate upward and may make up to one-half sponge volume; sponges lack prominent continuous longitudinal canals and continuous central spongocoel; skeletons of irregular fibers in loose upward and outward expanding pattern." (Rigby, Fan, and Zhang, 1989b, p. 796)

Type species.—*Cavusonella caverna* Rigby, Fan, and Zhang, 1989b.

CAVUSONELLA CAVERNA
Rigby, Fan, and Zhang, 1989b
Plate 9, figs. 4, 5; Figure 18

Cavusonella caverna RIGBY, FAN, AND ZHANG, 1989b, p. 796–798, figs. 12.1–12.3; RIGBY AND SENOWBARI-DARYAN, 1991, p. 28–29, Pl. 4, figs. 6–8, Pl. 44, fig. 7; Pl. 55, figs. 1–4; text-fig. 13.

Diagnosis.—"Cylindrical to subcylindrical sponges to 15 mm maximum diameter without a prominent central spongocoel but with interior penetrated by many irregular, coarse, probably exhalant canals and fine skeletal pores; irregular canals approximately 1 mm in diameter; skeleton of irregular fibers mostly 0.10 mm across that

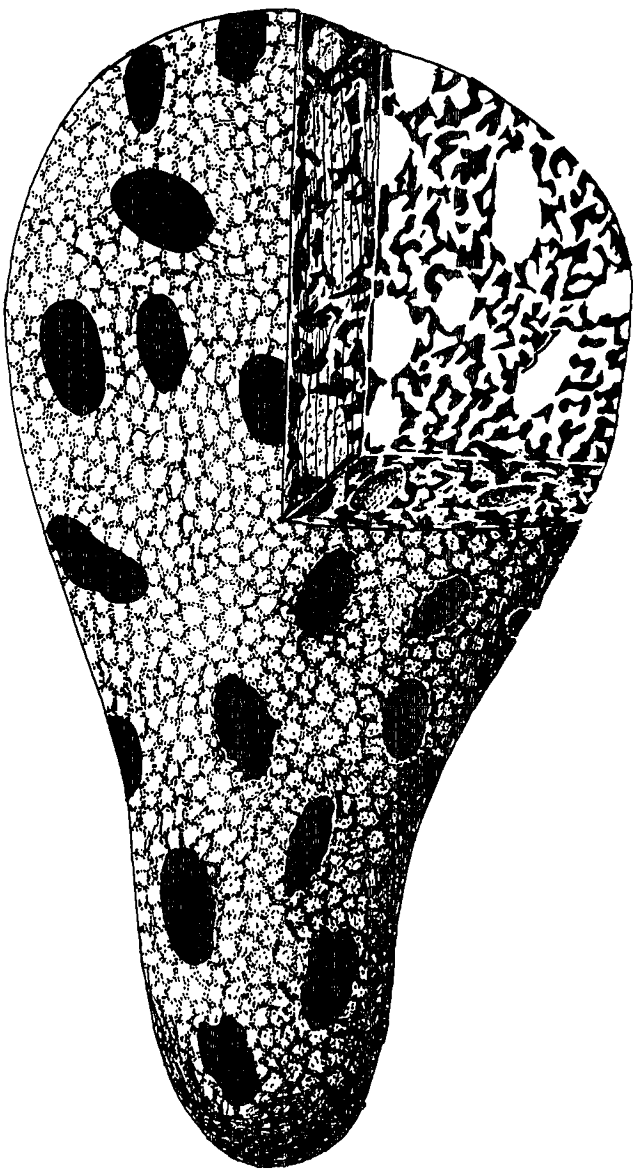

Figure 18. Reconstruction of Cavusonella caverna *Rigby, Fan, and Zhang, 1989b, showing the relatively large irregular canals that interrupt the fibrous skeletal structure; canals shown black in the exterior but white in the sections of the interior, not to scale (from Rigby and Senowbari-Daryan, 1996a).*

radiate upward and outward from an axial region; skeletal canals parallel fiber trends and 0.2–0.3 mm across." (Rigby, Fan, and Zhang, 1989b, p. 796)

Description.—Sponges of species in Guadalupe Mountains irregularly cylindrical, with uneven or undulating exteriors. Large specimens with diameters of up to 16 mm, but small specimen, seen only longitudinal section, with diameters of only 6–9 mm.

Specimens in collections with irregularly arranged and relatively large canals, ranging 0.5–1.5 mm in diameter. Canals may branch, with smaller ones 0.5–0.7 mm in diameter diverging from others up to 1.4 mm across. Most canals cut only in section and show no regular course, location, nor spacing within skeleton, but generally lead upward and outward within sponge. Canals commonly with thin walls generally 0.06–0.10 mm thick, pierced by small openings 0.02–0.04 mm in diameter, smaller than skeletal pores that are commonly 0.10–0.20 mm across between skeletal fibers in tracts between canals. Transverse section shows no spongocoel and canals separated irregularly 2–3 mm apart. Skeleton between canals relatively uniform throughout regular reticulate structure, with 3–4 skeletal pores and fibers per mm in interior and outer part. Fibers range 0.04–0.1 mm in diameter.

Discussion.—The general appearance and relationships between skeletal and canal elements and dimension of specimens from the Guadalupe Mountains correspond to those described and figured in the sponge *Cavusonella caverna* Rigby, et al., 1989b, which is the only described species of the genus.

Cavusonella caverna (Rigby, et al., 1989b) was described first from Middle and Upper Permian reefs of Xiangbo, Longlin County, northwestern Guangxi, China (Rigby, Fan, and Zhang, 1989b). Rigby and Senowbari-Daryan (1996a) have reported the same species from Upper Permian reef limestones of Djebel Tebaga, Tunisia. The occurrence of this sponge in the Guadalupe Mountains indicates its probable world-wide distribution in tropical Permian sequences. *Cavusonella caverna,* however, is a relatively rare sponge in all three localities where it has been reported.

Material.—Three figured specimens, including large sponge on UNSM 35068 from Chinaberry Draw, and two smaller specimens in etched UNSM 35297 from an uncertain locality. In addition the species occurs in UNSM 35067 and 35081 from Chinaberry Draw; and UNSM 35109, 35120, 35121, 35158, and 35180 from Dark Canyon; and UNSM 35211 and 35225 from Hackberry Draw; and UNSM 35254 from Bat Cave Draw, all in Sample Set B.

Subfamily GIGANTOSPONGINAE
Rigby and Senowbari-Daryan, 1996b

Diagnosis.—"Auriculospongiids sheetlike or palmate with both inhalant and exhalant transverse canals and major longitudinal exhalant canals. Sponges lack spongocoels and oscula." (Rigby and Senowbari-Daryan, 1996b, p. 351)

Genus GIGANTOSPONGIA
Rigby and Senowbari-Daryan, 1996b

Diagnosis.—"Discoidal inozoid sponges with prominent parallel to divergent longitudinal-radial canals and more irregular transverse canals generally at right angles or steep angles to dermal-gastral surfaces, with limited astrohizal development on dermal surface or absent. Skeletal tracts subhorizontal and radially divergent parallel to tubular canals, cross-connected by irregular to columnar, vertical, subparallel elements in transverse sections. Skeletal microstructure unknown because of diagenesis." (Rigby and Senowbari-Daryan, 1996b, p. 353)

Type species.—*Gigantospongia discoforma* Rigby and Senowbari-Daryan, 1996b.

GIGANTOSPONGIA DISCOFORMA
Rigby and Senowbari-Daryan, 1996b
Plate 9, figs. 8, 9; Plate 10, figs. 1, 2

Gigantospongia discoforma RIGBY AND SENOWBARI-DARYAN, 1996b p. 347–355, figs. 3–5; WOOD, DICKSON AND KIRKLAND, 1996, p. 739, pl. 3.

Discussion.—Rigby and Senowbari-Daryan (1996b) described these large discoidal sponges from major occurrences in the "Sponge Window" locality, in the mouth of Bat Cave Draw, and from the Hackberry Draw and Chinaberry Draw localities. These are the largest sponges known from the Permian, with diameters up to 2.5 m across, although the plate-like sponges are only to 20 mm thick. The discoidal sponges apparently projected as horizontal plates out from a steep, rough front of the reef and produced voids, below, that were occupied by smaller sponges, brachiopods, and bryozoans. Examples of *Lemonea cylindrica* (Girty, 1908a) and numerous *Lemonea micra*, new species, are attached in an inverted position to the underside of the plates, with their chamber interwalls arching downward. Several specimens of *Amblysiphonella* also grow inverted in the crypts in that structure, like those pointed out by Wood, et al., (1994, 1996) from their observations elsewhere in the Capitan Limestone.

Material.—The holotype, USNM 480456, and paratype, USNM 480457, are from the "Sponge Window" locality, and paratype, USNM 480458, is from the Hackberry Draw locality. They are deposited in the U.S. National Museum. Paratypes from Chinaberry Draw, UNSM 35005 and 35006, are in collections of the University of Nebraska State Museum, Lincoln. In addition, the sponge occurs in samples UNSM 35067A, from Chinaberry Draw; UNSM 35145 from Dark Canyon; UNSM 35257, 35258, and 35261 from Bat Cave Draw in Sample Set A and USNM 480458 from Hackberry Draw.

Family PERONIDELLIDAE
Wu, 1991

Emended diagnosis.—"Sponges in which excurrent system consists of only a spongocoel or a cluster of several coarse canals in axial region of sponges; water system of *Peronidella-* or *Precorynella*-type (modified from Wu, 1991, p. 56)." (Rigby and Senowbari-Daryan, 1996a, p. 50)

Subfamily PERONIDELLINAE
Rigby and Senowbari-Daryan, 1996a

Diagnosis.—"Sponges with axial spongocoel but lacking inhalant and exhalant canals." (Rigby and Senowbari-Daryan, 1996a, p. 58)

Type genus.—*Peronidella* Hinde, 1893.

Genus PERONIDELLA
Hinde, 1893

(*pro Peronella* Zittel, 1878,
non Peronella Gray, 1855)

Original diagnosis.—"Einfach oder durch Knospung ästig; Einzel-Individuen cylindrisch dickwandig; Scheitel gewölbt, seltener eben, in der Mitte mit engem, kreisrundem Osculum der röhrenförmigen Magenhöhle, welche mit nahezu gleichbleibendem Durchmesser die ganze Länge des Schwammkörpers bis in die Nähe der Basis durchbohrt. Einströmungscanäle fehlen. Wand der Magenhöhle und Oberfläche porös. Aussenseite entweder nackt oder an der Basis, zweilen auch bis in die Nähe des Scheitel mit dichter, concentrisch runzeliger Epidermis überzogen. Das Skelet besteht aus meist groben, wurmförmig gekrümmten, anastomosirenden Fasern, die ein wirres Gewebe bilden" (Single or branched through budding; individual specimens cylindrical, thick walled; summit arched, rarely flat, in the middle occurs a round osculum of the tubular spongocoel, which extends with nearly unchanged diameter for the entire length of the sponge body from the vicinity of the base. Inhalant canals lacking. Wall of the spongocoel and upper surface porous. Exterior either naked or secondarily coated on the base and up to the summit with a thick, concentrically wrinkled epidermis. The skeleton is composed mostly of large, vermiform, round, anastomosing fibers that form a confused net.) (Zittel, 1878, p. 30, 120).

Type species.—*Spongites pistilliformis* Lamouroux, 1821.

PERONIDELLA cf. P. RIGBYI
Senowbari-Daryan, 1991
Plate 12, figs. 5, 8

Peronidella parva RIGBY, FAN, AND ZHANG, 1989b, p. 789–790, figs. 9.7, 9.8, (non *Peronidella parva* NUTZUBIDZE, 1964).

Peronidella rigbyi SENOWBARI-DARYAN, 1991, p. 405; RIGBY AND SENOWBARI-DARYAN, 1996a, p. 60–61, Pl. 11, fig. 3; Pl. 47, fig. 5.

Original diagnosis.—"Small, branching(?), cylindrical *Peronidella,* stems 4 to 6 mm in diameter with tubular spongocoel 1.2 to 2.0 mm across; skeletal fibers generally 0.2 mm across and skeletal canals of essentially the same dimensions; well-defined gastral layer and dermal armor" (Rigby, Fan, and Zhang, 1989b, p. 789).

Description.—Specimens from Guadalupe Mountains are clusters of tubular, branching, sponges with through-going spongocoels, stems generally up to 5–6 mm in diameter and with spongocoels 0.4–0.6 mm in diameter and circular, surrounded by gastral layer up to 0.3 mm thick of thickened fibers of reticulate net. Net interrupted by what appear as canals, as openings of same size as reticulate skeletal pores, but aligned and through-flowing interruptions in skeleton traceable up to 1.0 mm from spongocoel wall as distinctly uparched linear features. No similar openings present in remainder of skeleton. Locally some larger canals, to 0.20–0.25 mm in diameter occur in upper and outer part of skeleton.

Skeleton regular reticulate net, with tracts 0.04–0.08 mm in diameter, most 0.06 mm in diameter, as short cylindrical segments around rounded quadrangular to circular skeletal pores, 0.10–0.14 mm in diameter. Horizontal "layers" in skeleton more prominent and more regular than irregularly spaced vertical tracts of same size and spacing, so skeleton with uniform general appearance as sublayered, with 5–6 layers per millimeter measured vertically. Such layers commonly arched upward, parallel to domed upper margins of sponge. Spongocoels apparently continuous through branches.

Discussion.—Our specimens are identified with question as *Peronidella* cf. *P. rigbyi* because of the only moderately developed interruptions in the skeletal net that appear as uparched exhalant openings in the thickened gastral layer and immediately adjacent part of the skeletal wall. These openings are essentially the same size as pores in the principal part of the skeleton, but are formed where individual tracts of the skeleton are not developed. *Peronidella rigbyi* Senowbari-Daryan, 1991, is a similar, small, questionably branching sponge with stems of essentially the same diameter as those seen in the Guadalupe Mountain collection, but with a somewhat larger tubular spongocoel and skeletal fibers over twice as large. It is one of the few species of *Peronidella,* however, that has a well-defined gastral layer.

Most species of *Peronidella* are unbranched and are significantly larger than the relatively small sponge described here. *Peronidella digitata* Rigby and Senowbari-Daryan, 1996a, is branched with individual stems 6–11 mm in diameter and a single spongocoel in each branch. It is also a somewhat larger sponge and with distinctly coarser skeletal fibers, up to 0.20 mm in diameter, around coarser skeletal pores that range 0.14–0.30 mm in diameter, with most approximately 0.25 mm across, more than double the common size of pores in the skeletal net of the species described here. *Peronidella multiosculata* Rigby and Senowbari-Daryan, 1996a, is also a branching species with stems only 5 mm in diameter, but those stems have 3–6 distinct oscula instead of the one large opening observed here.

Clusters of small chamberlets of *Parauvanella minima* Senowbari-Daryan, 1990, occur attached to stems of the *Peronidella.* Clusters of somewhat less well preserved *Minispongia constricta* (Girty, 1908a) also occur in the sample. These sponges all appear in growth position, with upward growth in a normal pattern, along with isolated stems of *Lemonea micra* n. sp.

Material.—Semilongitudinal and other diagonal subtransverse sections of the species occur in slabs of UNSM 34633 from the Dark Canyon locality, and other probable sections of the species occur Dark Canyon UNSM 34610, and in UNSM 34659 and 34668 from Chinaberry Draw, all in Sample Set A.

PERONIDELLA(?) DELICATA new species
Plate 10, fig. 6

Pseudovirgula tenuis Girty 1908a, p. 71 (pars), Pl. 7, fig. 17, *non* figs. 16, 16a.

Diagnosis.—Small stem-like cylindrical sponges with unwalled axial spongocoel but lacking major lateral canals. Skeletal net fine, upward and outward divergent, lacks skeletal interruptions and exaules.

Description.—Inozoid sponge irregularly cylindrical, curved, or lobate to branched, with outer diameters of approximately 8 mm and up to 55 mm tall; contains relatively, narrow, deep, through-going usually unwalled spongocoel, generally 1.0–1.5 mm in diameter.

Holotype, USNM 118133, cylindrical, weakly annulate stem fragment, 10 mm long, expands upward from diameter of 2.5 mm in lower preserved part to 3.0 mm wide in upper part. Longitudinal section fragment does not show full sponge but only approximately one-third of full diameter. Prominent dermal layer 0.10 mm thick in upper part, but only 0.04 mm thick and discontinuous in lower part of fragment. Sponge lacks coarse horizontal canals, ostia, exaules, and principal major skeletal interruptions that would divide sponge into chamberlets or segments.

Skeletal net fine, reticulate, fibers extend to dermal layer. Skeleton composed of fibers 0.04–0.06 mm in diameter around circular to subrectangular pores mainly 0.08–0.12 mm across or in diameter, although some openings as small as 0.04 mm occur in net in outer subdermal part of skeleton. Principal fabric dominantly vertical in interior of sponge and appears irregularly expanded upward and outward in other parts of specimen.

Somewhat larger specimen 8.5 mm in outer diameter and at least 30 mm tall, with spongocoel 3.0–3.8 mm in diameter. Walls generally lack inhalant canals in porous network of skeleton, but short openings, 0.25–0.30 mm in diameter may extend to 1 mm into wall from spongocoel, as exhalant canals, but not uniformly developed.

Skeletal wall composed of loosely packed and reticulate fibrous structures. Skeletal pores 0.15–0.40 in diameter, most commonly 0.20–0.30 mm across as spherical-subspherical spaces which openly intercommunicate throughout netlike skeleton. Fibers thin, generally 0.05–0.10 mm in diameter but expand up to 0.2 mm at junctions. Outer wall or dermal layer appears moderately well defined, but thin and 0.1 mm thick.

Discussion.—*Peronidella*(?) *delicata* new species, appears similar, in general skeletal makeup, to *Minispongia carinata* Rigby and Senowbari-Daryan, 1996a, but is significantly larger, lacks major lateral canals, and has a coarser textured skeletal structure. *Minispongia* generally reaches diameters of 3 mm or less and has a proportionally larger axial spongocoel.

Peronidella(?) *delicata* new species is probably most similar to *Peronidella* cf. *P. rigbyi* Senowbari-Daryan, 1991. Both are relatively small branching forms with a central axial spongocoel, but in *P. delicata* the spongocoel is usually unwalled and smaller throughout the sponge, although the stems are somewhat larger than in *P.* cf. *P. rigbyi.* In addition, the new species lacks the prominent horizontal "layers" in the skeletal walls and, instead, has a moderately uniform reticulate porous skeleton in which the principal fabric is dominantly vertical. Dimensions of skeletal tracts and skeletal pores are roughly the same in the two species. *Peronidella rigbyi* Senowbari-Daryan, 1991, is a small sponge, and is one of the few species of the genus that has a well-defined gastral layer. *Peronidella digitata* Rigby and Senowbari-Daryan, 1996a, is branched and somewhat larger and has coarser skeletal fibers and pores than in the new species. *Peronidella multiosculata* Rigby and Senowbari-Daryan, 1996a, is a small branching species but it has 3–6 distinct oscula on the summit instead of one oscular opening characteristic of the *P.*(?) *delicata.* Most other species of *Peronidella* are unbranched forms and are commonly much larger than representatives of the genus in the Guadalupe Mountains.

Material.—Three specimens occur on UNSM 35236-1 and on 35263-2, and one on 35229 in Sample Set B from the Rattlesnake Canyon short traverse. The species also occurs in Sample Set B on UNSM 35018, 35041, 35042, 35044 and 35076 from Chinaberry Draw; on UNSM 35100, 35120, 35137, 35148, 35151, 35155, and questionably in 35172 from Dark Canyon; UNSM 35191, 35205, 35219, 35220-1, and 35281 from Hackberry Draw, and in UNSM 35255, 35263 and 35264 from Bat Cave Draw, and in UNSM 34710TS from Sample Set A.

Subfamily PRECORYNELLINAE Rigby and Senowbari-Daryan, 1996a

Diagnosis.—"Sponges in which two or more axial spongocoels or clusters of coarse exhalant canals present; inhalant and exhalant canals present or absent." (Rigby and Senowbari-Daryan, 1996a, p. 74)

Genus MINISPONGIA Rigby and Senowbari-Daryan, 1996a

Diagnosis.—"Tiny, dichotomously branched, cylindrical sponges with one to several united or parallel spongocoels. Ring-like exterior annulations, or ridges, may merge in zigzag-like fashion. Outer surface without perforations. Skeletal fibers reticulate." (Rigby and Senowbari-Daryan, 1996a, p. 78)

Type species.—*Minispongia carinata* Rigby and Senowbari-Daryan, 1996a.

MINISPONGIA CONSTRICTA (Girty, 1908)

Plate 1, fig. 9; Plate 2, figs. 1, 4; Plate 3, fig. 1; Plate 4, figs. 2, 11; Plate 7, figs. 1, 7; Plate 9, fig. 7; Plate 10, figs. 3, 10; Plate 11, figs. 3–5, 7–10

Virgula rigida var. *constricta* GIRTY, 1908a, p. 75 (pars), Pl. 7, fig. 14.

Diagnosis.—Small annulate sponges up to 7 mm in diameter, with prominant axial spongocoel approximately one-half diameter of total sponge. Walls with reticulate structure lacking major canals.

Description.—Small sponge, holotype of variety (and of species here), distinctly annulate, approximately 25 mm high, with distinct bend at mid-height; exterior marked by prominent annulations spaced 1–1.5 mm, but with considerable irregularity, so one major annulation at midheight 3 mm high, with second-order irregular annulations with rounded crests but with weak, indented V-shaped troughs between. Sponge expands upward from broken polished cut approximately 4 mm in diameter, to maximum diameter of 7 mm near top.

Prominent spongocoel somewhat elliptical, 2.2 X 2.6 mm in diameter, exposed in cut base and surrounded by skeletal walls, 0.8–1.1 mm thick, in which reticulate structure faintly shown. Spongocoel filled with debris and sparry calcite.

Walls lack major canals in fine reticulate skeletal net, although fibers obscure in almost waxy-appearing sponge. Skeletal fibers and pores between reticulate skeletal elements appear approximately half size of those in holotype of *Virgula rigida* and figured specimen of Girty (1908a, Pl. 7, fig. 13).

Abundant tiny, cylindrical, to steeply obconical sponges usually seen as transverse or oblique sections in our collection, although longitudinal sections also observed. Largest specimen 22 mm high and only 3 mm in diameter. Sponges generally with diameters of 2–4 mm, but most specimens with diameters of approximately 3 mm. Relatively large axial spongocoel, 0.5–2.0 mm across and 30–50 percent of sponge diameter, passes vertically through entire sponge. Sponge walls usually thinner than diameter of spongocoel, and composed of coarse reticulation of fibers, more coarsely packed around spongocoel than in outer part of wall. Skeletal fibers relatively thin, 0.04–0.1 mm. Spaces or pores between fibers larger in diameter than fibers so entire skeletal net appears moderately open-textured.

Discussion.—The small sponge figured by Girty (1908a, Pl. 7, fig. 14) is here considered to be the holotype of the species *Minispongia constricta,* raising the variety to species rank. Most of the small sponges of the genus in our collection should probably be included in *Minispongia constricta* (Girty, 1908a). They generally have rounded annulations rather than the sharp, keel-like ridges characteristic of type specimens of *Minispongia carinata* Senowbari-Daryan and Rigby, 1988, from the Permian of Djebel Tebaga, Tunisia.

Minispongia constricta (Girty, 1908a) is the smallest and most abundant inozoid sponge recognized within collections from the Upper Capitan Limestone from the Guadalupe Mountains. Sections of the sponge, especially transverse and oblique sections, may be confused with exaules of *Exaulipora permica* (Senowbari-Daryan, 1990), an abundant sphinctozoid sponge in the Capitan Limestone collections. However, the sponges may be differentiated by recognition of the simple single pores in exaules of *Exaulipora* and by the reticulate fibrous skeletal structure characteristic of *Minispongia constricta* (Girty, 1908a).

Although the internal fibrous skeletal structure and dimensions of specimens of the species from the Guadalupe Mountains compares to those of the type species from Upper Permian carbonates of Tunisia (Rigby and Senowbari-Daryan, 1996a), the ring-like carinae or ridges on the periphery of the sponge that characterize the Tunisian species are not clearly evident in specimens from the Guadalupe Mountains. However, no specimens weathered free of matrix were observable. The record of the species in our collection is only on cut surfaces.

Material.—Holotype, USNM 118132, from Permian Capitan limestone, 1000 feet below the top of Guadalupe Peak, on a knob on the long northeast spur, to the south side of Pine Spring Canyon, at the entrance, in the Southern Guadalupe Mountains, Texas, as indicated on the specimen label. Girty (1908a, p. 75) noted the specimen came from the middle of the Capitan Limestone from Capitan Peak (now called Guadalupe Peak) at station 2926. The species occurs in our collection in numerous samples from all the principal localities. Figured specimens occur in UNSM 34623, and 34701, from Sample Set A, and UNSM 35009, 35077, 35114, 35155 and 35225, from Sample Set B.

The species is the most widespread and common inozoid sponge in the Upper Capitan Limestone in our samples. It has been observed in 207 samples and its distribution is shown in Table 1.

Genus BICOELIA new genus

Diagnosis.—Cylindrical sponges with two spongocoels in axial region of skeleton, each with own wall pierced by pores or tubes connecting to pores in reticulate skeleton of sponge wall around spongocoel. Outer surface of sponge characterized by perforated dermal layer. Skeleton between outer wall and walls of spongocoel loose and partially radially-arranged fibrous network. Some horizontal elements, tabulae, may occur within spongocoel.

Discussion.—*Bicoelia* and the similar appearing *Bisiphonella,* which was established by Wu (1991, p. 60), are both inozoan sponges that have two axial spongocoels. Wu defined *Bisiphonella* as a sponge with "Skeletons columnal in form. The canal system consists of two excurrent tubes vertically running through the axial region of skeleton. Fibers arranged into regular or irregular lattice. Skeleton surface with or without cortex." The principal difference separating *Bisiphonella* Wu from the new genus *Bicoelia* is that in the latter each of the spongocoels has a distinct, well differentiated gastral wall, which is not developed in *Bisiphonella* nor in the related *Peronidella.*

Specimens of the type species of *Bisiphonella,* described and illustrated by Wu (1991, p. 60, Pl. 7, fig. 5), have skeletal fibers of two different dimensions. The holotype has a coarser and much more irregular skeletal lattice than the partype (Wu, 1991, pl. 7, fig. 4). As noted by Rigby, et al., (1994, p. 102), Senowbari-Daryan and Ingavat-Helmcke (1994, p. 25), and Rigby and Senowbari-Daryan (1996a), these two specimens should be separated into distinct species.

Bisiphonella cylindrata, documented by Rigby, et al., (1994, Pl. 13, fig. 4) shows sponges with regular fibers around the spongocoel. These sponges do not have differentiated inhalant nor exhalant canals in their skeletons and lack a well-defined gastral layer around the spongocoels, and a differentiated dermal layer. *Bisiphonella* has construction and skeletal fiber make up similar to representative species of *Peronidella.* The principal difference between the genera is that *Peronidella* has a single spongocoel and *Bisiphonella* a double one.

Dickson, et al., (1996) described *Fissispongia tortacloaca* (King, 1933), from the Pennsylvanian of New Mexico and noted that it has "two parallel central oscular canals" (1996, p. 560). They observed that the well-preserved specimens from the Holden Formation in the Sacramento Mountains of New Mexico had aragonitic spherulitic skeletons.

Senowbari-Daryan and Ingavat-Helmcke (1994) described an inozoid sponge from the Upper Permian of Thailand which also has two spongocoels. They included it in *Bisiphonella,* as the new species *B. tubulara.* Sponges similar to *"Bisiphonella" tubulara* have also been found in our collections from the Upper Capitan Limestone in the northern Guadalupe Mountains. These latter sponges have two spongocoels and have additional characters which allow them to be differentiated from the Chinese species described as *Bisiphonella cylindrata* by Wu (1991). These characteristics include a distinct wall for each of the spongocoels, a lack of a fibrous skeletal structure between the spongocoels, development of an outer dermal layer in a differentiated wall, and a moderately loose reticulate fibrous structure between the outer wall and walls of the spongocoels. Because of these characteristics we have separated the Thailand species from *Bisiphonella,* and put it together with the species from the Guadalupe Mountains in the new genus *Bicoelia.*

Sponges with two spongocoels, each with its own wall, are known from Permian deposits from the Djebel Tebaga region of Tunisia. For example, *Imperatoria voluta,* described as a new species by Rigby and Senowbari-Daryan (1996a), also has two spongocoels with their own walls and a fibrous skeletal structure within the sponge walls, making it similar to *Bicoelia. Imperatoria voluta,* however, differs from *Bicoelia,* and especially from the new species *Bicoelia guadalupensis,* by having well differentiated outer segmentation and a turriculate growth form. However, the principal differentiating feature which separates the genera is the limitation of the spongocoels to only the upper parts of individual segments in *I. voluta.* In *Bicoelia* the spongocoels pass virtually through the entire sponge.

Type species.—Bisiphonella tubulara Senowbari-Daryan and Ingavat-Helmcke, 1994.

Etymology.—Bis, L., two; *coilos,* hollow; in reference to two spongoceol tubes that pass through the sponge.

BICOELIA GUADALUPENSIS
new species
Plate 11, figs. 1–4

Diagnosis.—Single or branched cylindrical sponges, with two distinct, relatively broad, spongocoels that extend vertically through entire sponge. Each spongocoel with distinct wall and these walls side by side, lacking fibrous structures between them. Skeleton around spongocoel walls and differentiated outer wall composed of irregularly arranged to reticulate fibrous structure which appears finer textured toward exterior of sponge. Walls of spongocoel pierced by numerous pores that branch laterally into pores between skeletal fibers. Because of skeletal elements within spongocoels, some sections may falsely appear as though sponge has three or four spongocoels.

Description.—Branched stems of cylindrical sponges usually with diameters of 5–8 mm, but range to maximum of 10 mm. Several individual sponges form clumps or clusters, similar to *Lemonea micra* new species. Maximum heights of individual stems cannot be determined, but longitudinal sections document occurrences of stems at least 40 mm high. Holotype branched and largest specimen, at least 40 mm high, but may have been considerably higher because only part of sponge cut in section. It has diameter of 10 mm.

Holotype, as well as paratypes, with two spongocoels in axial region as vertical tubes that pass nearly through entire sponge. Internal diameters of spongocoels somewhat proportional to diameters of major sponge and range between 0.8 and 2.0 mm, but usually 1.2 mm across. One branch of holotype with two spongocoel tubes with interior diameter of 1.2 mm; other branch shows only one spongocoel, with diameter of 1 mm.

Each spongocoel with distinct wall, generally about 0.5 mm thick, and common wall between spongocoels also approximately 0.5 mm thick. Walls of spongocoels and between spongocoels pierced by numerous small, branched, exaulos-like pores ranging 0.2–0.5 mm in diameter.

Walls around spongocoel range 2–4 mm thick and composed of fibrous structures which appear somewhat coarser in vicinity of spongocoel and finer toward periphery of sponge. Dermal layer of wall defined by thickening of fibrous structures, varies in distinctness between specimens and may be locally lacking in some sponges. Some specimens with exterior annulation that does not extend into sponge interior. Some horizontal or oblique, vesiculae-like, skeletal elements may occur within spongocoels and give sponge false appearance of sponge having up to three or four spongocoels.

Discussion.—Bicoelia guadalupensis n. sp. differs from the type species, *B. tubulara* (Senowbari-Daryan and Ingavat-Helmke, 1994), by being somewhat larger, having relatively finer fibrous structures, and having short exaulos-like tubes that pass from the walls of the spongocoel into the skeletal fiber of the principal skeleton around the spongocoel. In addition, the fibrous structures appear somewhat more radially arranged in *B. tubulara* than in *B. guadalupensis.*

Material.—The holotype UNSM 35175-1, and paratypes which also occur in other slices of UNSM 35175, are from

Dark Canyon. The species also occurs in UNSM 35100, 35104, 35107, 35115, 35121, 35139, 35143, 35146, 35151, 35152, 35158, 35178, 35164, 35167, 35170, 35171, and 35175 from Dark Canyon. It also occurs in UNSM 35037, 35044, and 35074 from Chinaberry Draw, in UNSM 35191, 35192?, 35193, 35212, 35223 and 35272 from Hackberry Draw, in UNSM 35239 from Rattlesnake Canyon, in UNSM 35263, and 35264? in Bat Cave Draw in Sample Set B. The species occurs in Sample Set A in UNSM 34607, 34608, and 34625 from Dark Canyon; 34651, 34654, 34665, 34667 from Chinaberry Draw; and 34681, 34699, 34703, and 34717 from Hackberry Draw, in a total of 37 samples.

Etymology.—Named for the occurrence of the species in the Guadalupe Mountains of New Mexico.

Family VIRGULIDAE
Termier and Termier, 1977a

Emended diagnosis.—Massive or subcylindrical to ramose inozoid sponges generally lacking spongocoels. Skeletal net uniform, relatively open-textured, scattered horizontal canals rare or absent.

Discussion.—The genus *Virgula* was proposed by Girty (1908a) based on specimens from the Capitain Limestone in the Southern Guadalupe Mountains of New Mexico. Termier and Termier (1977a) proposed the family Virgulidae without designating a type genus, but obviously their family was based upon their interpretation of the genus *Virgula*. They included in that family, in addition to the genus *Virgula*, the genera *Stylopegma* King, 1943, *Leiospongia* d'Orbigny, 1849, their new genus *Preeudea*, and *Himatella* Zittel, 1878. More recently, Rigby and Senowbari-Daryan (1996a) utilized the family Virgulidae as proposed by Termier and Termier and included in that family four subfamilies, including: (1) Virgulinae Termier and Termier, 1977a, represented by the genus *Intratubospongia* Rigby, Fan, and Zhang, 1989b; (2) the Preeudinae, represented by the genus *Preeudea* Termier and Termier, 1977a, and their new genera *Medenina, Polytubifungia,* and *Microsphaerispongia*; (3) the Pseudohimatellinae, for their new genus *Pseudohimatella*; and (4) the Parahimatellinae for the genus *Parahimatella.* The inclusion of these genera and subgenera within the family was based on acceptance of the definition of the family, as proposed by Termier and Termier (1977a).

Reexamination of type specimens of *Virgula neptunia* Girty, 1908a, the type species for the genus, shows that the interpretation of *Virgula* by Termier and Termier (1977a), including what they termed *Virgula osiensis* (de Gregorio, 1930), was based upon a complete misunderstanding of the basic structure of *Virgula.* The latter species was included by Rigby and Senowbari-Daryan (1996a) in *Intratubospongia osiensis,* sponges with a canal pattern vastly different from that in *Virgula neptunia. Virgula,* as the type-genus for the family Virgulidae, should define a totally different set of sponges than that included by Termier and Termier in their family.

Rigby and Senowbari-Daryan included Paracorynellidae Wu, 1991, and Polysiphonellidae Wu, 1991, as synonyms within the Virgulidae of Termier and Termier. The Paracorynellidae Wu, 1991, includes sponges with the canal pattern developed in *Intratubospongia* Rigby, Fan, and Zhang, 1989b, at least in the theoretical pattern shown by Wu (1991, fig. 12). Wu interpreted the oblique sections in the type-specimens of *Paracorynella* as having a clustered grouping of exhalant canals that emptied into a shallow spongocoel, with those subvertical canals being fed by uparched convergent exhalant canals in the inner part of the wall, but with the outer part of the wall lacking inhalant openings. The figure of the holotype (Wu, 1991, Pl. 9, fig. 2) clearly shows small canals in the lower right part of the sponge. There small canals connect to the coarser exhalant canal of the cluster and are like inhalant canals in patterns relatively common in Paleozoic demosponges and calcareous sponges. Such a pattern looks much more like that developed in *Precorynella* or in lower parts of *Permocorynella,* as described and figured by Rigby and Senowbari-Daryan (1996a).

Sponges much more like those used by Termier and Termier as exemplifying the Virgulidae are those described and figured by Wu (1991) as in the Polysiphonellidae, his new family based on the genus *Polysiphonella* Russo, 1981. Wu characterized the sponges included in that family as being conical, columnar, or elongate, but with a canal system consisting principally of coarse excurrent canals scattered through the whole skeleton and running essentially the length of the skeleton, opening on the upper sponge surface. These sponges, like those in the Paracorynellidae, are interpreted to lack differentiated inhalant canals as well as subhorizontal exhalant canals, with the system being characterized principally by only the subparallel, widely dispersed, vertical openings. It is this type of canal pattern, where the exhalant canals are scattered throughout the sponge skeleton and not clustered, that characterizes *Intratubospongia* and in particular *Intratubospongia osiensis* (de Gregorio, 1930) that is so common in the Tunisian Permian. Termier and Termier (1977a) included that species in *Virgula* and utilized it to define the Virgulidae in their major work on the Tunisian fossils. It was in that sense that Rigby and Senowbari-Daryan (1996a) also used the family in their major restudy of Permian sponges from Tunisia. One, thus, is faced with nomenclatorial problems. The family Virgulidae Termier and Termier 1977a, is based on non-virgulid sponges and, with the exceptions of almost tangential inclusion of the type species and the associated *Virgula rigida* Girty, 1908a, all other taxa included to date in the family have major vertical canals. Those sponges would fit much better within the emended Polysiphonellidae Wu, 1991. One then wonders, do we place those genera included by Termier and Termier (1977a) and Rigby and Senowbari-Daryan (1996a), for example, in the Polysiphonellidae and redefine the Virgulidae in terms of characteristics of the type genus, or do we preserve the term Virgulidae to include the sponges with the complex canal patterns in the family and exclude the type genus and species? We have chosen to redefine the Virgulidae based on the type genus and type species, and to preserve the grouping of taxa and apparent intentions of Termier and Termier (1977a). We have included those sponges in the Polysiphonellidae Wu, 1991, and have excluded those sponges with major canal systems from the redefined Virgulidae. The Virgulidae of Termier and Termier was defined on a misinterpretation of the type genus, a misinterpretation produced by lack of examination of the type material and reliance on the very generalized description and illustrations by Girty (1908a).

Type genus.—*Virgola* (Girty, 1908a)

Genus VIRGOLA De Laubenfels, 1955

(pro *Virgula* Girty, 1908a, *non* Simpson, 1900)

Diagnosis.—Subcylindrical to ramose sponges with few branches, irregular central spongocoel shallow, if present, in moderately open-textured, porous, uniform skeletal net generally lacking distinct inhalant or exhalant canals, or with rare short, walled, canals.

Discussion.—*Virgula* was renamed *Virgola* by De Laubenfels (1955) because of homonymy with *Virgula* Simpson (1900). The nature of the skeleton in the various species of *Virgola* described by Girty (1908a, p. 74–75) was initially intrepreted by Girty as composed of regular tetraxons, which would have placed the sponges in the demosponges, where De Laubenfels (1955) placed the genus, with some question. Finks (1960, p. 93) placed *Virgula* within the phaeretronid calcisponges, which includes the inozoid sponges in our current classification. Because of that confusion and assignment of other species to the genus, it is necessary to reexamine and redescribe *Virgula neptunia* Girty, 1908a, for that type species defines parameters of the genus, and that genus the family characteristics.

Type species.—*Virgula neptunia* Girty, 1908a

VIRGOLA NEPTUNIA (Girty, 1908a)
Plate 2, fig. 3; Plate 3, fig. 1; Plate 4, fig. 14;
Plate 7, fig. 7; Plate 8, fig. 7; Plate 11, figs. 4, 10;
Plate 12, figs. 6, 7, 10

Virgula neptunia GIRTY, 1908a, p. 74, Pl. 7, figs. 11, 12

Virgola neptunia (Girty, 1908a), DE LAUBENFELS, 1955, p. E54, fig. 36.3

Diagnosis.—Cylindrical to irregularly lobate or hemispherical sponges lacking central spongocoel, except as possible shallow oscular depression on summit. Trabecular skeletal network, uniform, perhaps with gently upward-divergent or outward radially-dominated structure, of skeletal tracts mostly 0.08–0.10 mm in diameter, in center around skeletal pores mostly 0.15–0.20 mm in diameter, but with some variation. Lacks coarse, horizontal canals but with some skeletal openings of pore-size extending part way through walls, but lacking coarse ostia. Dermal layer locally developed, as are plate-like interruptions in interior.

Description.—Species characterized by mushroom-shape to irregularly hemispherical or lobate cylindrical shape, lack central spongocoel but with scattered coarse exhalant canals. Holotype, USNM 118130, diagonal fragment of subcylindrical sponge, 8.5 mm in diameter and at least 10 mm tall, in which subtransverse section of upper part to 9 mm in diameter, shows central spongocoel or oscular depression 2.0–2.2 mm in diameter with walls of the principal skeleton 2.5–4.5 mm thick. No horizontal canals evident, only skeletal pores in regular, uniform skeletal net, with somewhat radial to gently upward divergent trend. Coarsest skeletal elements are tract junctions, 0.16–0.22 mm in diameter, formed where thinner segments 0.08–0.10 mm in diameter cross or converge. Thinner skeletal tracts in midwall or outer wall 0.05–0.08 mm in diameter, with tract junctions 0.10–0.12 mm in diameter. Tracts with sharply angular recrystallized microstructure with small crystals 0.01–0.02 mm across and high; tracts probably originally smooth and crystals may mark positions of original spherolites.

Skeletal pores in holotype circular to subquadrate or oval. Circular ones as small as 0.05 mm in diameter grade up to most common ones 0.15–0.20 mm across and to oval openings 0.15 X 0.25 mm across. Approximately four openings occur per mm radially and concentrically. Radial skeletal tracts generally more continuous and more nearly straight, to 4 segments or 4–5 pores long, connected by concentric tracts commonly extending only between radial ones or bounding single pores. Locally, some concentric tracts missing so crude radial canals traceable to 1 mm long but with normal pore diameter. Dermal layer on holotype moderately well developed.

Paratype, USNM 118129, also a diagonal fragment of sponge 15 mm tall and up to 9–10 mm in diameter, with uniform skeletal net essentially like that of holotype but with fibers, mostly 0.10–0.2 mm in diameter, around pores commonly 0.20–0.25 mm in diameter but ranging to 0.3

mm. Single exaulos-like tube cut on fractured margin and 1–1.5 mm long, out from general sponge surface, pierced by small canal, 0.10 mm in diameter on outer end but 0.2.0–0.25 mm in diameter at midlength and 0.40 mm in diameter where merged with smaller subparallel canal in interior. Other such structures not preserved around periphery of either type fragment nor on conspecific sponges in present collection.

Specimens of present study more nearly complete and at least 30 mm tall and 15 mm in diameter in upper parts, but perhaps only 8 mm in diameter in lower part. Specimen in UNSM 35146 completely preserved and several parallel longitudinal sections available. Exterior of sponge with minor depressions that coincide with positions of arched plate-like elements in interior skeleton. These plate-like elements produced by amalgamation, either grouping or local thickenings of skeletal fibers that arch upward more or less parallel to vaulted summit of sponge. These skeletal structure layers produced by pulsing growth of reticulate skeleton, not sponge segmentation such as in thalamid sponges.

Relatively continuous dermal layer 0.2–0.5 mm thick of closely spaced fibers with essentially same thickness as fibers in interior. Internally, reticulate skeletal net of relatively coarse, fibrous structures, appearing mostly polygonal to circular in cross-sections parallel to axis of sponge. These outline polygonal or subspherical cell-like pores, 0.2–0.5 mm, but usually about 0.4 mm in diameter, connected to neighboring "cells" by openings with diameters of 0.1–0.2 mm. Thicknesses of fibers within walls between individual "cells" mostly 0.1 mm, but range from 0.06–0.20 mm across. Some may be in pairs or in bead-like linear series of 3–5 pores; most, however, isolated and irregularly packed, though locally crudely aligned.

A few large, walled, short canals approximately 0.8–1.4 mm in diameter, may occur in outer parts of skeleton. Sections parallel to axis of sponge with different numbers of canals. One section with six large canals, another with only four such canals, and third with only one canal. These canals appear to diverge irregularly upward and outward and were probably exhalant.

Distinct fibrous wall around short canals 0.10–0.20 mm thick, pierced by openings of same general diameter as skeletal pores between fibers. Specimens in UNSM 35155 are more irregular but also have large short canals.

Smaller, irregular, possibly inhalant canals 0.4–0.6 mm in diameter, with perforated walls 0.10 mm thick, like skeletal fibers. Inhalant ostia of same diameter as canals are irregularly cut in sections where they pierce dermal layer, but canals not traceable far into interior before lost in coarse skeletal structure.

Discussion.—The skeleton of *Virgola neptunia* Girty, 1908a is considerably coarser textured than that in either *Cavusonella caverna* Rigby, Fan and Zhang, 1989b, or *Peronidella(?) delicata* new species, and it lacks the irregular large canals of these former species and the central spongocoel of the latter species.

Both *Virgola neptunia* and *Virgola rigida,* described by Girty (1908a) from the Capitan Limestone in the southern Guadalupe Mountains, have moderately coarse reticulate skeletal nets. The skeletal network in *Virgola neptunia* is relatively uniform, with skeletal pores mostly 0.15–0.2 mm in diameter, defined by tracts commonly 0.08–0.10 mm in diameter, where pores in *Virgola rigida* are 0.08–0.12 mm wide, but up to 0.3 mm high between moderately distinct, prominent horizontal layers. Both species have moderately well developed dermal layers but neither have prominent canals. Although a shallow spongocoel is developed in the holotype of *Virgola neptunia,* such openings are not present in *Virgola rigida.* A principal difference is that *Virgola rigida* tends to be subcylindrical and distinctly branched with prominent growth lines or annulations, whereas *Virgola neptunia* tends to be cylindrical to irregularly lobate or hemispherical, although it may have indistinct lobes or short branches in more massive forms. Some large, walled, canals may be locally developed in *Virgola neptunia,* but such canals are not developed in *Virgola rigida.*

Material.—Holotype, USNM 118130, and paratype, USNM 118129, Capitan Limestone approximately 1000 ft below the top of Guadalupe Peak, on the knob of the long northeast spur on the south side of the entrance to Pine Spring Canyon, Southern Guadalupe Mountains, Texas. Several specimens occur in Samples UNSM 35003?, 35009, 35010, 35013, 35017, 35024, 35025, 35034, 35053, 35054, and 35058? from Chinaberry Draw; in UNSM 35094, 35114, 35120, 35146, 35147, 35148, 35151, 35154, and 35155 from Dark Canyon; in UNSM 35182, 35193, 35194, 35195, 35196, 35197, 35212, 35214, 35220, 35225, 35250, 35276, 35278, and 35284 from Hackberry Draw; and in UNSM 35254? and 35261 from Bat Cave Draw, and 35289, etched specimen from an unknown locality, all from Sample Set B.

VIRGOLA RIGIDA (Girty, 1908a)

Plate 10, figs. 4, 5, 10; Plate 13, figs. 1–4

Virgula rigida GIRTY, 1908a, p. 74, Pl. 7, fig. 13.

Virgula rigida var. *constricta* GIRTY, 1908a, p. 75 (pars), Pl. 7, fig. 15, *non* 14.

Virgola rigida Girty 1908a, DE LAUBENFELS, 1955, p. E55, fig. 36.2.

Diagnosis.—Subcylindrical, branched, inozoid with prominent growth lines and annulations in dermal layer on exterior, interior lacking spongocoel and major canals. Outer skeleton fine reticulate net of fibers or tracts 0.04–0.08 mm in diameter, locally forming prominent layers

0.25–0.30 mm apart, skeletal pores up to 0.12 mm wide and 0.3 mm long in exterior, but tracts to 0.20 mm in diameter in interior as fairly coarse reticulate net with pores 0.2–0.3 mm across. Dermal layer with fibers and vertical pores more prominent and irregularly developed in outer 1 mm.

Description.—Holotype, branched, subcylindrical ovoid or palmate, in cross-section, relatively small sponges with prominent low annulations, 1.5–2.5 mm high, spaced such that 6 annulations occur per 10 mm, vertically. Spongocoel and large open canals lacking in reticulate fibrous skeleton. Holotype with one branch 39 mm tall, and another incomplete branch, 33 mm tall, above broken, almost blade-like to elliptical base, 7 mm thick and 13 mm wide. Individual branches with oval cross sections, 7 X 11 mm, but ranging up to 7.5 X 12 mm on crests of annulations, which range 0.5–1.1 mm high out from basic stem surface. Minor weak annulations occur 5–8 per major annulation and produced by dominant horizontal skeletal fibers on exterior that form plate-like minor indentations.

Vertical fibers on exterior generally 0.06–0.08 mm in diameter in centers of tracts between junctions that are 0.10–0.12 mm in diameter. Prominent horizontal layers of reticulate skeleton perforated but distinct on exterior and 0.25–0.30 mm apart, cross-connected by vertical segments of net to form pores 0.08–0.12 mm wide and 0.20–0.30 mm long between layers; pores more prominent in parts of dermal layer than in more evenly reticulated interior. Such skeletal tracts on exterior spaced 0.20 mm apart, vertically center to center. In etched surface, skeletal tracts appear dark and crystalline, but pore fillings between tracts light gray and microgranular.

Transverse section of base with skeletal structure weakly radiate only in outer 1–2 mm, with irregular reticulate pattern most prominent in interior, where most pores 0.2 mm in diameter as circular openings between rounded grid of skeleton replaced by sparry calcite. Broken transverse section of longest stem shows basically same pattern, with radial skeletal reticulation evident only in outer 1–1.5 mm and with regular reticulation showing in interior as uniform net with fibers 0.10–0.13 mm in diameter, around pores 0.2–0.3 mm in diameter as circular openings between tracts in the net.

Specimen USNM 118151, originally included as *Virgula rigida* var. *constricta* Girty, 1908a, also characteristic of species, but only somewhat smaller than holotype. Small cylindrical sponge 20 mm tall, from essentially complete base 4 mm in diameter, expands upward with angular weak annulations, as in holotype, up to maximum diameter of 8 mm near bevelled polished, diagonal upper surface. Skeletal net as in holotype, with moderately dense reticulate fibers forming prominent dermal layer, where horizontal, perforated, layer-like elements of reticulate net 0.10–0.12 mm in diameter are connected by subcylindrical segments 0.06–0.08 mm in diameter. Junctions of tracts 0.10–0.12 mm in diameter. Pores between tracts 0.08–0.12 mm in diameter, with those at surface somewhat longer, up to 0.20 mm high, and generally only 0.10–0.12 mm across. Most annulations, as in holotype, 1–1.5 mm high, with rounded crests and rounded to somewhat sharper troughs between. Specimen lacks spongocoel as in holotype.

Specimen referred with question to species cut in tangential to sublongitudinal section on UNSM 34710TS, of sponge at least 22 mm long or high, and 6–7 mm in diameter. Sponge mostly irregularly and coarsely recrystallized, but two patches of sparry calcite perforated by coarsely reticulate fibers or tracts 0.10–0.24 mm in diameter with most approximately 0.15 mm in diameter. Elements hollow, porous, reticulate with central pores 0.04–0.06 mm in diameter, surrounded by dense, light, microspar possibly dolomitic. Skeletal pores between fibers mostly 0.25–0.30 mm in diameter, interconnected throughout and locally expanding up to 0.50 mm in diameter as "canals" or pore junctions in fibrous or reticular net. Reticulate skeletal structure spaced 2–3 tracts per mm vertically or horizontally, in relatively open skeletal structure.

Discussion.—Girty (1908a, p. 75) apparently separated out the variety, *Virgula rigida* var. *constricta*, based on the somewhat smaller size of the specimens he included there, as well as on the somewhat irregular growth and the more or less pronounced constrictions or annulations that are more prominent in the small sponges than in the somewhat larger holotype of the species *Virgula rigida.* Girty (1908a, p. 75) noted that "a deep tube-like cloaca seems to be a constant feature," but such a major central opening is not developed in that holotype. We consider presence or absence of a major spongocoel as a significant generic-level character, and consequently, we have selected the specimen (USNM 118132) included by him as characteristic of the variety *constricta* as the holotype of the species *Minispongia constricta* (Girty, 1908a), and have included the other specimens in the type suite without a cloaca or spongocoel in *Virgola rigida* (Girty, 1908a).

So little of the sponge is preserved in UNSM 34710TS that generic and specific identification is uncertain, but the general nature of the skeleton, the pores between, and the lack of distinctive continuous canals, suggest the specimen is a piece of *Virgola rigida* (Girty, 1908a). It is associated with a poorly-preserved *Lemonea micra,* which is cut in tangential section, in the algal boundstone. Both the *Lemonea micra* and the *Virgola rigida* appear essentially horizontal in fallen position. Numerous examples of small transverse sections of *Minispongia constricta* occur in essentially vertical position in the boundstone, but their preservation is also obscure and possibly dolomitized, so their microstructure is largely gone. Comparison of the associated *Virgola neptunia* and *Virgola rigida,* both described by Girty (1908a), are discussed in the section on *Virgola neptunia.*

Material.—Holotype, USNM 118132, and figured specimens, USNM 118151 and 118133, figured by Girty (1908a, Pl. 7, figs. 13, 15 and 17.) These specimens are from Girty's locality, Capitan Limestone (1000 feet plus or minus below top) mostly higher, but some lower than 1000 feet below top of Guadalupe Peak, in the knob on the long northeast spur on the south side of Pine Spring Canyon, at its entrance, Guadalupe Mountains, Texas, USGS locality 2926a. A somewhat questionable section of the species occurs in UNSM 34710TS from the Hackberry Draw locality. Additional specimens of the species occur in Sample Set B in UNSM 35018, 35041 and 35044 from Chinaberry Draw; UNSM 35144, 35148, 35151, and 35160? and 35172 from Dark Canyon; UNSM 35182, 35183, 35194 and 35272 from Hackberry Draw; UNSM 35263 and 35264 from Bat Cave Draw, and UNSM 35298, an etched specimen from an uncertain locality, in our collections.

Family POLYSIPHONELLIDAE
Wu, 1991

Emended diagnosis.—Obconical cylindrical massive or irregularly spherical sponges with numerous coarse longitudinal exhalant canals or spongocoels throughout whole sponge, or radial where spherical; may include axial tubes or clusters of exhalant canals; inhalant canals absent or present but more or less horizontal where present.

Discussion.—The family Polysiphonellidae was proposed by Wu (1991, p. 56), based on the genus *Polysiphonella* Russo, 1981, and the same year Belyaeva (1991, p. 92) also proposed the family Polysiphonellidae based on the same genus. The exact date of both papers is difficult to establish. The Zoological Record (1992) recognized Wu as the author of the family; we have continued to recognize that authorship.

As used by Rigby and Senowbari-Daryan (1996a), the family Virgulidae Termier and Termier, 1977a, included the subfamilies Virgulinae, ascribed to Termier and Termier, 1977a, and the new subfamilies Preeudeinae, Pseudohimatellinae, and Parahimitellinae. The subfamily Virgulinae should be suppressed because it was proposed to include the genus *Virgula,* Girty, 1908a, as the type genus was understood by Termier and Termier (1977a). Rigby and Senowbari-Daryan (1966a, p. 85–88) placed the genus *Intratubospongia,* Rigby, Fan, and Zhang, 1989b, in the subfamily as well, not realizing at the time that Termier and Termier (1977a) based their description of the family on *Virgula osienis* (de Gregorio, 1930), a species now considered within *Intratubospongia.* That genus is now included within an emended Preeudeinae Rigby and Senowbari-Daryan 1996a, along with sponges initially included there in their publication on the Tunisian Permian sponges.

Several inozoid sponges with numerous and widespread exhalant tubes that trend upward and outward in the skeleton are known from the Permian at several localities. *Medenina* Rigby and Senowbari-Daryan, 1996a, *Polytubifungia* Rigby and Senowbari-Daryan, 1996a, *Intratubospongia,* Rigby, et al., 1989b, and *Preeudea* Termier and Termier, 1977a, all have canals that are vertical and parallel, and terminate at the top of the sponge (see Rigby and Senowbari-Daryan, 1996a, fig. 11). In *Radiotrabeculopora* Fan, et al., 1991, and *Disjectopora* Waagen and Wentzel, 1887, the canals extend upward and outward to the exterior of the skeleton.

The genera *Dendrosclera, Paracorynella, Permostroma, Tritubulostroma, Concentristroma,* and *Fungistroma* proposed by Wu (1991), are excluded from our discussion. Some of them are junior synonyms of taxa described by Rigby, et al., (1989b), or Fan, et al., (1991), and others are insufficiently described and too poorly documented for comparison.

Type genus.—*Polysiphonella* Russo, 1981.

Other included genera.—*Polysiphonella* Russo, 1981, *Preeudea* Termier and Termier, 1977a, *Intratubospongia* Rigby, Fan and Zhang, 1989, *Medenina* Rigby and Senowbari-Daryan, 1996a, *Polytubifungia* Rigby and Senowbari-Daryan, 1996a, *Microsphaerospongia* Rigby and Senowbari-Daryan, 1996a, and *Pseudovirgula* (Girty, 1908a).

Subfamily PREEUDEINAE
Rigby and Senowbari-Daryan, 1996a

Emended Diagnosis.—Polysiphonellid sponges with or without large osculum on summit but if present exhalant canals empty into depression. Transverse canals present or absent.

Type genus.—*Preeudea* Termier and Termier, 1977a.

Genus GROSSOTUBENELLA
Rigby, Fan, and Zhang, 1989b

Diagnosis.—"Cylindrical to subcylindrical sponges without a spongocoel, but with a weakly annulate exterior; interior pierced by many coarse, nearly equally spaced, subvertical, subparallel to sinuous exhalant canals that branch upward infrequently; incurrent canals not evident; skeleton even-textured, composed of fine vermiform fibers, pierced throughout by small irregular skeletal pores; spicules unknown." (Rigby, Fan, and Zhang, 1989b, p. 794)

Type species.—*Grossotubinella parallela* Rigby, Fan, and Zhang, 1989b.

GROSSOTUBINELLA PARALLELA(?)
Rigby, Fan, and Zhang, 1989b
Plate 9, fig. 6

Grossotubinella parallela RIGBY, FAN, AND ZHANG, 1989b, p. 796, figs. 12.4, 12.5, 12.8.

Diagnosis.—"Cylindrical to subcylindrical sponges, weakly annulate, coarse excurrent canals 1–2 mm apart and generally 1.0–1.2 mm in diameter, each with thin fibrous porous layer; skeletal fibers irregular and up to 0.10 mm in diameter, between skeletal pores 0.15–0.20 mm across." (Rigby, Fan, and Zhang, 1989b, p. 796)

Description.—Single diagonal section a cylindrical stem 3–3.5 mm in diameter, with length of 15 mm. Skeleton reticulate net pierced by subvertical coarse canals, 0.6–1.1 mm in diameter, with most 0.7–0.8 mm across as seen in sections, canals spaced 0.3–1.2 mm apart. Canals generally unwalled interruptions to ill-defined walled perforations, where walled structure appears as expansion of tract tips to produce irregular and commonly ill-defined thin layer, approximately 0.10 mm thick.

Reticulate skeletal net composed of fibers 0.06–0.10 mm in diameter, in relatively uniform structure, around skeletal pores that appear 0.06–0.15 mm high in diagonal section and up to 0.3 mm wide.

Exterior of sponge weakly annulate, with ill-defined dermal layer approximately 0.10–0.15 mm thick, produced by expansion of skeletal tracts near exterior. Lower part of sponge section appears more nearly transverse and upper part more sublongitudinal section, as though polished surface intersected elbow-shaped cylindrical sponge, with annuli 2–3 mm high, as low ridges 0.3–0.4 mm high, above somewhat sharper, V-shaped, notches between rounded surfaces.

Discussion.—The distinctive multiple, sub-vertical canals and lack of an axial spongocoel in the weakly annulate, stem-like sponge that also appears to lack distinctive inhalant canals, suggest inclusion of the New Mexico sponge, at least tentatively, in *Grossotubinella parallela* Rigby, Fan, and Zhang, 1989b. *Cavusonella* Rigby, Fan, and Zhang, 1989b, also initially described from the Permian of China, has a skeleton pierced by coarse irregular canals, but *Cavusonella* differs from *Grossotubinella* in having more irregularly distributed canals with irregular cross-sections and also has a skeleton that has principally horizontal canals. Rigby and Senowbari-Daryan (1996a) concluded that the cylindrical *Grossotubinella* had several coarse spongocoels rather than coarse vertical exhalant canals, and they included it in the subfamily Preeudeinae Rigby and Senowbari-Daryan, 1996a, now included within the family Polysiphonellidae Wu, 1991.

Both *Polysiphonella* Russo, 1981 and *Paracorynella* Wu, 1991 have major vertical exhalant canals but in those forms, these parallel canals terminate in an upper, large, bowl-shaped depression. Such a large osculum or depression is not developed in the fragment available to us. Hence, we have included the New Mexico sponge in the genus *Grossotubinella*. Because the dimensions of canals and the skeletal net are similar to the Chinese species, *G. parallela*, we have tentatively included the sponge there as well.

Material.—Figured single specimen occurs on UNSM 34676TS from the Chinaberry Draw locality, Sample Set A.

Genus PSEUDOVIRGULA
Girty, 1908a

Original diagnosis.—"This term is introduced for a species which I originally placed with the genus *Virgula*, but which on reconsideration it seems desirable to refer to a distinct group. The general appearance, as cylindrical stemlike growths, is similar, and the character and arrangement of the spicules also resemble those of *Virgula*. On the other hand, *Pseudovirgula tenuis* is provided with large ostia, structures which have not been observed in the other group. Inside the dermal layer, between it and the consolidated spicular median portion, is an empty or hollow zone, which if a real character (this being very doubtful) would constitute an important distinction between the form in question and those subsumed under the title *Virgula*. Again, *Pseudovirgula tenuis* is somewhat obscurely divided off into structural segments. The presence of large ostia is the only difference subsisting between *Pseudovirgula* and *Virgula* which can perhaps be called real and constant, but in view of the indications of the additional differences mentioned it hardly seems a sound course to place both types in the same genus." (Girty, 1908a, p. 75–76)

Type species.—*Pseudovirgula tenuis* Girty, 1908a.

PSEUDOVIRGULA TENUIS Girty, 1908a
Plate 10, figs. 7–9

Pseudovirgula tenuis GIRTY, 1908a, p. 76, Pl. 7, figs. 16, 16a, *non* fig. 17

Diagnosis.—Small subcylindrical sponges lacking axial spongocoel, with central region of well-developed, delicate, reticulate skeletal net and outer zone free of net except for irregularly developed uparched laminae of reticulation. Well-developed exaules, several per "chamber" extend as walled tubes outward from reticulate central region through skeletal free area and as open tubules radially from the periphery.

Description.—Holotype, USNM 118152, a small fragment of cylindrical sponge 6 mm tall, lacks a spongocoel, in stem with diagonal subtransverse, broken ends 3.3–3.4 mm in diameter. In side view, chamber-like subdivisions produced by layers of more dense skeletal net that interrupt cylindrical structure; within "chambers" outer ring of clear crystalline calcite shows no reticulate skeletal structure. That layer approximately 0.7 mm wide, around a central "column" 1.5–2.0 mm wide where fine reticulate skeletal net well-developed. Dense dermal layer 0.1 mm thick.

Skeletal structure of interior perforated by open horizontal canals 0.4–0.5 mm in diameter of interior ends of exaules surrounded by apparently impervious walls 0.1 mm thick. Canals broader at inner end, narrow peripherally, and thickness of exaulos walls decreases from 0.15–0.2 mm in the interior to only 0.10 mm thick near outer terminations. Exaules may extend radially to 1 mm beyond dermal layer. Inner ends of ostia apparently interrupt and pierce at least part of the central reticulated skeletal area.

Chamber-like partitions 1.5 mm apart so parts of 4 "chambers" present in holotype. Central area in which reticulate skeletal structure developed is column 1.5–2.0 mm in diameter, with some irregularity. Fibers of fine reticulate net 0.04–0.08 mm in diameter, with most 0.06 mm thick; some skeletal fibers arranged in radial linear series and somewhat continuous aligned pores, like short canals 0.1 mm across, traceable up to 0.3 mm in available surfaces mainly 0.08–0.10 mm in diameter, and circular to subquadrate in the outer part but up to 0.12–0.22 mm as coarse pores in center.

Discussion.—Girty (1908a, p. 76) observed the sponge appears to be divided into segments by "several cessations and renewals of growth," and that the skeletal structure did not extend all the way to the dermal layer. He interpreted that gap as destruction of the skeleton rather than that the skeleton originally occupied essentially only the interior of the stems supported by the skeletal interruptions. He also observed the tubular, projecting ostia or exaules and that the canals extended into the skeletal structure. These combinations of structural features clearly separate *Pseudovirgula tenuis* Girty, 1908a, from other sponges in the collection.

The sponge appears almost as a sphinctozoan because of interruptions produced by moderately dense thin layers of skeletal net, but that structure is discontinuous and does not clearly define distinct chambers, as in the sphinctozoans. The small species might appear similar to *Lemonea exaulifera* new species, because in that small stemmed sphinctozoan exaules are pronounced, but *L. exaulifera* has a distinct central spongocoel around which are arranged radial tubelike chambers rather than a reticulated skeletal interior.

Most of the other small sponge species in the collection are either distinctly chambered sphinctozoan forms or small inozoid forms lacking the prominent exaules and radial canals, as well as the dense skeletal layers and the outer clear layer so evident in the holotype of *Pseudovirgula tenuis.* For example, *Peronidella* cf. *P. rigbyi* Senowbari-Daryan, 1991, is a small, possible branching form of the same general dimensions as the type of *Pseudovirgula,* but *Peronidella* lacks the skeletal interruptions, has a prominent tubular spongocoel, and lacks the radial exaules, which clearly separate the species. *Minispongia constricta* (Girty, 1908a), may also appear superficially similar but it, too, has a well-developed spongocoel and lacks the exaules characteristic of *P. tenuis.*

Girty (1908a) initially included, with some doubt, USNM specimen 118133 in *Pseudovirgula tenuis.* That specimen lacks the internal skeletal interruptions and "chamberlets," the prominent exaules and the rings of unskeletonized areas. That sponge clearly belongs to a different species than the holotype, the only known specimen of *Pseudovirgula tenuis*. For the present, the species *Pseudovirgula tenuis* should probably be limited to the small holotype.

Material.—Holotype, USNM 118152 from the middle of the Capitan Formation, Guadalupe Mountains, Texas, collecting station 2916, from approximately 1000 ft below the top of Guadalupe Peak, on the knob on the long spur northeastward from the peak, on the south side of Pine Springs Canyon, at the entrance, southern Guadalupe Mountains, Texas.

Family STELLISPONGIELLIDAE Wu, 1991

Diagnosis.—"Massive to hemispherical or obconical and stem-like sponges with one to several oscula or astrohizal clusters of exhalant canals on upper surface; canal clusters may extend into skeleton but lack deep spongocoel; dense dermal layer may be developed on base; fibrous skeleton aspiculate, commonly reticulate, with fibers of spherulitic microstructure." (Rigby and Senowbari-Daryan, 1996a, p. 40)

Subfamily STELLISPONGIELLINAE Wu, 1991

Diagnosis.—"Stellispongiellids in which starlike oscula of convergent excurrent canals may be situated on mamelon-like elevations or impressed into generally smooth surface; sponges commonly ramose." (Rigby and Senowbari-Daryan, 1996a, p. 40)

Genus STELLISPONGIELLA Wu, 1991

Diagnosis.—"Cylindrical, stemlike to branching, or palmate to irregular encrusting sponges with numerous oscula uniformly distributed over stems, to which exhalant canals converge in stellate patterns; spongocoel lacking; oscula may be on nodes, on smooth stem, or impressed into stems; stem surface with numerous inhalant pores to short canals that may be lost in skeletal net or may lead to upwardly divergent axial canals, which connect to radial exhalant canals and ostia that may occur in tangential oscular canals or on the exterior between oscula; microstructure spherulitic." (Rigby and Senowbari-Daryan, 1996a, p. 41)

Type species.—Stellispongia bacilla Termier and Termier, 1955.

STELLISPONGIELLA(?) species
Plate 12, fig. 9

Description.—Irregularly branched, moderate-sized sponges, with stalk-like branches up to 9 cm tall and 13–15 mm in diameter in single specimen cut and exposed in upper and lower surfaces of slab. Surface with low mounds (?) 1–2 mm high and each with coarse, possible exhalant canals and fine convergent (?) canals. Skeleton of uniform reticulate net. Spongocoel not developed but principal skeleton interrupted by canal series of two sizes, coarser canals with irregular orientation, although part of crude upwardly-divergent system.

Coarser canals range 0.5–1.0 mm in diameter, with most 0.7 mm in diameter. Smaller canals 0.3–0.5 mm in diameter, with most 0.3 mm in diameter. Smaller canals converge irregularly toward coarser ones, although locally in moderately uniformly stacked and aligned series where spaced 0.5–2.5 mm apart, vertically, but commonly 1.5–2.0 mm apart, center to center, in single aligned series. In two areas, smaller canals aligned horizontally in upwardly arcuate cross-section, normal to length of branch and spaced 1–1.5 mm apart. Elsewhere, canals less regular in diagonal sections. Large canals apparently open to exterior, and perhaps exhalant, somewhat in fashion of *Stellispongiella,* and smaller canals appear to be inhalant interruptions of the skeleton.

Skeleton regular uniform net, with fibers 0.05–0.08 mm in diameter, most 0.05–0.06 mm, and spaced 5–7 fibers per mm, both vertically and horizontally. Pores defined by fibers and range 0.10–0.20 mm in diameter, with most 0.14 mm in diameter, as circular or oblong to rounded quadrate openings in regular skeleton.

Discussion.—Sponges most similar to this single specimen are perhaps those included in the cylindrical to branching, stem-like *Stellispongiella* Wu, 1991 (Figure 19). Species in that genus lack a spongocoel but have numerous oscula distributed over the surface of the stems, to which converge exhalant canals that are interruptions in the reticulate skeletal net. Numerous small inhalant pores to short inhalant canals are somewhat smaller.

Stellispongiella bacilla (Termier and Termier, 1955) generally has exhalant openings on prominent mounds or nodes and so is clearly differentiated from our specimen. *Stellispongiella insculpta* Rigby and Senowbari-Daryan, 1996a, has a reticulate skeleton with abrupt divergences in the skeletal tracts in the outer region, and has a skeletal structure unlike that seen here. *Stellispongiella reticulata* Rigby and Senowbari-Daryan, 1996a, has two distinct skeletal zones recognizable in the holotype, with an inner, gently upward-divergent cluster of axial tubules, in a structure not developed in the uniform reticulate skeletal net in the sponge from New Mexico. *Stellispongiella parva*

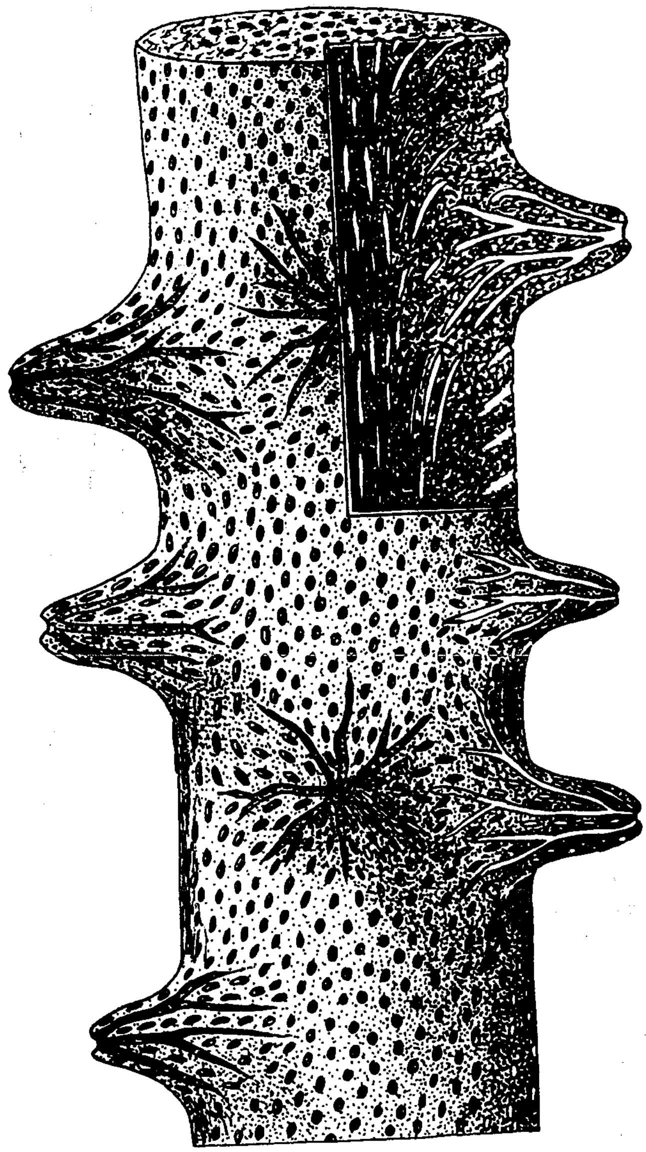

Figure 19. Generalized recontruction of Stellispongiella bacilla *(Termier and Termier, 1977a), the type species of the genus. Astorhizae-like canals are situated on mounds, these canals have somewhat irregular patterns in the interior of the stems (from Rigby and Senowbari-Daryan, 1966a).*

Rigby and Senowbari-Daryan, 1996a, generally has both exhalant and inhalant canals considerably finer than in the Guadalupe Mountain sponges, and a reticulate net that is generally finer textured, as well. *Stellispongiella amplia* Rigby and Senowbari-Daryan, 1996a, has two distinct skeletal zones, as in other species of the genus, in a skeletal arrangement dissimilar to the New Mexico collection, and it also has clusters of axial canals, unlike the canal pattern in the sponge here.

The Guadalupe Mountain sponge appears to have low mounds, 1–2 mm high, each with central coarse canals that might be exhalant canals, and finer canals that converge to them and perforate other skeletal parts, as well. This suggests that the sponge is a species of *Stellispongiella* that lacks a differentiated, divergent axial structure, and, therefore, probably should be considered as a new species.

Other inozoid sponges described from the Permian of Tunisia (Rigby and Senowbari-Daryan, 1996a), include similar forms that are included in the subfamily Preeudinae Rigby and Senowbari-Daryan, 1996a. These are sponges that lack a large osculum or depression on the summit, and that have reticulate skeletons. Within that subfamily, *Grossotubenella* Rigby, Fan, and Zhang, 1989b, is a cylindrical sponge with several coarse, irregularly oriented canals within the reticulate skeltal net. The interior of *Grossotubenella,* however, is pierced by many, nearly equally spaced, subvertical and subparallel, discontinuous exhalant canals that branch upward in a distinctly more porous, more uniformly canalled skeleton than in the Guadalupe Mountain sponge. *Preeudea* Termier and Termier, 1977a, is a similar form, but that sponge has distinct exaulos-appearing inhalant pores, structures that are not developed in the sponge here. *Polytubifungia* Rigby and Senowbari-Daryan, 1996a, is a mushroom-shaped sponge with coarse exhalant canals in the reticulate skeleton and contrasts in growth form to the sponge here. *Microsphaerispongia* Rigby and Senowbari-Daryan, 1996a, is a spherical sponge and also contrasts in growth form to the branching tubular sponge from the Capitan.

Cavusonella caverna Rigby, Fan, and Zhang, 1989b, is a cylindrical sponge with coarse, irregular openings that may bifricate upward and includes sponges that lack prominent continuous longitudinal canals and a central spongocoel. The skeleton of *Cavusonella* is composed of irregular fibers in a loose upward-and-outward expanding pattern, in distinct contrast to the marked uniform skeletal net seen in the sponge here.

The Guadalupe Mountain sponge is also similar to *Prestellispongia* Rigby and Senowbari-Daryan, 1996a, which also lacks a deep spongocoel, but which may have several separate oscula or astrorhizae distributed over the sponge surface. *Prestellispongia* is commonly massive but may be twig-like or branching subcylindrical, in a fashion somewhat like the sponge here. However, in species of *Prestellispongia* the skeletal net is considerably less uniform and perforated by somewhat coarser exhalant canal clusters and much more common, smaller, inhalant canals. In addition, *Prestellispongia* is commonly massive subhemispherical and so contrasts in general shape to our material.

Material.—Figured specimen cut in diagonal sections on upper and lower surfaces of a slab, approximately 1 cm thick, of UNSM 34717 from the Hackberry Draw locality and a second possible section is on UNSM 34633 from Dark Canyon, both on Sample Set A.

Class DEMOSPONGEA Sollas, 1875
Order EPIPOLASIDA Sollas, 1888
Family HELIOSPONGIIDAE Finks, 1960

Diagnosis.—"Skeleton very regularly organized into upwardly divergent ascending tracts connected by upwardly convex layers of horizontal tracts; each tract is a bundle of parallel, smooth oxeas of one kind, possibly cemented together by secondary silica; a thin dermal layer of tangentially disposed oxeas, with secondary siliceous cement, may be present; canal system well developed, with prosochetes parallel to ascending tracts and apochetes parallel to horizontal tracts; whole sponge commonly tubular and branching, with well-developed cloacas; no root tuft." (Finks, 1960, p. 40)

Genus HELIOSPONGIA
Girty, 1908b

Diagnosis.—"Large, cylindrical to flabellate, branching sponge, with thick body wall and relatively narrow cloaca; skeletal net relatively dense and tracts thick; horizontal tract layers strongly downturned about periphery; dermal layer essentially absent; large prosopores frequently stellate; large apopores circular, approximately as large as the prosopores and commonly arranged in vertical and horizontal rows." (Finks, 1960, p. 43)

Type species.—*Heliospongia ramosa* Girty, 1908b (according to Finks, 1960, p. 48, the variety parallela, separated by Girty 1908b, is identical with *H. ramosa ramosa*).

Other species.—*Heliospongia excavata* King, 1933, *Heliospongia vokesi* King, 1943, *Heliospongia finksi* Termier and Termier, 1977a, and *Heliospongia houchangensis* Deng, 1982b.

HELIOSPONGIA RAMOSA
Girty, 1908a
Plate 11, fig. 6, Plate 13, figs. 7, 8

Heliospongia ramosa GIRTY, 1908b, p. 289–290, Pl. 16, figs. 8, 9, Pl. 17; FINKS, 1960, p. 47–48, Pl. 2, fig. 3, Pl. 3, figs. 2–4.

Heliospongia ramosa var. *parallela* GIRTY, 1908b, p. 290, Pl. 16, fig. 10, Pl. 18.

non Heliospongia ramosa GIRTY, 1908a, KING, 1933, p. 84. Pl. 8, fig. 6, ?*Stylopegma conica* KING, 1943, p. 20, Pl. 2, fig. 2.

Diagnosis.—"Form of sponge digitate, with slender, cylindrical, subparallel branches, each with a deep, relatively narrow, central cloaca opening terminally; horizontal layers spaced approximately 1.0 mm apart, and ascending tracts spaced approximately 0.6 mm apart." (Finks, 1960, p. 47)

Description.—Single specimen unbranched stem 45 mm high cut in longitudinal section almost in axial plane, shows unwalled spongocoel almost 2 mm in diameter with net-like skeletal walls 1.5–2.0 mm thick. Diameter of whole sponge 8 mm in lower part, but where cut in oblique section in upper part, because sponge curved, preserved width is 5–6 mm.

Skeleton with both vertical and prominent, uparched, horizontal rod-like elements in three-dimensional grid work. Distances between horizontal elements range 0.3–0.8 mm, most 0.4 mm, so 10–12 horizontal layers per 5 mm. Horizontal layers 0.08–0.12 mm thick and more continuous than vertical connecting elements 0.06–0.08 mm in diameter. Poorly preserved vertical elements extend only from one horizontal layer to another, much like spicular structure in *Anthracosycon* Girty, 1908a (see Finks, 1960, Pl. 20, figs. 4–6) or in *Preverticillites* Parona, 1933. Distances between horizontal layers 0.9–1.2 mm, but mostly approximately 0.9 mm (Finks, 1960).

Discussion.—The genus *Heliospongia* has been reported from the Carboniferous and Permian of the USA (Girty, 1908b; King, 1933; 1943; Finks, 1960) and Tunisia (Termier and Termier, 1977a; Rigby and Senowbari-Daryan, 1995). Finks (1960) detailed description of *Heliosponga ramosa* Girty, 1908b, was based on excellently silicified materials.

Deng (1982a) reported the occurrence of the genus in the Permian of Guizhou Province, China. However, the specimen determined as *Heliospongia* sp. (Deng, 1982b, Pl. 1, fig. 7) is not certainly a *Heliospongia*, and may belong to the genus *Peronidella*. The specimen identified by Deng (1982b) as *Heliospongia*? "*houchangensis* n. sp." is only half of a cylindrical(?) sponge and can not be specifically determined. The occurrence of the genus *Heliospongia* in Permian rocks of China, thus, remains uncertain.

Heliospongia ramosa Girty, 1908b, apparently is known only from the Carboniferous and Permian of the United States. Sponges described as cf. *Heliospongia ramosa* by Parona (1933, p. 51, Pl. 9, figs. 5–6) are not of the species (see King, 1943, p. 9). Finks (1960, p. 48) observed that the specimen of *Stylopegma conica* described by King (1943, p. 20) may be a piece of a large *H. ramosa* Girty. The type species, *Stylopegma dulce* King, 1943, is a thalamid sponge closely related to *Amblysiphonella*, according to Finks (1960, p. 48).

Material.—Three figured specimens of the species are in the collections of Sample Set B, two on UNSM 35185 from Hackberry Draw and one on UNSM 35232 from Rattlesnake Canyon. In addition, one specimen occurs on both UNSM 34654 and 34680 from Chinaberry Draw in Sample Set A.

HELIOSPONGIA VOKESI
King, 1943
Plate 13, fig. 1

Heliospongia vokesi KING, 1943, p. 8, Pl. 1, figs. 1, 2; FINKS, 1960, p. 48–50, Pl. 1, fig. 7, Pl. 2, figs. 4, 9, Pl. 4, figs. 1–5.

Diagnosis.—"Large, openly branching cylinders of greater diameter than those of either *ramosa* or *excavata*, each with a deep, relatively broad, central cloaca opening terminally; horizontal layers spaced more closely than in either *ramosa* or *excavata*, being less than 1.0 mm apart; ascending tracts spaced as in *ramosa*, approximately 0.6 mm apart." (Finks, 1960, p. 49)

Description.—Large, cylindrical, curved to branching sponges up to over 300 mm tall and with diameters to 60 mm, penetrated by simple tubular spongocoels, 25 mm in diameter. Weathered transverse sections show walls 15–18 mm thick, pierced by radial canals 1.3–1.6 mm in diameter, which locally appear partially walled. These canals spaced 0.5–2.0 mm apart in irregular diagonal sections in wall. They appear parallel to radial series of skeletal tracts and may arch upward but ends indefinite in available specimens. Smaller circular skeletal pores 0.7–0.8 mm in diameter form spherical spaces between more-or-less rectangularly placed tracts 0.15–0.25 mm in diameter, at thinnest, but expand up to 0.5 mm at tract junctions.

Horizontal skeletal tracts spaced 6–7 tracts per 5 mm, vertically, in general structure, although locally in some coarser parts only 5 per 5 mm vertically. Horizontal tracts up-arched and curve downward toward periphery, maintaining orientation essentially normal to ascending or vertical tracts that arch upward and outward to meet exterior at about 90 degrees. Spicular structure of tracts obscure because of replacement.

Discusssion.—*Heliospongia vokesi* King, 1943 was reported in Wolfcampian to middle Leonardian beds in the Glass Mountains and Sierra Diablo of western Texas. Our Guadalupian examples are the youngest yet reported and extend the range of the species through most of the Permian. Finks (1960) noted that the Wolfcampian forms occur in shale facies and that the Leonardian forms are common in patchreef and backreef facies in the Sierra Diablo. The Upper Capitan occurrences are in the lower or middle part of the massive reef, equivalent to the lower and middle Tansill Formation.

The largest specimen of the species in our collection, UNSM 35268, was collected from the lowest exposures in the sample grid of the Hackberry Draw locality and, thus, is one of the oldest sponges from that area. The projected age of the specimen in UNSM 35228 from Rattlesnake Canyon is probably somewhat older.

Finks (1960, p. 50) concluded that Leonardian representatives of the genus can be referred to *Heliospongia vokesi* based on their size and tract spacing. Those same characteristics, in addition to the size of horizontal canals, indicate that the specimens in our collection belong to that species as well. Finks also observed (1960, p. 48) that "the only characters by which *vokesi* can be distinguished from *ramosa* are its larger size and closer tract spacing." He noted that in *Heliospongia ramosa* Girty, 1908b, horizontal tracts are 0.9–1.2 mm apart and ascending tracts are spaced 0.4–0.8 mm apart in that slender, branched, cylindrical form. *Heliospongia excavata* King, 1933, is also digitate branched but with the cylindrical branches containing multiple spongocoels and with a more coarsely spaced skeletal net than in either *H. ramosa* or *H. vokesi. H. excavata* is commonly flabellate, as well, and so contrasts in growth form and skeletal texture with *H. vokesi. Heliospongia excavata* is known from the Lower and Middle Missourian in the Missouri region, and as silicified specimens from the Glass Mountains in Texas. *Heliospongia ramosa* ranges from the Upper Missourian to Wolfcampian in Kansas and the Glass Mountains of West Texas (Finks, 1960).

Aulocospongia sp. Termier and Termier, 1955, was placed in synonomy, with question, by Finks (1960) but was later described by Termier and Termier (1977a, p. 678) as *Heliospongia finksi*.

Material.—One fragmentary specimen on UNSM 35228 from Rattlesnake Canyon; and one large figured specimen on UNSM 35268 1a–d, and smaller specimens on UNSM 35273 and 35276 from Hackberry Draw, all in Sample Set B.

Genus NEOHELIOSPONGIA
Deng, 1981

Diagnosis.—"Branching sponge cylindrical. Skeleton organized into upwardly divergent ascending tracts connected by convex layers of horizontal tracts. Skeletal net relatively dense. Tracts thick. Horizontal tract layers strongly downturned around periphery, thus concentrically arranged around axial area in transverse section. Canal system well-developed, partly parallel to ascending tracts and partly to horizontal tracts; ascending canals often passing through horizontal ones. Surface having irregularly netted pores." (Deng, 1981, p. 426)

Discussion.—The genus *Neoheliospongia* was established by Deng (1981) for sponges that he interpreted to be similar to *Heliospongia* Girty 1908a, but without a spongocoel. *Heliospongia*, however, is a demosponge and the tracts are made by bundles of monaxial spicules, as was shown by Finks (1960, Pl. 2, fig. 5) in the species *Heliospongia excavata*, King, 1943. Spicules, however, are not known in *Neoheliospongia*, either in the Chinese collection described by Deng or in the sponge described below from the Guadalupe Mountain collections. The uncertain assignment of the Capitan sponges to *N.* cf. *N. typica* is based on overall morphological features, nature of the skeletal net and canal pattern as described and figured by Deng (1981).

Type species.—*Neoheliospongia typica* Deng, 1981.

NEOHELIOSPONGIA cf. N. TYPICA
Deng, 1981
Plate 13, figs. 9, 10

Neoheliospongia typica DENG, 1981, p. 423, Pl. 2, fig. 1.

Description.—Several specimens of species occur in collection, one represented by 3 parallel polished slabs and others only by single polished slabs. Subcylindrical to somewhat irregular sponges with heights of at least 9 cm and diameters of approximately 28 mm, may be branched. Interiors of sponges lack spongocoel or large canals and largely recrystallized so skeletal structure only locally evident, but near periphery skeletal elements and canals clearly recognizable. Skeleton a uniform reticulation of fine fibers, 0.08–0.12 in diameter, with most 0.10 mm in diameter around interconnected spherical skeletal pores 0.08–0.12 mm in diameter. Pores commonly aligned, bead-like, in outer part parallel dominantly radial rod-like structures in skeleton and scattered smooth-marginal canals 0.12–0.15 mm in diameter, which interrupt skeleton. Skeleton commonly preserved as replaced calcareous mold so microstructure destroyed. Recognizable canals diverge upward and outward toward sponge exterior.

Discussion.—The genus *Neoheliospongia* and the type species *N. typica* Deng, 1981, have been previously reported only from the Upper Permian of Guangxi, China.

Skeletal and canal pattern shown in the transverse section of the holotype (Deng, 1981, Pl. 2, fig. 1) are strikingly similar to sections of the Guadalupe examples. Sponges from the Guadalupe Mountains are encrusted, almost totally, by the vesiculate and attached richthofenid brachiopods, *Sestropoma cribriferum* Cooper and Grant, 1969, as noted by Senowbari-Daryan and Rigby (1996a).

Material.—Several specimens occur in Sample Set B, including figured specimen on UNSM 35113 and 35122, which also includes numerous examples; and a reference specimen on UNSM 35118; and in UNSM 34607, 34610, 34618 and probably in 34662 in Sample Set A.

FOSSILS OF UNKNOWN TAXONOMY

FORM A
Plate 13, fig. 4

Description.—Moderately coarse-textured, annulate impression approximately 45 mm high, as cut in section, with maximum diameter of 15–16 mm. Fossil composed of 4 "segments" 10, 10, 15, and 11 mm high, from the bottom, or from the narrowest impression upward. Entire structure filled with fibers or filling tissues in vermiculate, irregular undulating, or reticulate patterns. Individual fibers 0.3–0.5 mm in diameter, as thicker structures than filling structures in associated sponges. Each fiber hollow, with pores 0.1–0.15 mm in diameter, surrounded by walls 0.20 mm thick, and separated by linear pores between spaghetti-like segments.

Interfiber pores 0.05–0.25 mm across, most 0.06–0.10 mm, as branched and rounded, interconnected, openings. Ill-defined central spongocoel-like opening 1.0–1.5 mm in diameter occurs in irregular sections in at least two "segments." Those openings and linear pores between fibers now filled with clear sparry calcite, which also extends as irregular "crusts" around exterior of impression. Those "crusts" 0.2–1.2 mm thick combine with thin dense layer, 0.1–0.2 mm thick, to define undulating annulate exterior. Pores ill-defined in exterior, except in one area where dense fibrous elements, 0.4–0.6 mm in diameter, extend out through two exopores and merge, somewhat like branches whose finer tips extend into fossil impression as branches. Those branches outside impression range 4–5 mm long and apparently hollow like those in the interior.

Discussion.—At first glance, the fossil appears as an irregularly chambered to annulate sphinctozoan sponge filled with coarse, reticulate, filling structures. These fibrous fillings are unique in being consistently hollow tubes, or branching reticulate structures, almost as though some soft part had become coated by marine cement and then not preserved. Interwalls are ill-defined and so the structure takes on the appearance of an inozoid sponge with coarse reticulate skeletal structure. Such hollow, coarse, macaroni-like filling structures are not known in other inozoan sponges from the Upper Paleozoic and, hence, the sponge origin of the structure is much in question.

The annulate exterior impression, now marked by the crystalline sparry crust, may have marked the initial exterior on a sponge whose interior has been largely destroyed by a fungal or algal structure. Because of these difficulties the fossils remain with uncertain affinity and taxonomy.

Material.—Figured impression of specimen cut in sublongitudinal sections on UNSM 34639 of Sample Set A from the Dark Canyon locality. Similar fossils, probably the same species, occur in Sample Set B in UNSM 35068 from Chinaberry Draw; in UNSM 35191, 35195, and 35196 from Hackberry Draw, and in UNSM 35254 from Bat Cave Draw.

FORM B
Plate 13, fig. 5

Description.—Common, digitate, finger-like to irregular branching stems of dense, microporous, organisms moderately common in sponge-algal boundstone of Sample 34618. Stems to 6–7 cm long and 1–2 cm in diameter, with considerable irregularity for stem diameters apparently increase to maximum width at apparent branching. Exterior irregular, with some indentations marked by initiation of new laminae in the interior. Interior dense, microporous, with upward arcuate laminae defined by relatively thin, dense layers in the fibers around the micropores. Those bubble-like openings, mostly 0.18–0.20 mm in diameter, defined by fibers or walls 0.01–0.2 mm in diameter or thick, up to approximately double that in junction areas between adjacent micropores.

Laminae, defined by gradational thickening of fibrous interpore skeletal elements to 0.04–0.05 mm thick. Locally, pores aligned almost as "canal" segments to 0.20 mm in diameter and up to 0.5 mm long, as unwalled perforations of the microskeletal structure. Such "canals" relatively rare and evident only where cut longitudinally in tips of the fingerlike digitations. Near base, skeletal structure appears concentric and individual laminae draped far down along flanks from crests of digitations. Locally, organism overgrew bryozoans and elsewhere locally bryozoans overgrew it or are attached to it.

Discussion.—The structures here appear more algal or hydrozoan-like than even the very fine-textured inozoan sponges. Form B specimens lack the canal patterns of most sponges in the collections. They appear to have the moderate skeletal density of algae, such as *Solenopora,* like that intergrown in the bryozoans *Acanthocladia guadalupensis* Girty. The micropores and fibers are somewhat coarser textured than in *Tubiphytes.* There is little question, however, that the organism is not a sponge, but belongs in the algae or hydrozoans, although it lacks zooidal tubes of the hydrozoans, and looks like it should more properly be included in the algae.

Material.—The fossil is common in UNSM 34618 of Sample set A from Dark Canyon and also is questionably identified in UNSM 35181 of Sample Set B, from Hackberry Draw.

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The University of Nebraska Research Council supported Liu's preparation and his visit to Brigham Young University in 1988. Sample Set A was collected as part of the same study by Fagerstrom and his students, and is distinct from Sample Set B. The latter samples were cut, in part, by Liu and further processed by Rigby and C.A. Cohen at Brigham Young University.

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REFERENCES CITED

Achauer, C.W., 1969, Origin of Capitan Formation, Guadalupe Mountains, New Mexico and Texas, American Association of Petroleum Geologists Bulletin, v. 53, p. 2314–2325.

Akagi, S., 1958, On some Permian Porifera from Japan, p. 66–73, Jubille Publication Commemorating Professor H. Fujimoto, Institute of Geology and Mineralogy, Tokyo Kyoiku Daigaku.

Aleotti, G., Dieci, G., and Russo, F., 1986, Éponges Permiennes de la Vallee de Sosio (Sicile). Révision systematique des sphinztozoaires, Annales de Paléontologie, v. 73, p. 211–246.

Babcock, J.A., 1974, The role of algae in the formation of the Capitan Limestone (Permian, Guadalupian), Guadalupe Mountains, West Texas-New Mexico, Unpublished Ph.D. dissertation, University of Wisconsin. Madison, 241 p.

Babcock, J.A., 1977, Calcareous algae, organic boundstone, and the genesis of the Upper Capitan Limestone (Permian, Guadalupian), Guadalupe Mountains, New Mexico and West Texas, p. 3–44, *in* Hileman, M.E., and Mazzulo, S.J,. eds., Upper Guadalupian facies, Permian reef complex, Guadalupe Mountains, New Mexico and West Texas, Society of Economic Paleontologists and Mineralogists, Permian Basin Section Publication 77-160.

Beede, J.W., 1900, Carboniferous invertebrates, Kansas Geological Survey, Bulletin 6, part 2, p. 14–16.

Belyaeva, G.V., 1991, The Upper Permian of the Far East, p. 67–108, *in* Boiko, E.V., Belyaeva, G.V., and Zhuravleva, I.T., Phanerozoic sphinctozoans from the Territory of UdSSR, Akademy Sciences of UdSSR, Sibirian Department, Institute of Geology and Geophysics. Akademy of Sciences Tajikistan, UdSSR, Institute of Geology Tajikistan, Moscow, 223 p. (in Russian).

Boiko, E.V., and Belyaeva, G.V., 1991, The Upper Triassic of the Northern Caucasus (r.r. Belaja and Knop Basins), p. 158–171, *in* Boiko, E.V., Belyaeva, G.V., and Zhuraveva, I.T., Phanerozoic sphinctozoans from the Territory of UdSSR, Akademy of Sciences of UdSSR, Sibirian Department, Institute Geology and Geophysics, Akademy of Sciences of Tajikistan, UdSSR, Institute of Geology of Tajikistan, Moscow, 223 p. (in Russian).

Bowerbank, J.S., 1864, A monograph of British Spongidae, vol. III, Royal Society of London, 367 p.

Clarke, J.M., 1897, A sphinctozoan calcisponge from the Upper Carboniferous of eastern Nebraska, American Geologist, v. 20, p. 387–392.

Cooper, G.A., and Grant, R.E., 1969, New Permian Brachiopods of West Texas, I., Smithsonian Contributions to Paleobiology, 1, 20 p.

Cossman, M., 1909, Rectifications de nomenclature, Revue critique Paléozoologie, v. 13, p. 67–68.

Cys, J.M., 1971, Discussion: Origin of Capitan Formation, Guadalupe Mountains, New Mexico and Texas, American Association Petroleum Geologists Bulletin, v. 55, p. 310–315.

Cys, J.M., 1977, Capitan reef—evolution of a concept, p. 201–322, *in* Hileman, M.E., and Mazzullo, S.J., eds., Upper Guadalupian facies, Permian reef complex, Guadalupe Mountains, New Mexico and West Texas, Society of Economic Paleontologists and Mineralogists, 1977 Publication 77-16, Field Conference Guidebook, p. 201–322.

Dahlbom, A.G., 1854, Hymenoptera Europaea praecipue borealia, v. 2, p. xv, 9, Berlin.

Deng, Zhan-Qiu, 1981, Upper Permian sponges from Laibin of Guangxi, Acta Palaeontologica Sinica, v. 9, p. 418–427.

Deng, Zhan-Qiu, 1982a, Palaeozoic and Mesozoic sponges from southwest China, *in* Stratigraphy and Palaeontology in W. Sichuan and E. Xizang, China, Part 2, Sichuan Renmin Chuban She, Chengdu, p. 245–258.

Deng, Zhan-Qiu, 1982b, Late Palaeozoic and Mesozoic fossil sponges of Xizang, Series of the Scientific Expeditions to the Qinghai-Xizang Plateau, Palaeontology of Xizang, p. 245–266.

Dickson, J.A.D., Wood, R.A., and Kirkland, B.L., 1996, Exceptional preservation of the sponge *Fissispongia tortacloaca* from the Pennsylvanian Holder Formation, New Mexico. Palaios, v. 11, no. 6, p. 559–570.

Driggs, A.F., 1977, The petrology of three Upper Permian bioherms, southern Tunisia, Brigham Young University Geology Studies, v. 24 no. 1, p. 37–53.

Dunham, R.J., 1962, Classification of carbonate rocks according to depositional texture, p. 108–121, *in* Ham, W.E., ed., Classification of Carbonate Rocks, American Association of Petroleum Geologists Memoir 1.

Dunham, R.J., 1965, Vadose pisolites in the Capitan reef, Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Program 10th Annual Meetings, p. 13–14.

Dunham, R.J., 1972, Capitan reef New Mexico and Texas, facts and questions to aid interpretation and group discussions, Society of Economic Paleontologists and Mineralogists, Permian Basin Section, Special Publication 72-14, 235 p.

Endo, R., 1951, Stratigraphical and paleontological studies of late Paleozoic calcareous algae in Japan, I, Several new species from the Sakamotozawa sections, Hikoroichi-mura, Kensen-gun, in the Kitakami mountainous land. Paleontological Society of Japan, Transactions and Proceedings, New Series, No. 4, p. 121–128.

Engester, T., 1986, Nomenklatorische Notiz zur Gattung *Dictyocoelia* Ott, 1967 ("Sphinctozoa," Porifera), Neues Jahrbuch für Geologie und Paläontologie, Monatshefte 1986, v. 10, p. 587–590.

Fagerstrom, J.A., 1987, The evolution of reef communities, John Wiley & Sons, New York, 628 p.

Fagerstrom, J.A., Weidlich, O., Rigby, J.K., and Senowbari-Daryan, B., 1995, Sponges of the Capitan Limestone (Late Permian) Texas-New Mexico, USA: skeletonization, taphonomy, guilds, Seventh International Symposium on Fossil Cnidaria and Porifera, Madrid, Spain, Abstracts, p. 21.

Fan, Jiasong, and Zhang, Wei, 1985, Sphinctozoans from Late Permian of Lichuan, West Hubei, China, Facies, v. 13, p. 1–44.

Fan, Jiasong, Rigby, J.K., and Qi Jingwen, 1990, The Permian reefs of South China and comparisons with the Permian reef complex of the Guadalupe Mountains, West Texas and New Mexico, Brigham Young University Geology Studies, v. 36, p. 15–55.

Fan, Jiasong, Rigby, J.K., and Zhang, Wei, 1991, "Hydrozoa" from Middle and Upper Permian reefs of South China, Journal of Paleontology, v. 65, p. 45–68.

Finks, R.M., 1955, *Conularia* in a sponge from the West Texas Permian, Journal of Paleontology, v. 29, p. 831–836.

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

Finks, R.M., 1983, Pharetronida: Inozoa and Sphinctozoa, p. 55–59, *in* Broadhead, T.W., ed., Sponges and Spongiomorphs; Notes for a Short Course, University of Tennessee, Department of Geological Sciences Studies in Geology 7.

Finks, R.M., 1995, Some new genera of Paleozoic calcareous sponges, The University of Kansas Paleontological Contributions, new series, Number 6, 9 p.

Flügel, E., Kochansky-Devide, V., and Ramov, S.A., 1984, A Middle Permian calcisponge/algal/cement reef: Straza near Bled, Slovenia, Facies, 10:179–256.

Flügel, E., and Reinhardt, J., 1989, Uppermost Permian Reefs in Skyros (Greece) and Sichuan (China): Implications for the Late Permian extinction event, Palaios, v. 4, p. 502–518.

Flügel, E., Di Stefano, P., and Senowbari-Daryan, B., 1991, Microfacies and depositional structure of allocthonous carbonate base-of-slope deposits: The Late Permian Pietra de Salomone Megablock, Sosio Valley (W Sicily), Facies, v. 25, p. 147–186.

Flügel, H.W., 1980, *Permosoma* Jaekel, 1918, ein Problematikum aus dem Perm Siziliens, Palaeontographica, Abteilung A, v. 167, nos. 1–3, p. 1–9.

Girty, G.H., 1908a, The Guadalupian Fauna, U.S. Geological Survey Professional Paper 58, 651 p.

Girty, G.H., 1908b, On some new and old species of Carboniferous fossils, Proceedings of the U.S. National Museum, v. 34, p. 281–303.

Graffe, W.J.E., Van De, 1969, Carboniferous Sphinctozoa from the Cantabrian Mountains, Spain, Leidsche Geologische Mededelingen, v. 42, p. 239–257.

Gray, J.E., 1855, Catalogue of the Recent Echinida, or sea eggs, in the collections of the British Museum, Part I, Echinida irregulara. British Museum of National History, London, 69 p.

Gregorio, A. De, 1930, Sul Permiano di Sicilia (Fossili del calcare con Fusulina de Palazzo Adriano), Annales de Geologie et Paleontologie, v. 50, p. 1–70.

Haas, O., 1909 (1908), Bericht über neue Aufsammlungen in den Zlambach-Mergeen der Fischerwiese bei Alt-Aussee, Beiträge Paläontologie Österreich Ungarn, v. 22, p. 143–167.

Hartman, W.D., and Goreau, T.F., 1970, Jamaican coralline sponges: their morphology, ecology, and fossil relatives, p. 23–40, *in* Fry, W.G., ed., The Biology of the Porifera, Symposium of the Zoological Society of London 25.

Hayasaka, I., 1918, *Amblysiphonella* from Japan und China, Scientific Reports of the University of Sendei, v. 5, p. 1–10.

Hayes, P.T., 1957, Geology of Carlsbad Caverns East Quadrangle, New Mexico, U.S. Geological Survey Quadrangle Map GQ 98.

Hayes, P.T., 1964, Geology of the Guadalupe Mountains, New Mexico, U.S. Geological Survey Professional Paper 446, 69 p.

Hayes, P.T., and Koogle, R.L., 1958, Geology of Carlsbad Caverns West quadrangle, New Mexico-Texas, U.S. Geological Survey Quadrangle Map GQ 112.

Hinde, J.T., 1893, A monograph of the British fossil sponges, Part III, Sponges of Jurassic strata, Palaeontographical Society, v. 47, p. 189–254.

Inai, Y., 1936, *Discosiphonella*, a new ally of Amblysiphonella. Proceedings of the Imperial Academy of Japan, v. 12, p. 169–171.

Jaekel, D., 1918, Phylogenie und System der Pelmatozoen, Paläontologische Zeitschrift, v. 3, p. 1–128.

King, P.B., 1934, Permian stratigraphy of Trans-Pecos Texas, Geological Society of America Bulletin, v. 45, p. 697–798.

King, P.B., 1942, Permian of West Texas and southeastern New Mexico, American Association of Petroleum Geologists Bulletin, v. 26, p. 535–763.

King, P.B., 1948, Geology of the southern Guadalupe Mountains, Texas, U.S. Geological Survey Professional Paper 215, 183 p.

King, R.H., 1933, A Pennsylvanian sponge fauna from Wise County, Texas, The University of Texas Bulletin 3201, p. 75–85

King, R.H., 1938, Pennsylvanian sponges of north-central Texas, Journal of Paleontology, v. 12, p. 498–504.

King, R.H., 1943, New Carboniferous and Permian sponges, State Geological Survey of Kansas Bulletin 47, p. 1–36.

Kovacs, S., 1978, New sphinctozoan sponges from the North Hungarian. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, 1978, no. 11, p. 685–697.

Kügel, H.W., 1987, Sphinctozoen aus den Auernig-Schichten des Nassfeldes (Oberkarbon, Karnische Alpen, Österreich), Facies, v. 16, p. 143–156.

Lamouroux, J., 1821, Exposition méthodique des genres de l'ordre de Polypers, Agasse, Paris, 115 p.

Laube, G.C., 1865, Die Fauna der Schichten von St. Cassian, I, Abteilung, Spongitarien, Corallien, Echiniden und Crinoiden, Denkschriften der Koeniglichen Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse, v. 24, p. 223–296.

Laubenfels, M.W., DE., 1955, Porifera, p. E21–E112, *in* Moore, R.C., ed., Treatise on Invertebrate Paleontology, Part E, Geological Society of America and University of Kansas Press, Lawrence.

Lévi, C.L., 1973, Systematique de la classe des Démospongiaria (Demosponges), p. 572–631, *in* Grassee, P.P., ed.; Traité de Zoologie, v. 3, part 1, Masson et cie, Paris.

Mansuy, H., 1914, Faune des calcaires a Productus de l'Indochina, 2., Memoir Service Geologique du Indochina, v. 3, p. 1–59.

Mazzulo, S.J., and Cys, J.M., 1978, *Archaeolithoporella*-boundstones and marine aragonite cements, Permian Capitan reef, New Mexico and Texas, USA, Neues Jahrbuch für Geologie, v. 63, p. 301–309.

Newell, N.D., and Rigby, J.K., 1957, Geological studies on the Great Bahama Bank, Society of Economic Paleontologists and Mineralogists Special Publication 5, p. 15–72.

Newell, N.D., Rigby, J.K., Fischer, A.G., Whiteman, A.J., Hickox, J.E., and Bradley, J.S., 1953, The Permian reef complex of the Guadalupe Mountains Region, Texas and New Mexico—A Study in Paleoecology, W.H. Freeman and Company, San Francisco, 236 p.

Newell, N.D., Rigby, J.K., Driggs, A.F., Boyd, D.W., and Stehli, F.G., 1976, Permian reef complex, Tunisia, Brigham Young University Geology Studies, v. 23, no. 1, p. 72–112.

Nutzubidze, K.SH., 1964, Liassic sponges on Dzirul Massiv. Akademy of Sciences, Georgian Soviet Socialist Republic, Trudy Geologischeskaya Institut, Seriya Geologicheskaya, v. 14, no. 19, p. 5–35.

Orbigny, M.A., DE., 1849, Note sur la classe des Amorphozoaires, Revue et Magazine de Zoologie, series 2, v. 1, p. 545–551.

Ott, E., 1967, Segmentierte Kalkschwämme (Sphinctozoa) aus der alpinen Mitteltrias und ihre Bedeutung als Riffbildner im Wettersteinkalk, Bayerische Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse, Abhandlungen, Neue Folge, v. 131, p. 1–96.

Parona, C.F., 1933, Le spugne della fauna permiana di Palazzo Adriano (Bacino del Sosio) in Sicilia, Memoire della Societa Geologica Italiana, v. 1, p. 1–58.

Pomel, A., 1872, Paléontologie ou description des animaux fossiles de la province d'Oran, 5, Spongiares, Oran, 256 p.

Rauff, H., 1938, Über einige Kalkschwämme aus der Trias der peruanischen Kordillere, nebst einem Anhang über *Stellispongia* und ihre Arten, Paläontologische Zeitschrift, v. 20, p. 177–214.

Reinhardt, J.W., 1988, Uppermost Permian reefs and Permo-Triassic sedimentary facies from the southeastern margin of Sichuan Basin, China, Facies, v. 18, p. 231–288.

Rigby, J.K., 1984, Permian sponges from western Venezuela. Journal of Paleontology, v. 58, p. 1436–1462.

Rigby, J.K., 1987, Phylum Porifera, p. 116–139, *in* Boardman, R.S., Cheetham, A.H., and Rowell, A.J., eds., Fossil Invertebrates, Blackwell Scientific Publications, Palo Alto, CA.

Rigby, J.K., and Blodgett, R.B., 1983, Early Middle Devonian sponges from the McGrath Quadrangle of west-central Alaska, Journal of Paleontology, v. 57, p. 773–778.

Rigby, J.K., Fagerstrom, J.A., Senowbari-Daryan, B., Weidlich, O., and H. Liu, 1995, Upper Permian Capitan Limestone of the Guadalupe Mountains of New Mexico, its origin and community structures, Seventh International Symposium on Fossil Cnidaria and Porifera, Madrid, Spain, Abstracts, p. 74–75.

Rigby, J.K., Fan, Jiasong, and Han, Nairen, 1995, Upper Permian silicified sponges from central Guangxi and western Hubei, South China, Journal of Paleontology, v. 69, p. 232–250.

Rigby, J.K., Fan, Jiasong, and Zhang, Wei, 1988, The sphinctozoan sponge *Intrasporeocoelia* from the Middle and Late Permian of China; reexamination of its filling structures, Journal of Paleontology, v. 62, p. 747–753.

Rigby, J.K., Fan, Jiasong, and Zhang, Wei, 1989a, Sphinctozoan sponges from the Permian reefs of South China, Journal of Paleontology, v. 63, p. 404–439.

Rigby, J.K., Fan, Jiasong, and Zhang, Wei, 1989b, Inozoan calcareous Porifera from the Permian reefs in Southern China, Journal of Paleontology, v. 63, p. 778–800.

Rigby, J.K., Fan, Jiasong, Wang, Shenghai, and Zhang, Xiaolin, 1994, Sphinctozoan and inozoan sponges from Permian reefs of South China, Brigham Young University Geology Studies, v. 40, p. 43–109.

Rigby, J.K., and Millward, A.B., 1988, A look back at the Permian reefs of West Texas and New Mexico, Earth Science History, v. 7, p. 71–89.

Rigby, J.K., and Potter, A.W., 1986, Ordovician sphinctozoan sponges from the eastern Klamath Mountains, northern California, Paleontological Society Memoir 20, 47 p.

Rigby, J.K., and Senowbari-Daryan, B., 1995, Chapter 4, Phylum Porifera, p. 153–166 *in* Scholle, P.A., Peryt, T.M., and Ulmer-Scholle, D.S., eds., The Permian of Northern Pangea, Volume 1, Paleogeography, Paleoclimates, Stratigraphy, Springer-Verlag, Berlin.

Rigby, J.K., and Senowbari-Daryan, B., 1996a, Upper Permian inozoid, demosponge and hexactinellid sponges from Djebel Tebaga, Tunisia, University of Kansas Paleontological Contributions, new series, Number 7, 130 p.

Rigby, J.K., and Senowbari-Daryan, B., 1996b, *Gigantospongia*, new genus, the largest known Permian sponge, Capitan Limestone, Guadalupe Mountains, New Mexico. Journal of Paleontology, v. 70, p. 347–355.

Russo, F., 1981, Nuove spugne calcarea triassiche die Campo (Cortina d'Ampezzo, Belluno), Bolletino della Societa Paleontologica Italiana, v. 20, p. 3–17.

Seilacher, A., 1962, Die Sphinctozoa, eine Gruppe fossiler Kalkschwämme, Abhandlungen der Akademie der Wissenschaften und der Literatur in Mainz, Mathematisch-naturwisschaftlische Klasse, 1961, v. 10, p. 720–790.

Senowbari-Daryan, B., 1990, Die systematische Stellung der thalamiden Schwämme und ihre Bedeutung in der Erdgeschichte, Münchener geowissenschaftliche Abhandlungen, Reihe A, Geologie und Paläontologie, v. 21, p. 1–326.

Senowbari-Daryan, B., 1991, Nomenclatorische Notiz unter Berüksichtigung des Homonymiegesetzes, Paläontologische Zeitschrift, v. 65, p. 405.

Senowbari-Daryan, B., 1994, Mesozoic sponges of the Pucará Group, Peru, Palaeontographica, A, v. 233, p. 57–74.

Senowbari-Daryan, B., and Flügel, E., 1993, *Tubiphytes* Maslov, an enigmatic fossil: Classification, fossil record and significance through time, Part I: Discussion of Late Paleozoic material. Bolletino della Societa Paleontologica Italiana, Special Volume 1, p. 353–382.

Senowbari-Daryan, B., and Ingavat-Helmcke, R., 1993, Upper Permian sponges from Phrae province (northern Thailand), International Symposium on Biostratigraphy of Mainland Southeast Asia: Facies and Paleontology, Bangkok, p. 439–451.

Senowbari-Daryan, B., and Ingavat-Helmcke, R., 1994, Sponge assemblage of some Upper Permian reef limestones from Phrae province (Northern Thailand). Geologija, v. 36, p. 5–59.

Senowbari-Daryan, B., and Rigby, J.K., 1988, Upper Permian segmented sponges from Djebel Tebaga, Tunisia, Facies, v. 19, p. 171–250.

Senowbari-Daryan, B., and Rigby, J.K., 1991, Three additional thalamid sponges from the Upper Permian reefs of Djebel Tebaga (Tunisia), Journal of Paleontology, v. 65, p. 623–629.

Senowbari-Daryan, B., and Rigby, J.K., 1996a, Brachiopod mounds not sponges reefs, Permian Capitan-Tansill Formations, Guadalupe Mountains, New Mexico, Journal of Paleontology, 70:697–701.

Senowbari-Daryan, B., and Ribgy, J.K., 1996b, First report of *Lercaritubus* in North America, from the Permian Capitan Limestone, Guadalupe Mountains, New Mexico, Journal of Paleontology, v. 70, p. 22–26.

Senowbari-Daryan, B., Ribgy, J.K., Fagerstrom, J.A., Weidlich, O., and Liu, H., 1995, Taxonomy, diversity and the role of sponges in the Capitan Reefs of Texas and New Mexico, USA, Seventh International Symposium Fossil Cnidaria and Porifera, Madrid, Spain, Abstracts, p. 83.

Senowbari-Daryan, B., and Stanley, G.D., 1992, Late Triassic thalamid sponges from Nevada. Journal of Paleontology, v. 66, p. 183–193.

Senowbari-Daryan, B., and Di Stefano, P., 1988a. Microfacies and sphinctozoan assemblage of some Lower Permian breccia from Lercara

Formation (western Sicily), Revista Italiano Paleontologia e Stratigrafia, v. 94, p. 3–34.

Senowbari-Daryan, B., and De Stefano, P., 1988b, *Amblysiphonella maxima* n. sp., a new sphinctozoan sponge from Upper Triassic reefs in Sicily. Bollettino della Società Paleontologica Italiana, v. 27, p. 17–21.

Simpson, C.T., 1900, Synopsis of the najades or pearly freshwater mussels, U.S. National Museum Proceedings, v. 22, p. 501–1044.

Skinner, J.W., and Wilde, G.L., 1954, The fusulinid subfamily Boltoniinae, Journal of Paleontology, v. 28, p. 434–444.

Skinner, J.W., and Wilde, G.L., 1955, New fusulinids from the Permian of West Texas, Journal of Paleontology, v. 29, p. 927–940.

Sollas, W.J., 1875, Sponges, p. 451, *in* Baynes, T.S., ed., A Dictionary of Arts Sciences and General Literature, Encyclopaedia Brittanica, 9th edition, Edinburgh.

Sollas, W.J., 1888, Report on the Tetractinellida collected by H.M.S. Challenger during the years 1873–1876, p. 1–458, *in* Report on the Scientific Results of the Voyage of H.M.S. Challenger during 1873–1876, London, Zoology, v. 25.

Steinmann, G. 1882, Pharetronen-Studien, Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, v. 2, p. 139–191.

Termier, H., and Termier, G., 1955, Contributions a l'étude des Spongiaires permiens du Djebel Tebaga (Extreme Sud Tunisien), Bulletin Société Géologique de France, Series 6, v. 5, p. 613–630.

Termier, H., and Termier, G., 1977a, Paléontologie des Invertébrés, p. 255–299, *in* Termier, H., Termier, G., and Vachard, D., Monographie Paléontologique des affleurements Permiens du Djebel Tebaga (Sud Tunisien), Palaeontographica, Abteilung A, v. 156, nos. 1–3, p. 1–109.

Termier, H., and Termier, G., 1977b, Structure et evolution des spongiaires hypercalcifies du Paleozoique superieur, Memoire Institute Geologique Université Catholique de Louvain, v. 29, p. 57–109.

Toomey, D.F., 1979, Role of archaeolithophyllid algae within a Late Carboniferous algal-sponge community, southwestern United States, Bulletin, Centres de Recherches Exploration-Production Elf-Aquitaine, v. 3, no. 2, p. 843–853.

Toomey, D.F., and Babcock, J.A., 1983, Precambrian and Paleozoic algal carbonates, West Texas and New Mexico, Colorado School of Mines Professional Contribution 11, 345 p.

Tyrell, W.W., Jr., 1969, Criteria useful in interpreting environments of unlike but time-equivalent carbonate units (Tansill-Capitan-Lamar), Capitan reef complex, West Texas and New Mexico, p. 80–97, *in* Friedman, G.M., ed., Depositional Environments in Carbonate Rocks, Society of Economic Paleontologists and Mineralogists Special Publication 14.

Vinassa, De Regny, P., 1901, Trias-Spongien aus dem Bakony, Resultate wissenschaftlichen Erforschung des Balatonsees, 1, Paläontologische Anhang, Budapest, 22 p.

Waagen, W., and Wentzel, J., 1887, Salt Range Fossils. 1, Productus Limestone fossils, 7, Coelenterata-Amorphozoa-Protozoa, Geological Survey of India, Memoir, Palaeontologica Indica, p. 925–988.

Weidlich, O., Fagerstrom, J.A., Rigby, J.K., and Senowbari-Daryan, B., 1995, Capitan Reef litho- and biofacies: implications for community structure, Seventh International Symposium on Fossil Cnidaria and Porifera, Madrid, Spain, Abstracts, p. 100–101.

Weidlich, O., and Senowbari-Daryan, B., 1996, Late Permian "sphinctozoans" from reefal blocks of the Ba'id area, Oman Mountains, Journal of Paleontology, v. 70, p. 27–46.

Wood, R., 1995, The changing biology of reef building, Palaios, v. 10, p. 517–529.

Wood, R., Dickson, J.D., and Kirkland-George, B., 1994, Turning the Capitan reef upside down; A new appraisal of the ecology of the Permian Capitan reef, Guadalupe Mountains, Texas and New Mexico, Palaios, v. 9, p. 422–427.

Wood, R., Dickson, J.D., and Kirkland-George, B., 1996, New observations on the ecology of the Permian Capitan Reef, Texas and New Mexico, Palaeontology, v. 39, p. 733–762.

Woodruff, E.G., 1906, The geology of Cass County, Nebraska, Nebraska Geological Survey Bulletin 2, p. 171–302.

Wu Ya Sheng, 1991, Organisms and communities of Permian reef of Xiangbo, China. International Academic Publishers, Beijing, 192 p.

Yurewicz, D.A., 1976, Sedimentology, paleoecology and diagenesis of the massive facies of the Lower and Middle Capitan Limestone (Permian), Guadalupe Mountains, New Mexico and West Texas, Unpublished Ph.D. dissertation, University of Wisconsin, Madison, 248 p.

Yurewicz, D.A., 1977, The origin of the massive facies of the lower and middle Capitan Limestone (Permian), Guadalupe Mountains, New Mexico and West Texas, p. 45–92, *in* Hileman, M.E., and Mazzullo, S.J., eds., Upper Guadalupian facies, Permian reef complex, Guadalupe Mountains, New Mexico and West Texas. Society of Economic Paleontologists and Mineralogists, Permian Basin Section, 1977 Field Conference Guidebook Publication 77-16.

Zhang Wei, 1983, Study on the sphinctozoans of Upper Permian Changing Formation from Lichuan area, West Hubei, China, p. 1–11, *in* A collection of theses for master's degree 1983, Institute of Geology, Academia Sinica, Beijing.

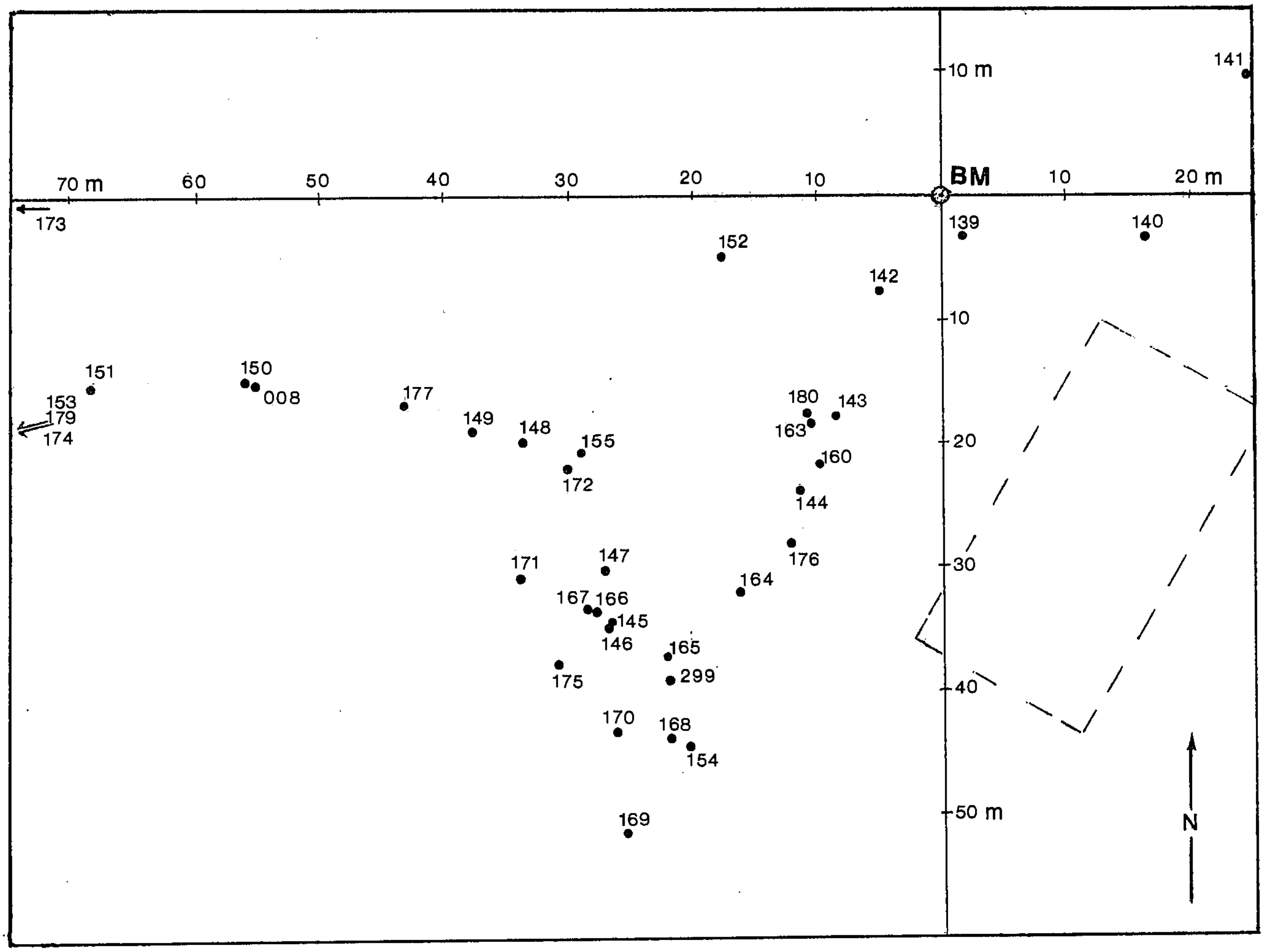
Zhang Wei, 1987, A new genus *Neoguadalupia*, with notes on connections of interrelated genera in Sebargasiidae, Sphinctozoa, Scientia Geologica Sinica, v. 7, p. 231–239.

Zhuravleva, I.T., 1962, Incertae Sedis, Class Sphinctozoa, p. 98–103, *in* Sokolov, B.S., ed., Fundamentals of Paleontology, Vol. II: Porifera, Archaeocyatha, Coelenterata, Vermes. (Israel Program for Scientific Translation, Jerusalem, 1971).

Zhuravleva, I.T., 1991, Lower Permian of the North Pamir (Darwaz and Piotr I Mountains, p. 58–67, *in* Boiko, E.V., Belyaeva, G.V., and Zhuravleva, I.F., Phanerozoic sphinctozoans from the Territory of UdSSR, Akademy Sciences of UdSSR, Sibirian Department, Institute of Geology and Geophysics, Akademy of Sciences Tajikistan, UdSSR, Institute of Geology Tajikistan, Moscow, 223 p. (in Russian).

APPENDIX 1

Locality map showing distribution of samples in Set B collected from outside the grid area, shown in dashed line, in the Dark Canyon locality. The origin of measurements, in the upper right, is the elevated bench mark and cairn west of Hidalgo Road and on the north side of the mouth of the Dark Canyon (see Figure 3.2).



APPENDIX 2

Locality maps of samples of Set A collected from sample grids from Dark Canyon and Chinaberry Draw. A, Samples collected from the grid in the Dark Canyon locality on the north edge of the mouth of the Dark Canyon (see Figures 3.2 and 8 for location and comparison). UNSM samples 34602–34640 are from the locality. B, Samples collected from the grid of the Chinaberry Draw Locality (see Figures 3.3 and 7 for location and comparison). UNSM samples 34641–34680 are from the locality.

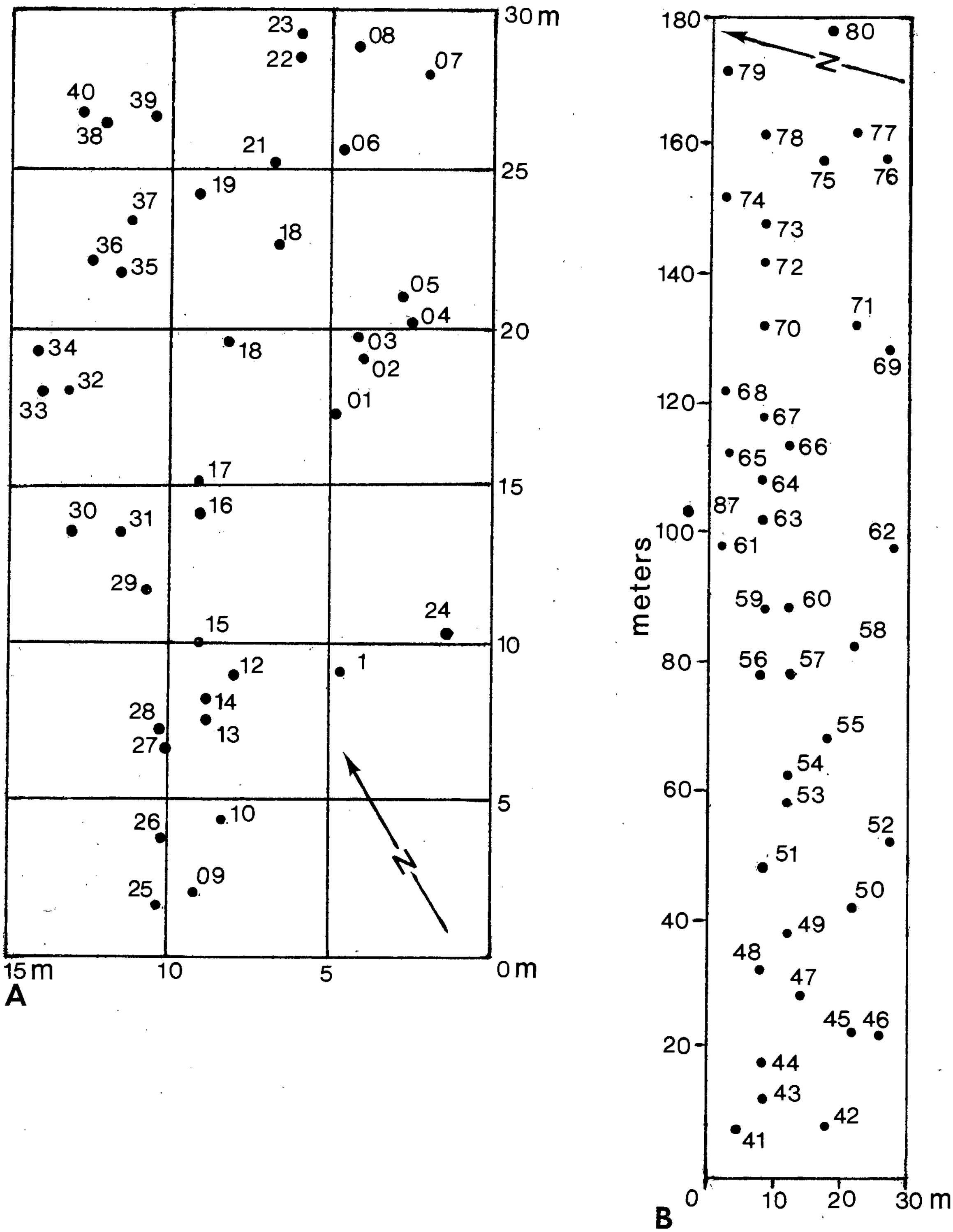


PLATE 1

Species of *Amblysiphonella, Cystothalamia,* and *Discosiphonella* from the Upper Capitan Limestone in the Guadalupe Mountains of New Mexico and Texas

Figures *1, 4, 5, Amblysiphonella* sp. A, UNSM 34602, Dark Canyon; *1,* transverse sections of the relatively small species show the complete ring-like chambers around the broad central spongocoel characteristic of the form, in matrix with the abundant foraminiferal(?) tubes and a transverse section of a chamber of *Sollasia* (S) in the lower left, x1; *4, 5,* polished surfaces all glued to glass slides, x2.

Figures *2, 3, 7, Amblysiphonella* sp. B, UNSM 35231, Rattlesnake Canyon, all are x1; *2,* diagonal section showing the stacked ring-like chambers around the moderately open spongocoel filled with fine dark matrix; pores in chamber walls show best in the lower right and in the upper part of the recrystallized sponge. *3,* Transverse section in the lower part and a diagonal section in the upper part show the porous wall with ring-like chambers and the porous interwall in the lower subtransverse section. Stems of *Lemonea micra* (L) are cut in transverse section above the letter and in diagonal sublongitudinal section in the lower right, associated with a transverse section of a cylindrical stem of a cryptostome bryozoan (B). Both are in growth position buried in fine matrix. *7,* Tangential section shows general section of ring-like chambers and the perforate walls characteristic of the species. An associated small *Lemonea micra* (L) is cut in transverse section in the lower left.

Figure *6, Cystothalamia guadalupensis* (Girty, 1908a), holotype, USNM 118150, U.S. Geological Survey Locality 2966, from the Southern Guadalupe Mountains. Specimen shows the cystose outer appearance of the moderately annulate sponge, with each cyst produced by a chamberlet in the monoglomerate species, x2.

Figure *8, Amblysiphonella* cf. *A. merlai* Parona, 1933, recrystallized and weathered specimen cut in diagonal section showing the general dimensions of the relatively small spongocoel in the center, and the arcuate ring-shaped chambers, best shown where filled with dark fine matrix, UNSM 34678, Chinaberry Draw locality, x2.

Figure *9, 10, Discosiphonella mammilosa* (King, 1943), *9,* tangential section through vertical stem showing numerous chamberlets, some filled with dark matrix and others with crystalline calcite cement, some with vesiculae, particularly near the center; section shows the irregular nodose profile of the exterior of the sponge. The central spongocoel was not intersected in the section. A sub-transverse section of *Minispongia constricta* (Girty, 1908a) is cut in the center of the left margin. All sponges are coated with thick crusts of *Archaeolithoporella,* which appears irregularly laminar and dark in the figure, UNSM 35064, from the Chinaberry Draw locality, x1. *10,* Diagonal subtransverse section of a stemlike specimen of the species showing the relatively small, open, central spongocoel characteristic of the species and the cyst-like chambers forming the outer part of the skeleton; walls are perforate in several chambers, others with irregular diaphragm-like vesiculae, UNSM 34701, from the Hackberry Draw locality, x2.

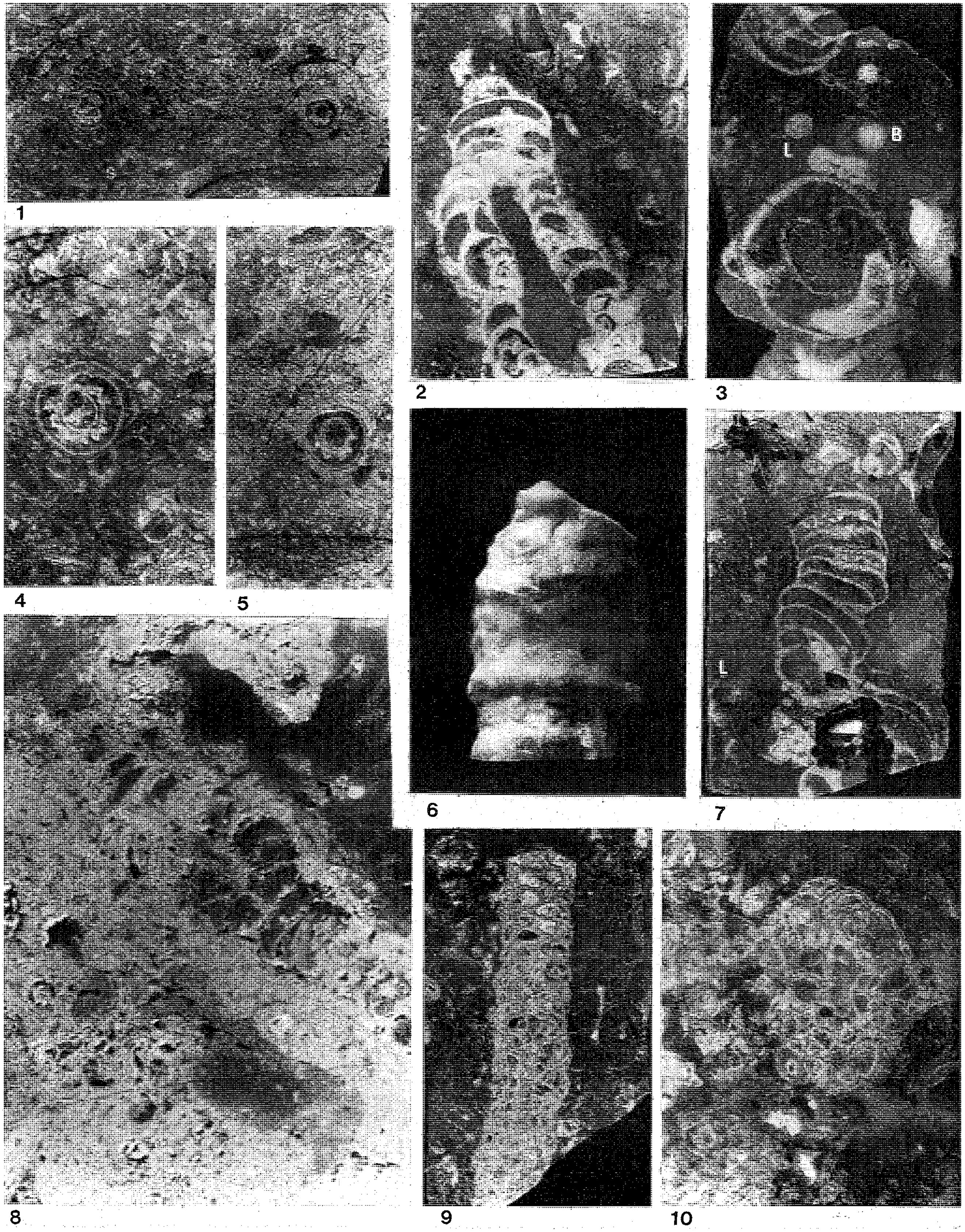

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PLATE 2

Species of *Platythalamiella*(?), *Discosiphonella* and *Exaulipora* from the Upper Capitan Limestone in the northern Guadalupe Mountains of New Mexico.

Figure *1*, *Platythalamiella*(?) sp. (n. sp.?), incompletely preserved specimen of the tubular or platelike sponge cut essentially transverse to the tube-like chambers; many of the chambers with numerous vesiculae; specimens of small *Minispongia constricta* (Girty, 1908a) (M) and bryozoans (B) are cut in subtransverse sections, UNSM 35225, from the Hackberry Draw locality, x2.

Figures *2*, *3*, *Discosiphonella mammilosa* (King, 1943), *2*, diagonal sections of branching cluster of the species, generally cut in tangential sections, showing the cyst-like, upwardly arcuate, porous-walled chambers, UNSM 34701, from the Hackberry Draw locality, x2. *3*, Simple stem with porous-walled chambers arranged in a single layer around a central narrow spongocoel; vesiculae rare in the steeply diagonal section. A small specimen of *Virgola neptunia* (Girty, 1908a) shows as the light-colored, only moderately well preserved specimen in the upper left, UNSM 34718, from the Hackberry Draw locality, x2.

Figures *4–7*, *Exaulipora permica* (Senowbari-Daryan, 1990), all from weakly etched cut surfaces of UNSM 35114, from the Dark Canyon locality, all x1; *4*, sections of four chambers, two of which have long porous exaules distinctive of the species; *5*, transverse section of several chambers of a glomerate individual showing branching growth, generally toward the right, and with porous tubular exaules from two chambers, in the upper right, walled off at their bases like exaules in Figure 4; chambers lack vesiculae; several specimens of the small *Minispongia constricta* (Girty, 1908a) are associated, particularly in the upper left and lower right; *6*, tangential to transverse sections through individual chambers, two of which have prominent tubular porous exaules in the lower left, both of which appear walled off from the principal chambers of the sponge; several transverse sections of exaules occur aligned in the right; *7*, two rows of globular chambers, one of which has a prominant tubular exaulos in the left center; Figures 6 and 7 are mirror images on opposite sides of a saw cut separating the block.

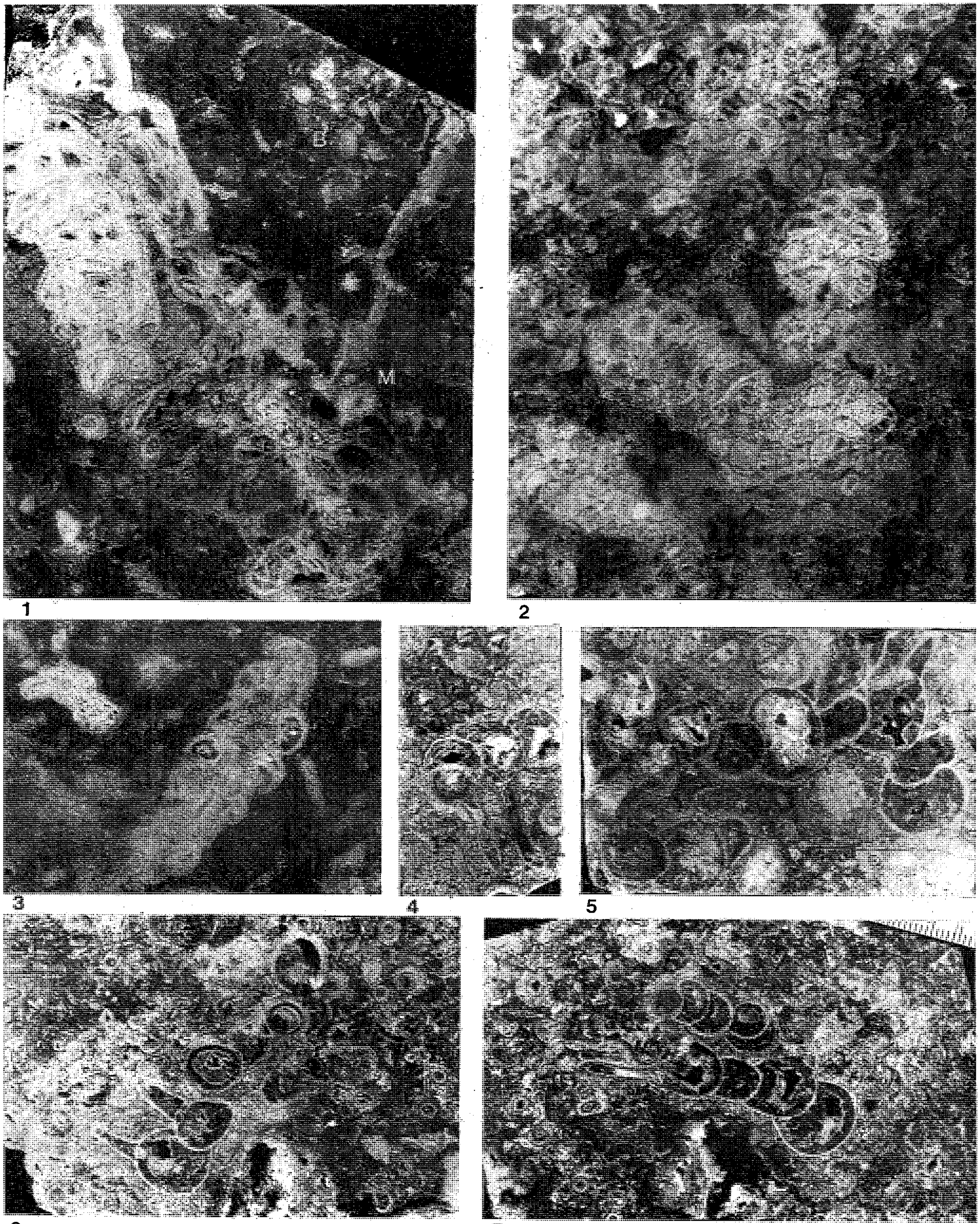
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PLATE 3

Species of *Guadalupia, Lemonea,* and *Discosiphonella* from the Upper Capitan Limestone of the northern Guadalupe Mountains, New Mexico.

All surfaces were photographed coated with a film of water or dilute glycerine. Figure *1, Guadalupia zitteliana* Girty, 1908a and *Lemonea cylindrica* (Girty, 1908a), with smaller sponges and bryozoans; honeycomb-like chamberlets of *Guadalupia zitteliana* (G) are cut essentially in longitudinal section in the upper right and in transverse section in the lower left of the large specimen. The irregular gastral layer appears almost spinose in the central part of the obconical specimen. *Virgola neptunia* (Girty, 1908a) (V) is the fine-textured inozoid sponge attached to the *Guadalupia* on the upper left. *Lemonea cylindrica* (Girty, 1908a) (C) is cut in diagonal section in the upper part of the figure, and shows the chamberlets in the lower part and cross sections of the chamberlets in the upper left. Three specimens of *Minispongia constricta* (Girty, 1908a) occur in the lowest right corner of the figure, and bryozoans in the upper right and lower left, UNSM 35009, from the Chinaberry Draw locality, x2.

Figures *2–4, Discosiphonella mammilosa* (King, 1943); *2,* branching cluster shown in longitudinal and diagonal views with a single row of upperward arcuate, porous-walled, chambers on either side of the open central spongocoel. Some walls appear almost spinose, and section emphasizes the pores, as in some parts of sponges in the lower left and in the upper left center; etched specimen, uncertain locality, UNSM 35281, x1. *3,* Long straight stem with characteristic upward-arched chamberlets that lack vesiculae in the upper part, but with many subvertical vesiculae in the lower half. Branched *Lemonea micra* new species (M) occurs in the upper right, and sections of *Lemonea conica* (Girty, 1908a) (C) occur in the lower left and lower center. A moderately well-preserved *Girtyocoelia beedei* (Girty, 1908b) (G) occurs between the tip of the scale and the lower part of the stem of the *Discosiphonella.* Circular sections of bryozoans also occur in the *Archaeolithoporella* crusts, UNSM 35011, from the Chinaberry Draw locality, x1. *4, Discosiphonella mammilosa* (King, 1943) and *Lemonea polysiphonta* Senowbari-Daryan, 1990, shown in different sections. Two upright stems of *Discosiphonella* to the lower left and upper right of the D, occur with more common *Lemonea polysiphonata* (P) shown in different sections, but generally cut subtransversely. In the large sponge in left center, the cluster of upright tubules typical of the species has been removed by weathering, to produce a void and light crystalline calcite infill. A more typical transverse section is shown by the large specimen in the lower right, where sections of the vertical axial tubules and the surrounding honeycomb-like chambers are well shown. Smaller specimens occur in the lower center, at the left center, and at the upper right, UNSM 35028, from the Chinaberry Draw locality, x1.

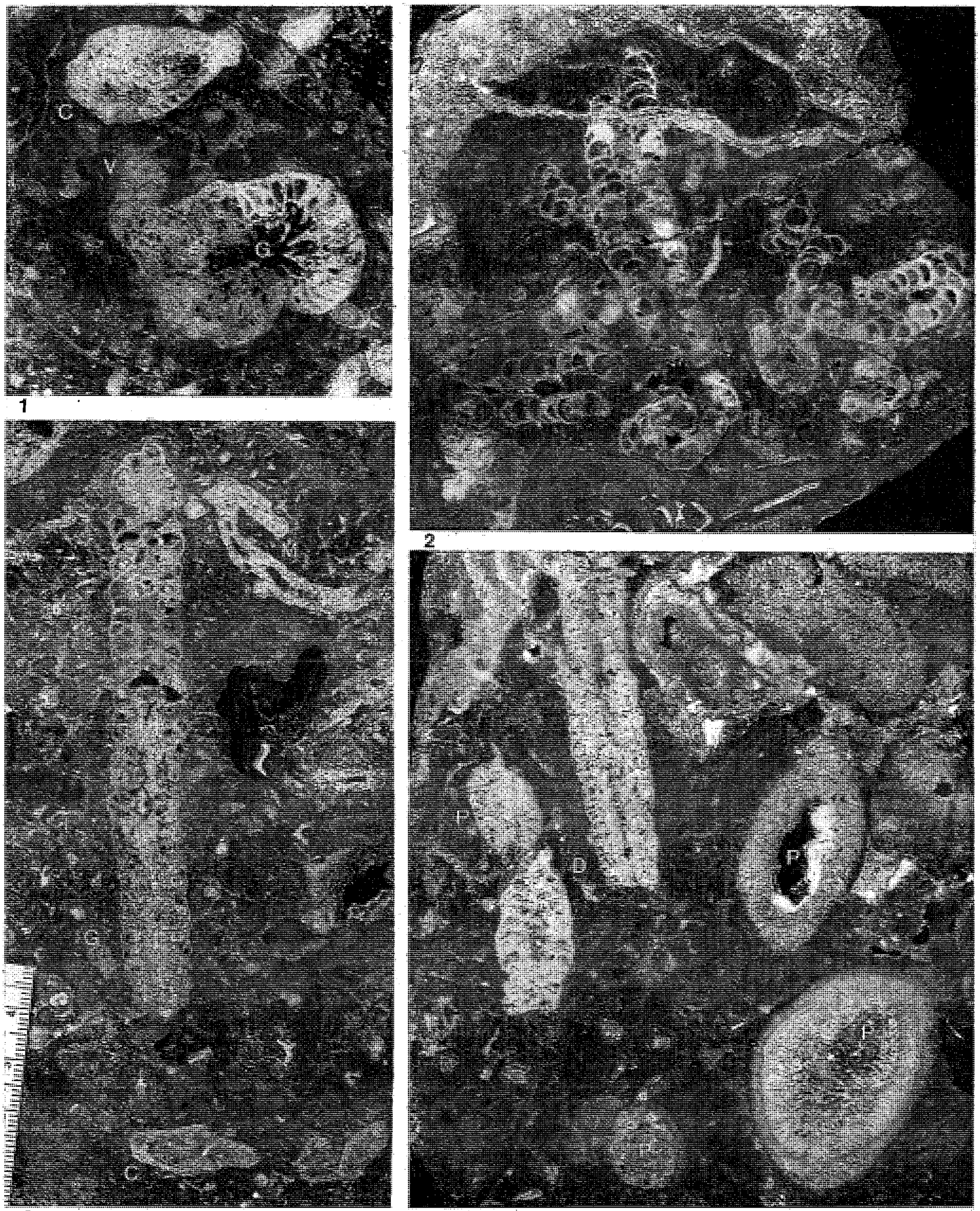
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PLATE 4

Sections of *Tristratocoelia, Girtyocoelia, Sollasia,* and *Parauvanella* with other associated sponges from the Upper Capitan Limestone of the northern Guadalupe Mountains, New Mexico

Figures *1–4, Tristratocoelia rhythmica* Senowbari-Daryan and Rigby, 1988; *1,* longitudinal section showing distinctive chambers with thickened interwalls characteristic of the species, abundant foraminiferal(?) tubes make up much of the surrounding matrix, UNSM 34627, from the Dark Canyon locality, x2. *2,* Characteristic longitudinal section with high, barrel-shaped chambers and thick interwalls, forming almost secondary chambers between, to produce an alternating beaded structure typical of the sponge, porous interwalls show in the chambers of the upper center. Transverse sections of *Minispongia constricta* (Girty, 1908a) (M) occur in the *Archaeolithoporella*-foraminiferal(?) tube-dominated rocks, UNSM 34623, from Dark Canyon, x1. *3,* Sublongitudinal section shows characteristic form of the species; a transverse section of *Sollasia ostiolata* Steinmann, 1882, (S) occurs in the lower center, UNSM 35063, from the Chinaberry Draw locality, x1. *4,* Sublongitudinal section showing characteristic barrel-shapped chambers and thickened interwalls, UNSM 35004, from the Chinaberry Draw locality, x1.

Figure *5, Parauvanella minima* Senowbari-Daryan 1990, encrusting a stem of *Preverticillites parva* new species; *Parauvanella* is the glomerate clusters of small chamberlets (arrow) attached to the larger sponge, UNSM 34701, from the Hackberry Draw locality, x2.

Figures *6–10, Girtyocoelia beedei* (Girty, 1908b), *6,* vertical sections of beaded segments which superficially appears like *Sollasia,* except for the central tube or spongocoel fragment at the base of the lowest chamber; specimen is embedded in irregularly laminate crusts of *Archaeolithoporella,* UNSM 34717, from the Hackberry Draw locality, x2; *7,* two distinct chambers connected and pierced by the long central tube or spongocoel, UNSM 34627, from the Dark Canyon locality, x2; *8,* two subparallel examples showing chambers pierced by and connected by the tubular spongocoel or central tube, in a matrix that contains abundant foraminiferal(?) tubes, UNSM 35120, from the Dark Canyon locality, x1; *9,* minichambered segment showing adnate chambers pierced by the central spongocoel tube, in the upper part, but the section cuts subtangentially through chambers in the lower part; cement fill and diagensis have created the false impression of a two-layered chamber wall, UNSM 35120, from the Dark Canyon locality, x1; *10,* separated beadlike chambers connected by the tubular, walled, spongocoel emphasises growth form of the species, UNSM 35267, from the Chinaberry Draw locality, x1.

Figures *11–14, Sollasia ostiolata* Steinmann, 1882, *11,* small specimen of adnate chambers lacking a central tube but with a pseudospongocoel produced by cryptosiphonate openings in chamber interwalls; sponge associated with foraminiferal(?) tubes and *Minispongia constricta* (Girty, 1908a) in the upper left and lowest right, UNSM 35291, etched specimen, uncertain locality, x1; *12,* aligned beaded chambers, some of which have tubular exaulos-like openings in chamber walls, particularly in the upper three chambers; associated *Virgola neptunia* (Girty, 1908a) (V) shows the same vertical growth orientation, both encrusted by *Archaeolithoporella,* UNSM 35292, etched specimen, uncertain locality, x1; *13,* long stem of adnate spherical chambers characteristic of the species, associated with brachiopods and other fine bioclastic debris, UNSM 35197-1, from the Hackberry Draw locality x1; *14,* beaded *Sollasia ostiolata* in the lower left, associated with a larger *Virgola neptunia* (Girty, 1908a) (V), the larger reticulate sponge skeleton in the central part of the figure; and a less well-preserved specimen in the lower left center, which is also probably a *Virgola.* All sponges occur in thick crusts of *Archaeolithoporella*; porous area on the right is a secondary weathering feature, UNSM 35293, etched specimen, uncertain locality, x1.

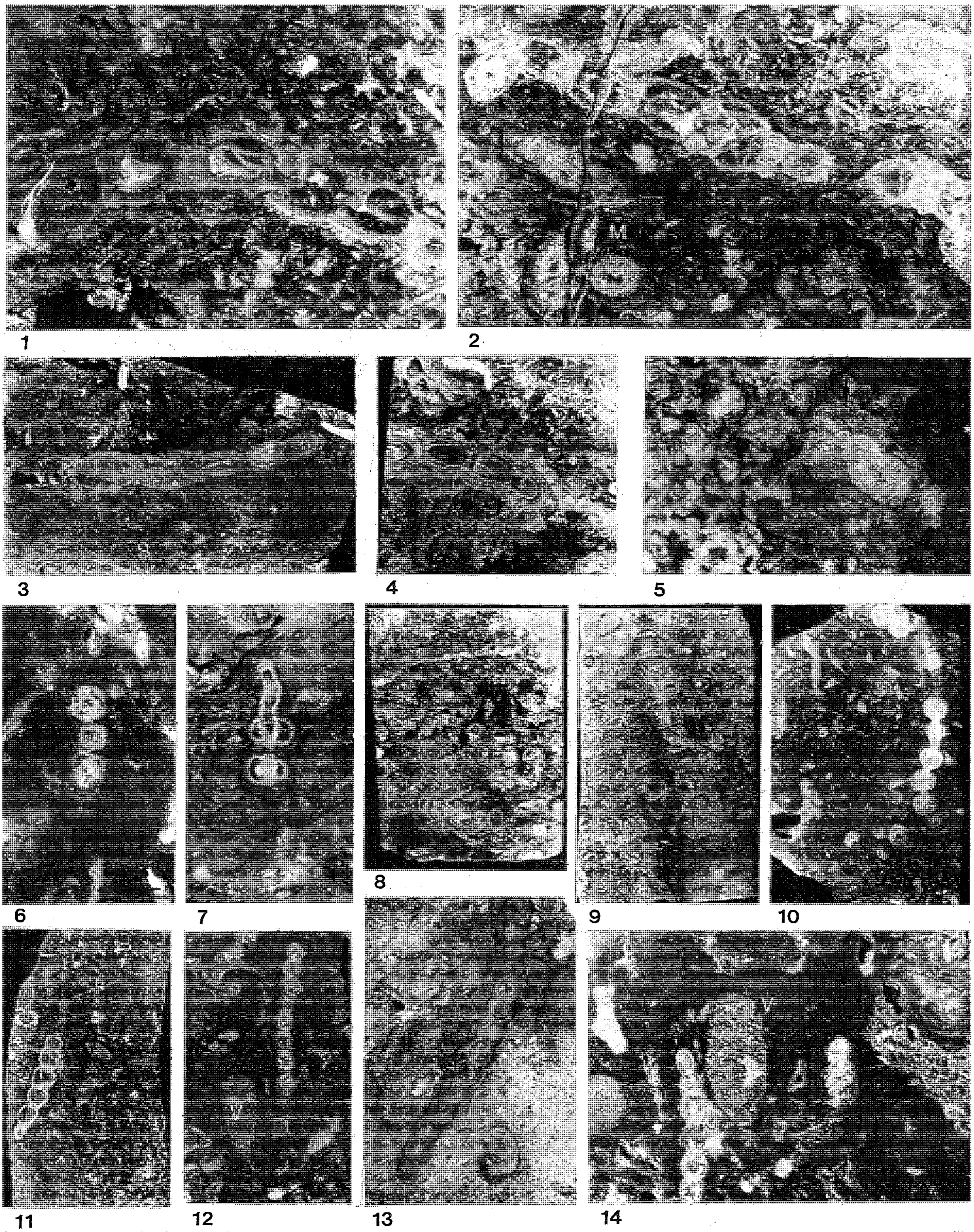
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PLATE 5

Species of *Sollasia*, *Guadalupia*, and *Preverticillites* from the Upper Capitan Limestone of the northern Guadalupe Mountains, New Mexico.

Figures *1, 2*, *Sollasia ostiolata* Steinmann, 1882, characteristic beaded specimen showing gradual vertical increase in chamber size and with one ostium as a tubular exaulos of one of the upper chambers; the sponge is thickly coated with irregularly laminate *Archaeolithoporella* crusts, UNSM 35220-1, from the Hackberry Draw locality, x2; *2*, beaded sections, possibly two segments of the same sponge, with the lower part showing the subspherical chambers filled with dark matrix and with a cryptosiphonate central opening between two chambers in an interwall in the middle part of the sponge segment. Upper segment with crystalline cement-filled globular chambers, some of which have short tubular exaules; common *Acanthocladia* bryozoans in matrix in the lower left, UNSM 35045, from the Chinaberry Draw locality, x1.

Figures *3–5, 7–9*, *Guadalupia zitteliana* Girty, 1908a, *3*, vertical section through the plate-like sponge showing the honeycomb-like chamberlets on the right and somewhat diagonal transverse sections of the chamberlets on the left, UNSM 35211, from the Hackberry Draw locality, x1; *4, 5, 7*, holotype, USNM 118135, from the Capitan Limestone in the southern Guadalupe Mountains, Texas; *4*, photomicrograph of vertical section through the chamberlets showing their long, tube-like, structure terminating in an irregular net-like pattern of the dermal layer, below, x10; *5*, side view of irregularly obconical specimen showing its weakly annulate growth form, x1; *7*, photomicrograph of the dermal area showing the irregular nature of the skeleton (dark gray) and light-colored matrix, from the upper left of the holotype, as shown in Figure 5, x10; *8*, view from above of weakly rippled plate showing the circular honeycomb-like cross sections of the vertical chamberlets locally blanketed by a thin dermal layer, where it has not been eroded and where it has a micronodose appearance over much of the sponge. The small size of the chamberlets allow differentiation of even fragments of the species from the coarser-chambered *Guadalupia explanta* (Girty, 1908a), UNSM 35275, from the Hackberry Draw locality, x1. *9*, Horizontal subtransverse sections through a broad saucer-shaped sponge, which has been partially recrystallized but shows sizes of the small chamberlets, the irregular gastral layer on inside surfaces toward the right, and the thin dermal layer on the outside, to the left. The sample block was cut and reglued with epoxy, which now shows as the thick black vertical line on the left. A section of the tubular coral *Cladopora* occurs in the upper center. Nature of the dermal layer in the subtransverse section perhaps shows best in the lower right side of the small sponge piece in the lower left. Alignments of canals shows in the dermal layer near the black epoxy fill of the saw mark, UNSM 34717, from the Hackberry Draw locality, x1.

Figure *6*, *Preverticillites parva* new species, holotype, showing the tubular sponge with an axial spongocoel that pierces the stacked chambers, with columnar to locally reticulate filling structures, UNSM 34701, from the Hackberry Draw locality, x2.

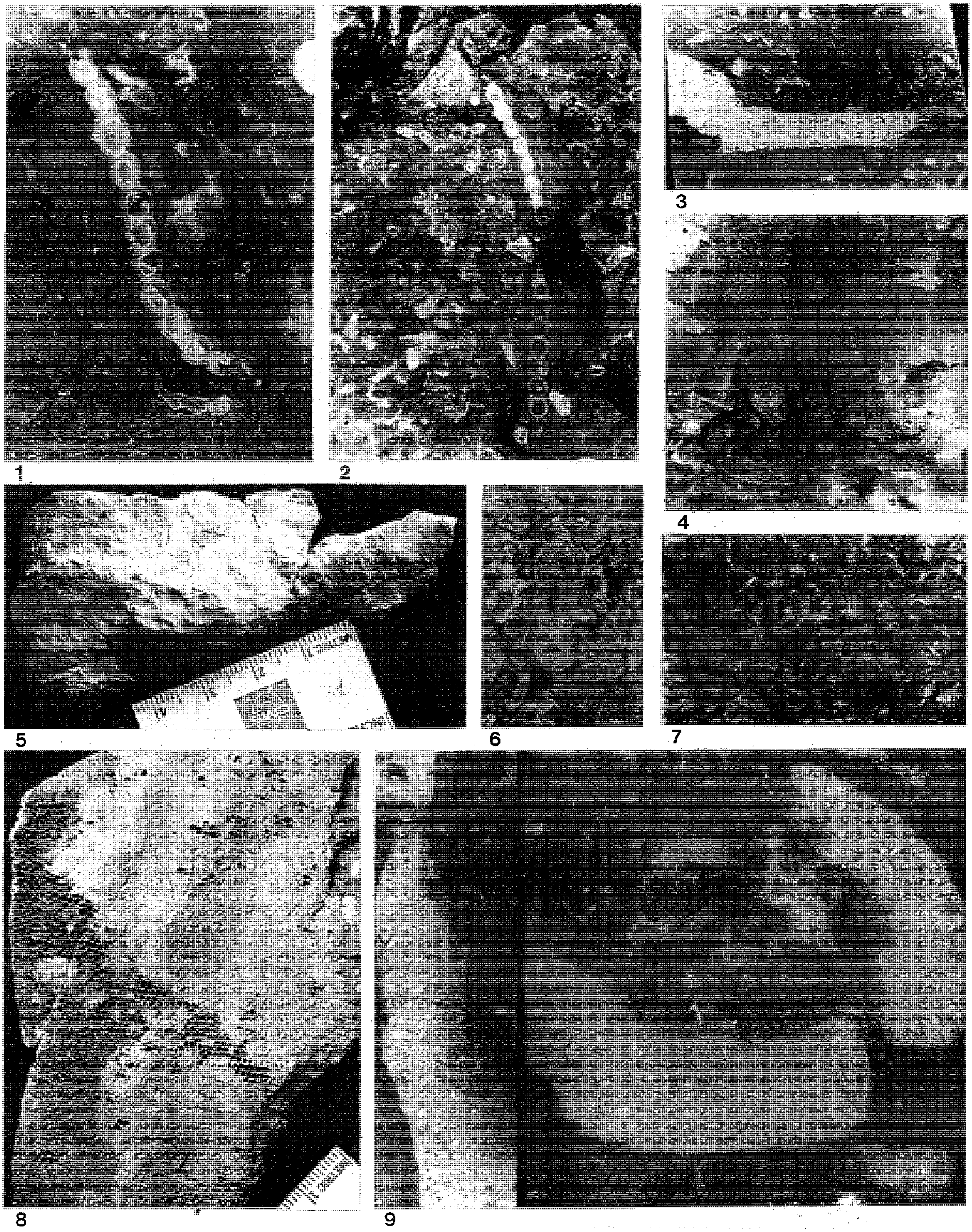

PLATE 6

Examples of *Guadalupia* and *Lemonea* from the Upper Capitan Limestone of the northern Guadalupe Mountains, New Mexico.

Figures *1–4*, *Guadalupia explanta* Girty, 1908a; *1*, vertical section through a horizontal plate showing the relatively course arcuate chamberlets of the honeycomb-like structure, that curve outward in the direction of growth, toward the left, UNSM 35050, from the Chinaberry Draw locality, x1; *2*, horizontal transverse section through a plate showing the stacked arcuate chambers, again curved in the direction of growth, toward the upper right, and showing variation in sizes and shapes of chambers, UNSM 35050, from the Chinaberry Draw locality, x1; *3*, vertical to subtransverse sections through two specimens of the species, one considerably more clearly defined and preserved than the other, the better preserved one shows relatively thin walls of the arcuate chamberlets, growing to the right; the gastral layer forms an irregular, almost reticulate, skeletal part in the upper interior of the U-shaped sponge; both sponges blanketed in part by algal crusts and laminated by *Archaeolithoporella*; microstructure of the second specimen less well preserved, UNSM 35004, from the Chinaberry Draw locality, x1; *4*, tangential section through the gastral layer of the species showing astrorhizal canal structure in that somewhat reticulate part of the skeleton, with chambers of the lower part of the skeleton on the left, UNSM 35004, from the Chinaberry Draw locality, x1.

Figures *5–7*, *Lemonea conica* Senowbari-Daryan, 1990; *5*, *7*, sublongitudinal sections showing clusters of subvertical parallel exhalant tubes (T) surrounded by horizontal honeycomb-like chamberlets, shown in the sections as upperward arcuate where cut longitudinally, and circular to oval where cut in transverse sections in both surfaces, UNSM 35296, etched specimen, uncertain locality, x1; *6*, section through a large specimen showing several clusters of vertical tubules surrounded by the honeycomb-like structure, particularly well shown in the lower left where parallel walls of chamberlets contrast sharply with the circular cross sections of the vertical tubules, which also are darker gray in that area; clusters of vertical tubules in other parts of the sponge show as relatively smooth circular areas approximately one centimeter across, but with considerable variation; the principal section and other sections in the upper left and left center are encrusted by dark *Archaeolithoporella*. A small *Lemonea micra* new species (L) occurs in the lower right, UNSM 35019, from the Chinaberry Draw locality, x1.

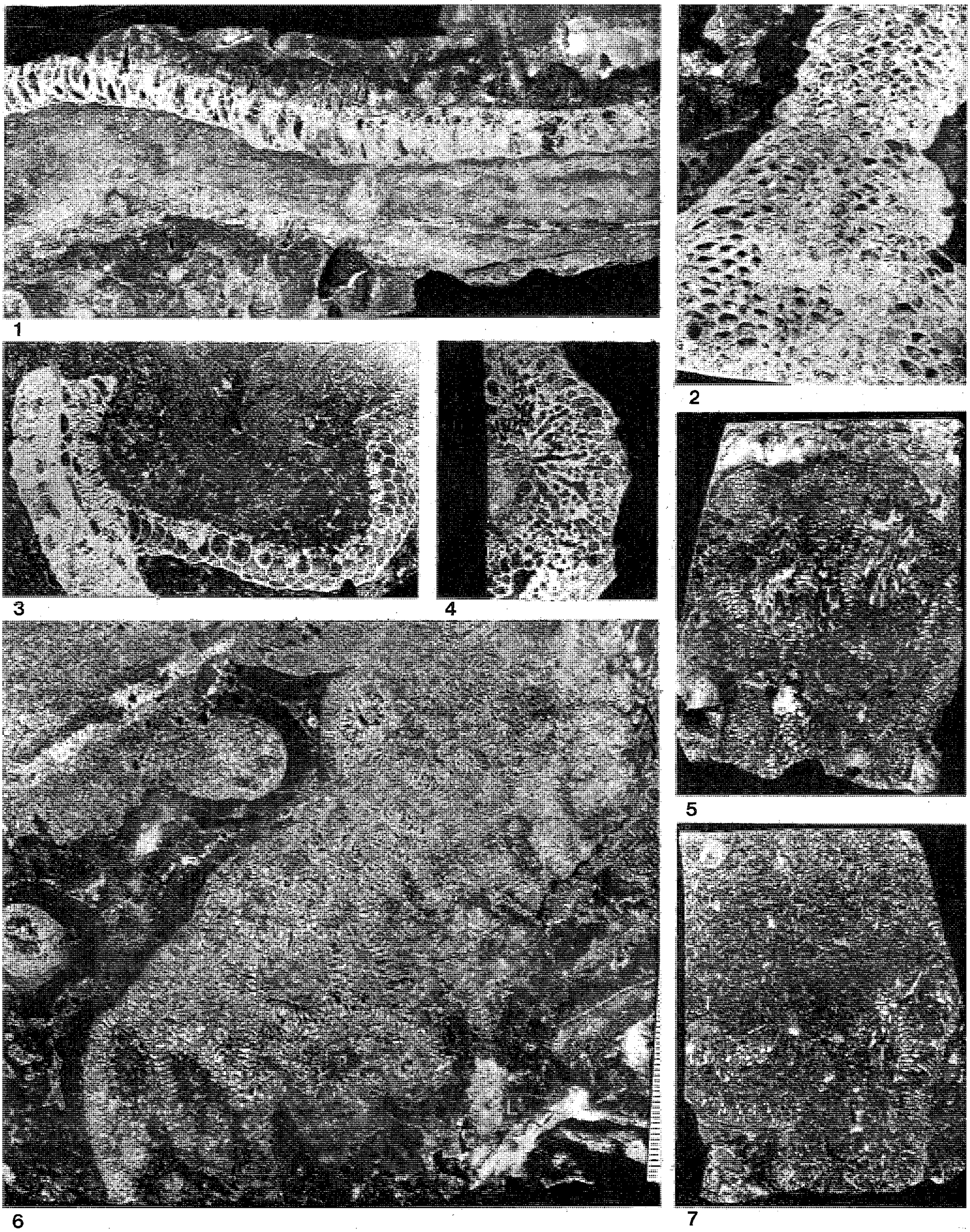

PLATE 7

Lemonea species and other sponges from the Upper Capitan Limestone in the northern Guadalupe Mountains, New Mexico.

Figures *1–4, Lemonea cylindrica* (Girty, 1908a) and associated sponges; *1,* transverse sections of three moderately large examples showing the characteristic open central spongocoel and honeycomb-like outer layer of radially arranged chamberlets, best shown in the example on the right center. Longitudinal section of *Sollasia ostiolata* Steinmann, 1882, (S) in the upper right and *Minispongia constricta* (Girty, 1908a) (M) in the lower left, UNSM 35077, from the Chinaberry Draw locality; x1; *2,* sublongitudinal sections of the species, one on the left shows the matrix-filled central spongocoel and the somewhat draped, radial chamberlets in the outer layer of characteristic structure; two diagonal subtangential sections on the right show transverse cross sections of chamberlets in the small specimens in the center, and similar sections and longitudinal section of chamberlets partially filled with dark matrix in the upper right, UNSM 35019, from the Chinaberry Draw locality, x1; *3,* subtransverse section of the species showing the dark, matrix-filled, open spongocoel and chamberlets in the outer part of the wall, in sublongitudinal section in the lower part of the sponge but cut diagonally in other parts of the wall, UNSM 346232, from the Dark Canyon locality, x2; *4,* longitudinal section of steeply obconical example showing the open, but matrix-filled, spongocoel and section through the chamberlet layer on either side, with transverse sections of chamberlets in the base of the sponge where it is cut tangentially, UNSM 35186, from the Hackberry Draw locality, x1;

Figures *5, 6, 8, Lemonea polysiphonata* Senowbari-Daryan, 1990; *5,* transverse section of three stems with multiple tubules in the central axial area (P) and in characteristic chamberlets forming the outer layer, typical of the genus, associated with several transverse and sublongitudinal sections of *Lemonea micra* new species (M) with the same orientation as the larger species, UNSM 35108, from the Dark Canyon locality, x1; *6,* sublongitudinal section of moderately large specimen showing the subparallel vertical tubules in the lower left center and longitudinal sections of the subhorizontal canals in the undulate layer on the right of the sponge, with transverse sections of that same layer in the upper left, in bioclastic matrix with abundant foraminiferal(?) tubes and dark-appearing *Archaeolithoporella,* on the right, UNSM 35117, from the Dark Canyon locality, x1; *8,* several transverse sections of stems showing the central axial cluster of vertical tubules and the surrounding layer of radial chamberlets, associated with a coarsely chambered *Discosiphonella mammilosa* (King, 1943), (D) in the upper center part, foraminiferal(?) tubes prominent in the upper right, associated with abundant crusts of *Archaeolithoporella,* UNSM 35020, from the Chinaberry Draw locality, x1.

Figure *7, Lemonea micra* new species, the tubular sponges in the lower part with open central spongocoels and small chamberlets that form the outer part of the wall, cut longitudinally in the upper part of the small specimen, in the lower left, or tangentially in the lower right parts of both specimens. *Virgola neptunia* (Girty, 1908a) (V) in the upper central part shows characteristic relatively coarse skeletal net of the species. Numerous branches of the cryptostome bryozoan *Acanthocladia* (A) occur in the central part; transverse sections of the small *Minispongia constricta* (Girty, 1908a) (M) are coated with crusts of *Archaeolithoporella,* which appears dark in the figure. Fractured light-weathering area in upper right is a result of recent weathering, UNSM 35225, from the Hackberry Draw locality, x1.

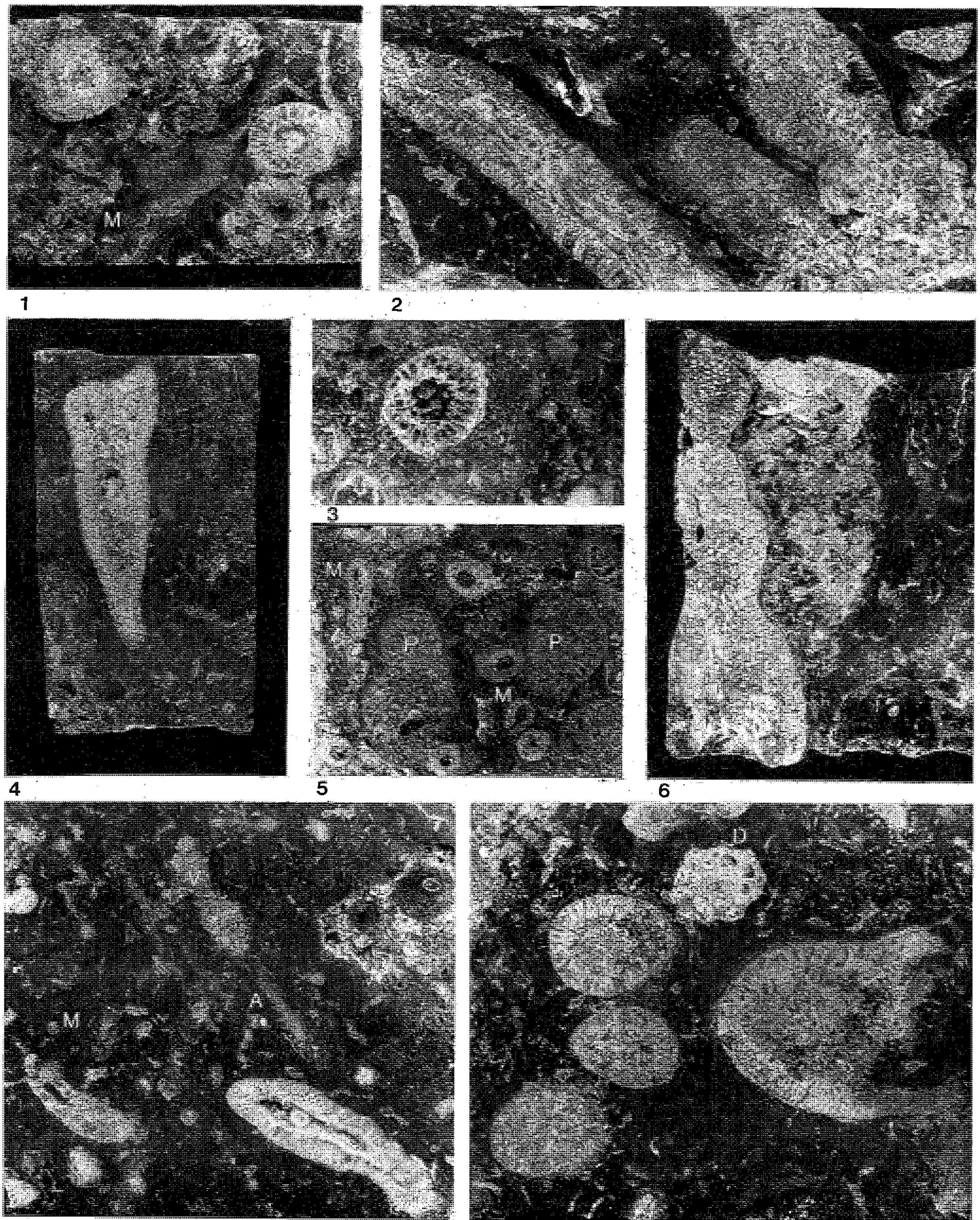
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PLATE 8

Species of *Lemonea* from the Upper Capitan Limestone of the northern Guadalupe Mountains, New Mexico

Figures *1–6, Lemonea micra* new species, *1,* holotype, straight-stem with prominent central spongocoel with outer wall composed of small horizontal chamberlets, shown in longitudinal section in the central part of the sponge, but in sub-transverse section in the upper part of the specimen, UNSM 35022, from the Chinaberry Draw locality, x1; *2,* weathered surface through a small stem showing the central spongocoel and surrounding chamberlets, in longitudinal section near the center and in subtransverse section in the upper part, UNSM 35028, from the Chinaberry Draw locality, x1; *3,* sublongitudinal sections of branched specimen, above, and an unbranched specimen, below, each showing the characteristic central spongocoel and the surrounding layer of chamberlets cut transversely, in the upper right, and nearly longitudinally in the center and lower right in the branched specimen, and in the lower center in the unbranched specimen, UNSM 34628, from the Dark Canyon locality, x2; *4,* cluster of typical stems cut essentially transversely showing dimensions of their central spongocoel and chamberlets which form the outer part of the sponge skeleton, UNSM 35037, from the Chinaberry Draw locality, x1; *5,* sublongitudinal and somewhat diagonal subtransverse sections of a cluster of the species, showing the central spongocoels and their surrounding chambers, best seen in longitudinal sections in the upper center and in transverse section in the upper right; surface weakly etched with dilute acetic acid, UNSM 35138, from the Dark Canyon locality, x1; *6,* sublongitudinal and transverse sections of the species showing characteristic chamberlets of outer walls and central tubular spongocoels, perhaps most obvious in the branched specimen in the lower center, UNSM 34628, from the Dark Canyon locality, x2.

Figures *7, 8, Lemonea exaulifera* new species, UNSM 35215 from the Hackberry Draw locality, both figures x1; *7,* sublongitudinal and transverse sections of the species showing the prominent small tubular exaules extending radially from the outer wall, apparently as inhalant openings into chambers; a tubular spongocoel shows best in the tall specimen near the center. *Virgola neptunia* (Girty, 1908a) (V) occurs in the upper right, perhaps attached to one of the stems of *Lemonea exaulifera.* Black areas are pits eroded below the polished surface; *8,* diagonal and subtransverse sections showing the prominent small tubular exaules characteristic of the species, extending outward from the dermal surface of the chamberlet layer, which surrounds the cylindrical central spongocoel, apparent in the center of the small section in the middle of the figure; all of the sponges are encrusted with thick laminar layer of *Archaeolithoporella.*

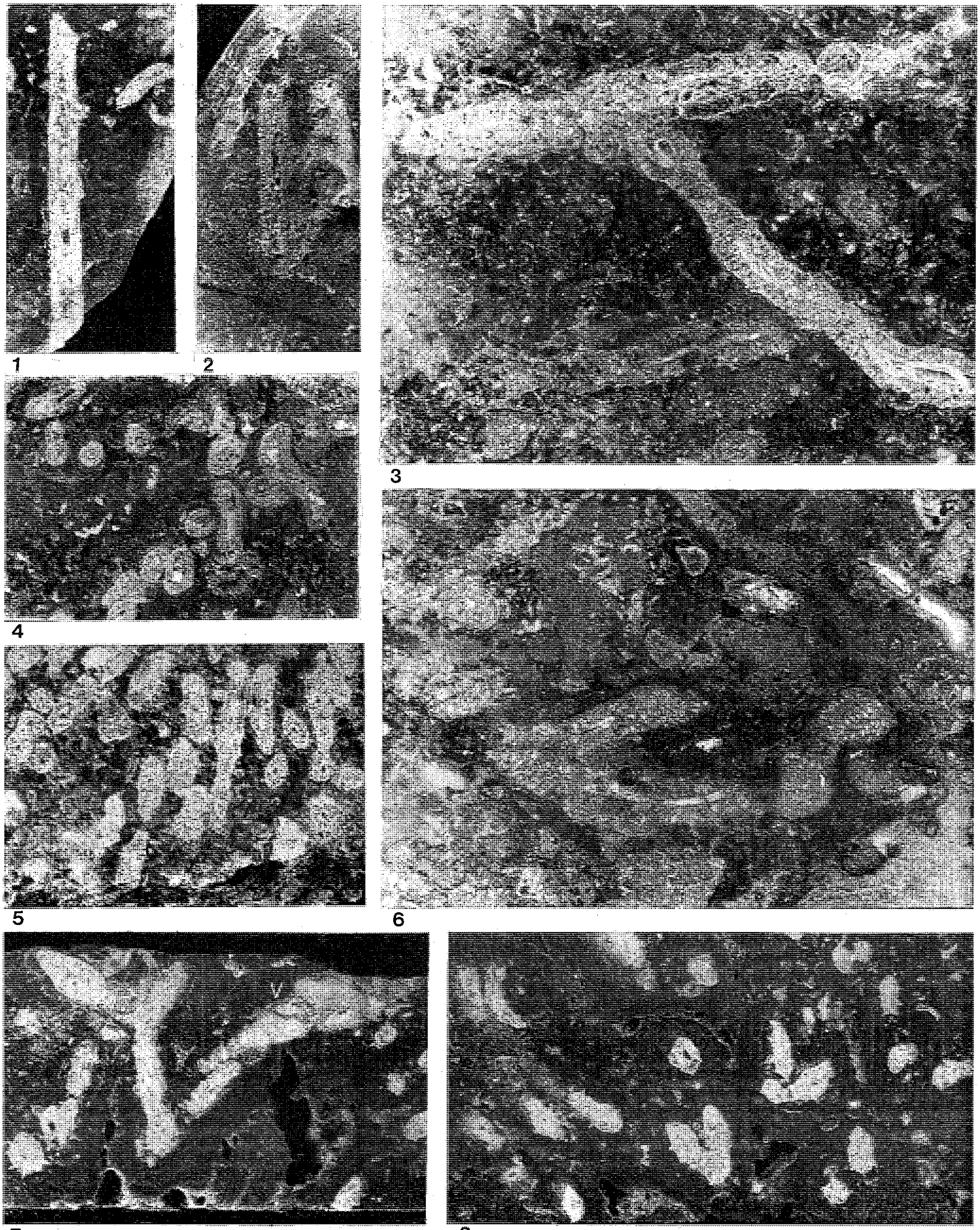
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PLATE 9

Species of *Lemonea, Cavusonella, Grossotubinella, Minispongia,* and *Gigantospongia* from the Upper Capitan Limestone of the northern Guadalupe Mountains, New Mexico

Figures *1–3, Lemonea exaulifera* new species, UNSM 35215, from the Hackberry Draw locality, *1,* holotype, sublongitudinal section of prominent stem showing the central tube-like spongocoel, chamberlets of the lateral walls, and exaules as the small tubular projections from the sides; several transverse sections show characteristic on exteriors, dark areas are weathered pits below the polished surface, x2; *2,* polished surface showing several aligned stems cut in near-longitudinal or diagonal sections of the typically straight stems, their axial spongocoels, laterally chambered walls of the outer layer of the sponge, with projecting tube-like exaules characteristic of the species, x1; *3,* subtransverse sections showing prominent exaules around the exterior, and the chambered interior of walls around the central spongocoel, x2.

Figures *4, 5, Cavusonella caverna,* Rigby, Fan and Zhang, 1989b, *4,* species occurs above and below C in the right part of the figure, showing numerous irregular canals that interupt the reticulate skeleton; a possible osculum and convergent canals show at the top of the specimen, in the upper right, where canals are filled with darker gray matrix; both specimens are coated by the common encrusting *Archaeolithoporella.* A curved tubular specimen of *?Lemonea micra* new species (L) in the lower part; small section of *Virgola* sp. (V) is cut near the left center margin; UNSM 35297, etched sample, uncertain locality, x1. *5,* Diagonal section with moderately developed canals, sections of *Lemonea micra* new species (L) are cut in the lower parts and upper left, UNSM 35068, from the Chinaberry Draw locality, x1.

Figure *6, Grossotubinella parallela* Rigby, Fan and Zhang, 1989, a coarsely canalled inozoid sponge in which canals make up approximately one half of internal volume of the stems. The unique specimen in the Guadalupe Mountains collection is above the G in the central part of the figure, UNSM 34676-TS from the Chinaberry Draw locality, x2.

Figure *7, Minispongia constricta* (Girty, 1908), a cluster of the small sponges, some cut longitudinally and others transversely, UNSM 35155, from the Dark Canyon locality, x2.

Figures *8, 9, Gigantospongia discoforma* Rigby and Senowbari-Daryan, 1996b, holotype, USNM 480456, in place in the "Sponge Window" locality; *8,* vertical section through the large discoidal sponge, the horizontal fossil in the center part of the figure, below the irregular *Lemonea conica* Senowbari-Daryan, 1990 (C); scale in inches above, and centimeters below; *9,* segment of the holotype showing branching canals in the interior and the differentiated dermal surface, below, and gastral surface, above, in the discoidal sponge. Dark depression on the right is the same depression in the sponge shown in the right part of Figure *8,* x1.

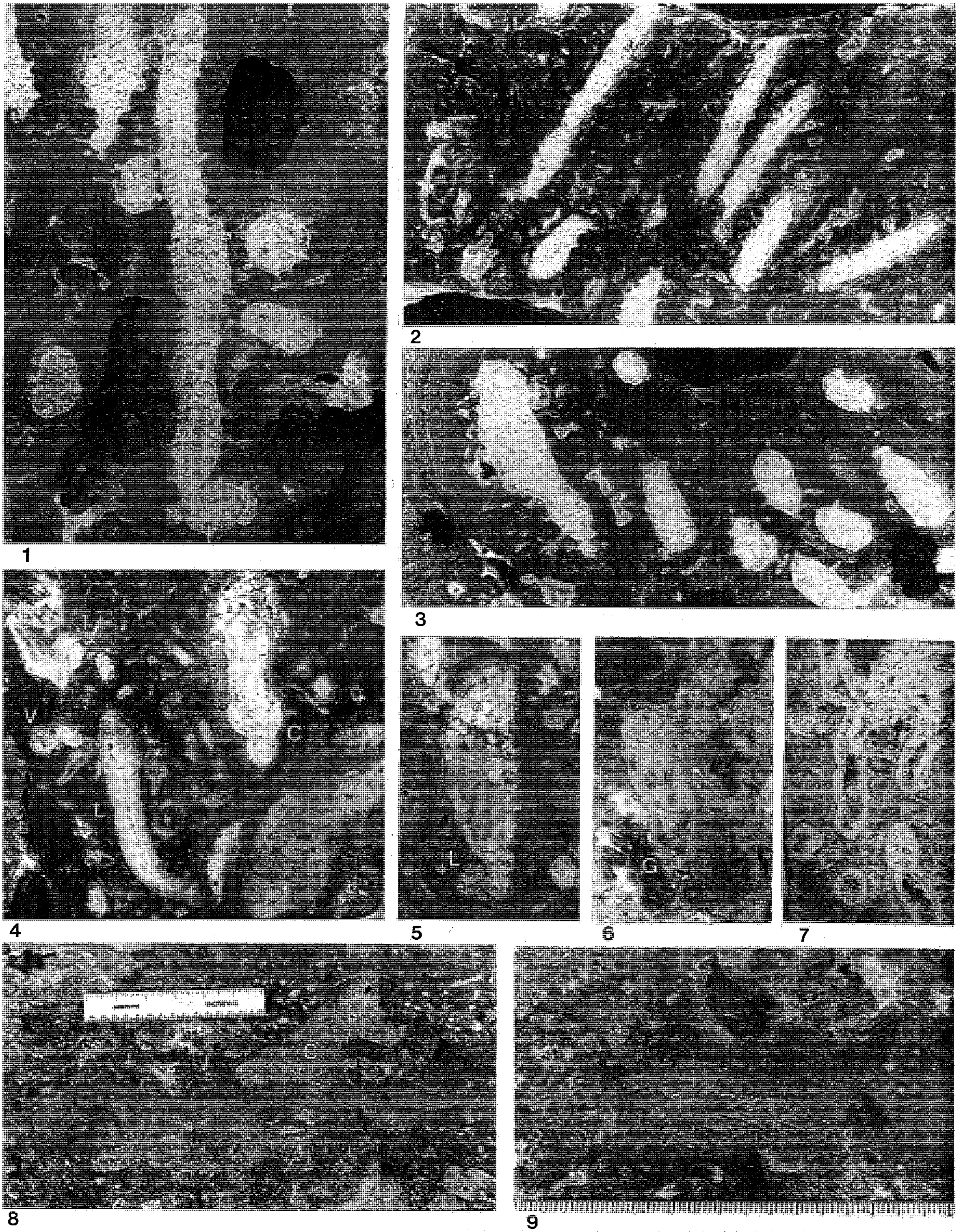
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PLATE 10

Species of *Gigantospongia, Minispongia, Peronidella(?), Virgola,* and *Pseudovirgula* from the Upper Capitan Limestone in the Guadalupe Mountains, New Mexico and Texas

Figures *1, 2, Gigantospongia discoforma* Rigby and Senowbari-Daryan 1996, *1,* prominent undulating disc of reference specimen through the central part of the weathered exposure, approximately 1 meter below the holotype in the "Sponge Window" exposure, numerous attached *Lemonea* grew downward from the lower side of the sponge in a crypt formed by the discoidal plate; 2, Senowbari-Daryan on the upper part of the "Sponge Window" exposure with his left hand indicating the position of the holotype and with the scale in his right hand pointing to the reference specimen shown in Figure *1.* The holotype extends approximately one meter, both left and right, of the small clump of grass. The reference specimen, below, is approximately 80 cm across, and only the central part of it is shown in Figure *1.*

Figure *3, Minispongia constricta* (Girty, 1908a), *3,* holotype, side view showing the annulate nature of the small sponge, USNM 118132, x2; collecting locality USGS 2926, middle Capitan, Guadalupe Peak, southern Guadalupe Mountains, Texas.

Figures *4, 5, 10, Virgola rigida* Girty, 1908a, figured specimen, *4, 5,* side views showing differences in the moderately weathered surface in Figure *4* and the relatively fresh annulate exterior in Figure *5,* USNM 118151, x2; *10,* photomicrograph showing the relatively broad central spongocoel, filled with dark matrix, and the light skeletal structure of the surrounding walls, generally in bioclastic matrix, UNSM 32598, etched specimen, uncertain locality, x5.

Figure *6, Peronidella(?) delicata* new species, holotype, showing the very fine reticulate skeletal structure of the only moderately well preserved tube-like form, a faint ill-defined and probably discontinuous spongocoel interrupts the skeletal structure, specimen was initially referred with question, by Girty, to *Pseudovirgula tenuis* Girty, 1908a, USNM 118133, middle Capitan Limestone, USGS locality 2926, Guadalupe Peak, southern Guadalupe Mountains, Texas, x4.

Figures *7–9, Pseudovirgula tenuis* Girty, 1908a, holotype and only known specimen of the species, USNM 118152, middle Capitan Limestone, USGS 2926, Guadalupe Peak, Southern Guadalupe Mountain, Texas, all x4. *7,* side view of the small sponge showing clear (dark) areas along the weathered margin and in the summit, suggesting coarse canals and lack of fine skeletal net in the outer part of the sponge; *8,* view of the upper surface, as shown in Figure 7, with a prominent tubular exaulos (arrow) extending from the skeletonized interior through the open, unskeletonized, area beneath the medium-gray dermal layer; 9, lower surface of the holotype showing the central, very finely reticulate skeletal net and the outer "moat" of unskeletonized area inside the well-defined dermal layer.

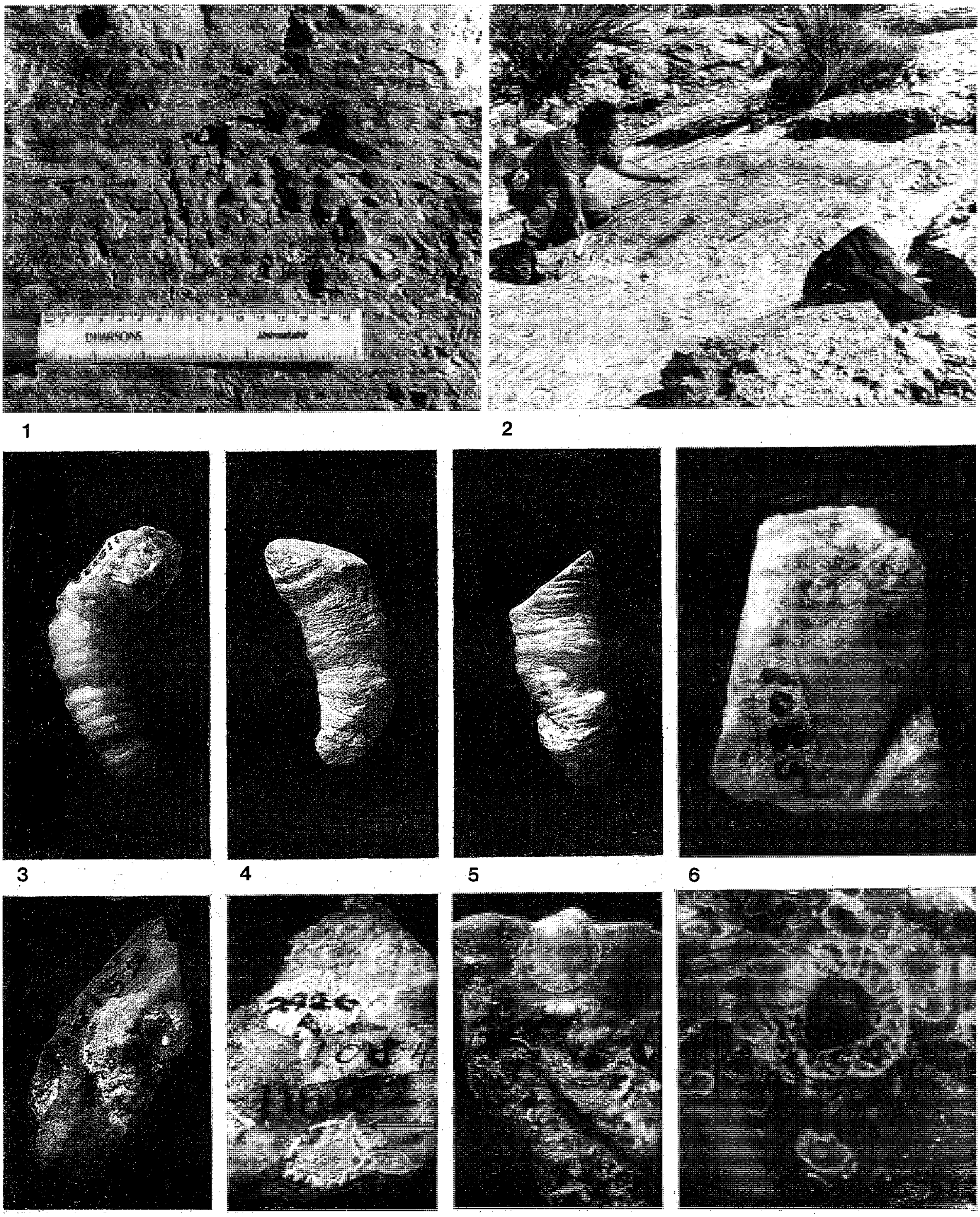
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PLATE 11

Species of *Bicoelia, Minispongia,* and *Heliospongia* with associated fauna from the Upper Capitan Limestone in the northern Guadalupe Mountains, New Mexico.

Figures *1–4, Bicoelia guadalupensis* new species; *1,* paratype, showing principally transverse sections of numerous stems, each with two spongocoels in the axial region and each with its own wall, but lacking fibrous skeletal structure between them; outer principal wall composed of irregular reticulate fibrous network, UNSM 35175-2, Dark Canyon locality, x2; *2,* paratype, polished section from the same locality shows several stems of the sponge, UNSM 35175-3, Dark Canyon locality, x2; *3,* holotype (arrow) and several other large examples of the sponge with typical double spongocoel development in the axial region, surrounded by the coarsely reticulate wall; a small specimen of *Minispongia constricta* (Girty, 1908a) (M), occurs in the lower part and a fragment of *Guadalupia zitteliana* (Girty, 1908a) (G) occurs in the lower right, UNSM 35175-1, Dark Canyon locality, x2; *4,* polished surface in which several examples of *Biocelia guadalupensis* new species (B) occur in the upper and left center associated with small stems of *Minispongia constricta* (Girty, 1908a) (M) in the *Archaeolithoporella*-encrusted structure, a small specimen of *Virgola neptunia* (V) is the reticulate structure in the upper right, UNSM 34717, Hackberry Draw locality, x2.

Figures *5, 7–10, Minispongia constricta* (Girty, 1908a), figured specimens; *5,* prominent irregular tubular sponge on the right shows the characteristic thin-walls in sublongitudinal sections; transverse sections are the circular impressions in the left center, all showing the relatively coarse skeletal structure of the walls. The coarsely porous structures, well developed in the lower part of the figure, are sections through a clump of *Parauvanella minima* Senowbari-Daryan, 1990 (P), UNSM 35155, Dark Canyon locality, x2. *7,* Diagonal section through a small stem of *Minispongia constricta* showing the characteristic, relatively coarse, skeletal structure of the thin walls around the central spongocoel, UNSM 35175, Dark Canyon locality, x10; *8,* subtransverse section of the upper end of a small *Minispongia constricta* showing the oscular opening at the summit of the spongocoel and the relatively coarse reticulate skeleton, which locally is somewhat finer textured in the outer part, beneath the perforated outer wall, UNSM 35175, Dark Canyon locality, x10; *9,* transverse sections of *Minispongia constricta* in the left center (M) and in the lower left, associated with relatively massive *Virgola neptunia* (Girty, 1908a) (V) shown in sections in lower right, and a small brachiopod clast in the lower center, on UNSM 35155, Dark Canyon locality, x2; *10,* diagonal sections through *Minispongia constricta* in the lower center (M), associated with diagonal sections of *Bicoelia guadalupensis* new species (B), UNSM 35175-4, Dark Canyon locality, x2.

Figure *6, Heliospongia ramosa* (Girty, 1908a), branching specimen with open spongocoel in each branch, skeletal structure not well defined in replaced walls, sponge attached to spore(?)-filled structures near arrow, UNSM 35185, from Hackberry Draw locality, x1.

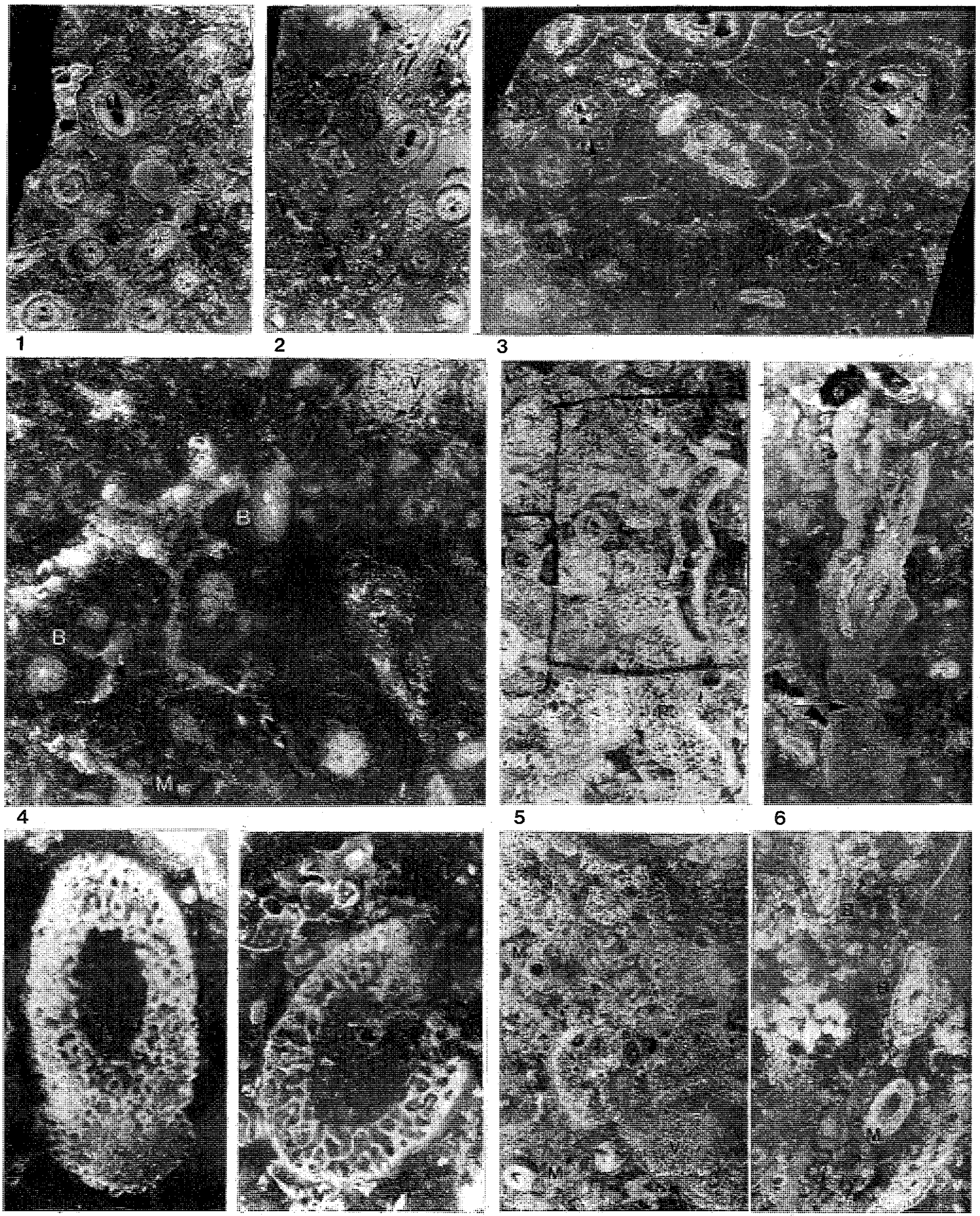
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PLATE 12

Species of *Virgola, Peronidella,* and *Stellispongiella(?)* from the Capitan Limestone of the Guadalupe Mountains, Texas and New Mexico

Figures *1–4, Virgola rigida* (Girty, 1908a) *1, 2,* holotype, USNM 118131, middle Capitan Limestone, USGS locality 2926, Guadalupe Peak, southern Guadalupe Mountains, *1,* side view showing annulate exterior of the branched sponge, exposed sections at the summit show no evidence of a spongocoel in the reticulate skeletal structure, x2; *2,* dermal skeletal net of the lower part of the branch on the right, skeleton dark gray, matrix light gray, x10; *3,* diagonal section through a stem tentatively included in the species, in which the skeletal net is moderately well preserved in only a small patch, with much of the remainder of the skeleton as ghost-like traces, USNM 34710, from the Hackberry Draw locality, x2; *4,* transverse section of the small stem showing the reticulate skeletal net lacking a central axial spongocoel, UNSM 35229 from the Rattlesnake Canyon traverse, x1.

Figure *5, 8, Peronidella* cf. *P. rigbyi* Senowbari-Daryan, 1991, polished sections through a small branched form, the upper surface of the slab shown in *5* and the lower surface in *8*; *5,* two small discontinous spongocoels filled with dark matrix interrupts the reticulate skeletal net, which shows modest uparched linearity in both branches and in the base of the specimen; *8,* interior section of the small specimen, on the opposite, lower side of the slab, showing the reticulate skeletal structure interrupted by a possible spongocoel in the upper part, now filled with dark matrix, UNSM 34633, from the Dark Canyon locality, both x2.

Figure *6, 7, 10, Virgola neptunia* (Girty, 1908a), holotype, USNM 118130, from the middle Capitan Limestone, USGS locality 2926, Guadalupe Peak, southern Guadalupe Mountains, x4; *6,* transverse section of the interior of the small sponge showing the coarse reticulate skeletal net characteristic of the species and lack of prominent canals and a through-going spongocoel; *7,* probable upper part of the sponge showing the shallow, but prominent, spongocoel interrupting the poorly preserved skeletal net, here not well preserved, x4; *10,* oblique section through a branched specimen showing the characteristic coarse skeletal structure, largely uninterrupted by canals, and the lack of a spongocoel in either branch, UNSM 35009, from the Chinaberry Draw locality, x4.

Figure *9, Stellispongiella*(?) sp., diagonal section showing the poorly preserved fine reticulate skeletal net interrupted by relatively small canals, many of which are filled with dark matrix, irregular surfaces suggest low mounds toward which exhalant canals converge, but in an irregular fashion, in the single specimen questionably assigned to the genus in the Guadalupe Mountain collection, UNSM 34717, from the Hackberry Draw locality, x2.

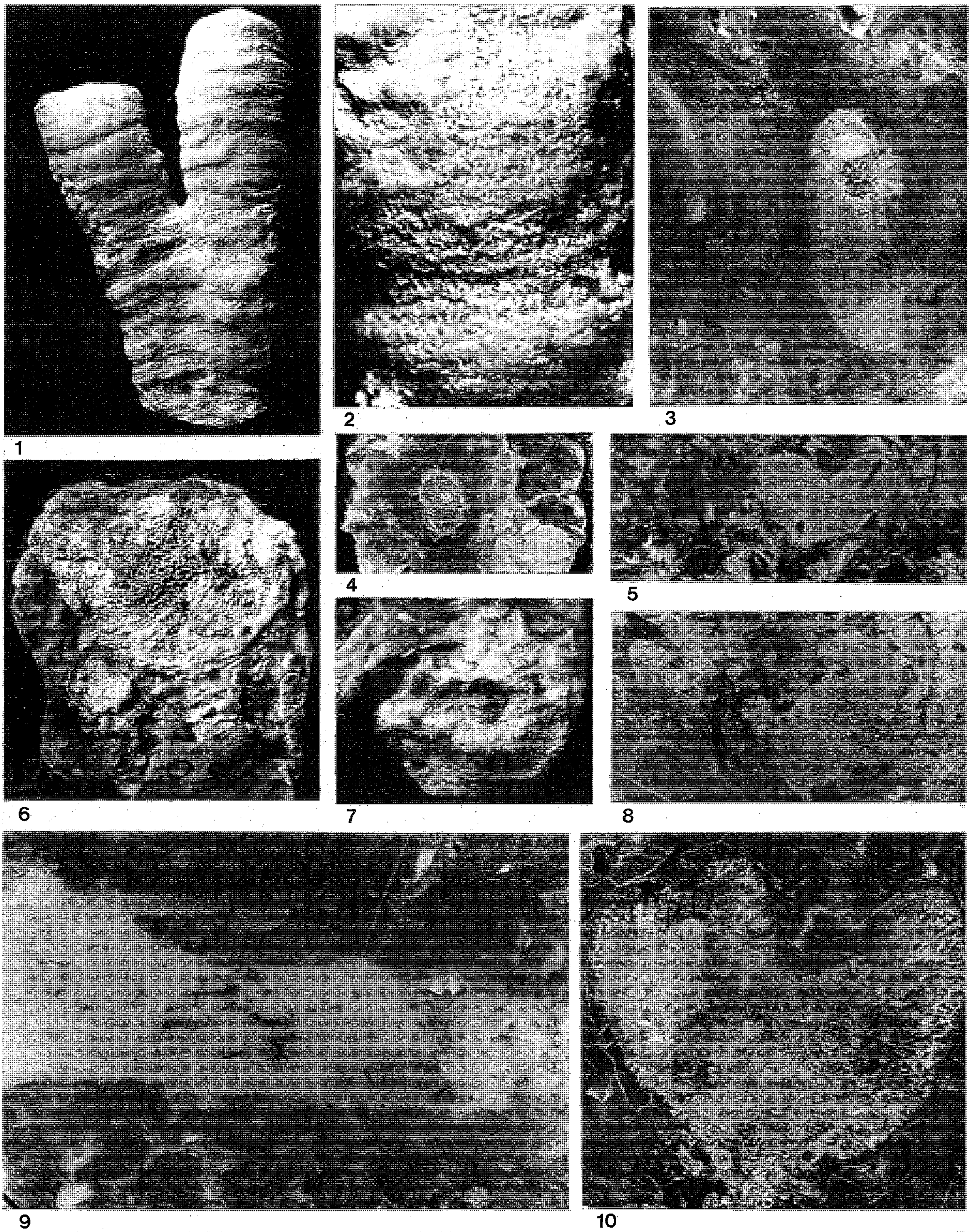
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PLATE 13

Species of *Heliospongia, Lemonea,* and *Neoheliospongia* with two unnamed forms, from the Capitan Limestone in the Guadalupe Mountains, New Mexico and Texas.

Figure *1, Heliospongia vokesi* (King, 1943), a large sponge showing the regular skeletal structure, cut transversely so that the concentric and radial structure of the skeletal tracts show prominently, but the large central spongocoel is not evident in the section, UNSM 35268, from the Hackberry Draw locality, x1.

Figure *2, Lemonea digita* (Girty, 1908a), holotype and only known specimen of the species, lower cylindrical part branched upward into at least three small branches, each pierced by a central spongocoel, in the upper part, USNM 118140, from the Capitan Limestone on Guadalupe Peak, USGS collecting locality 3902, southern Guadalupe Mountains, x1.

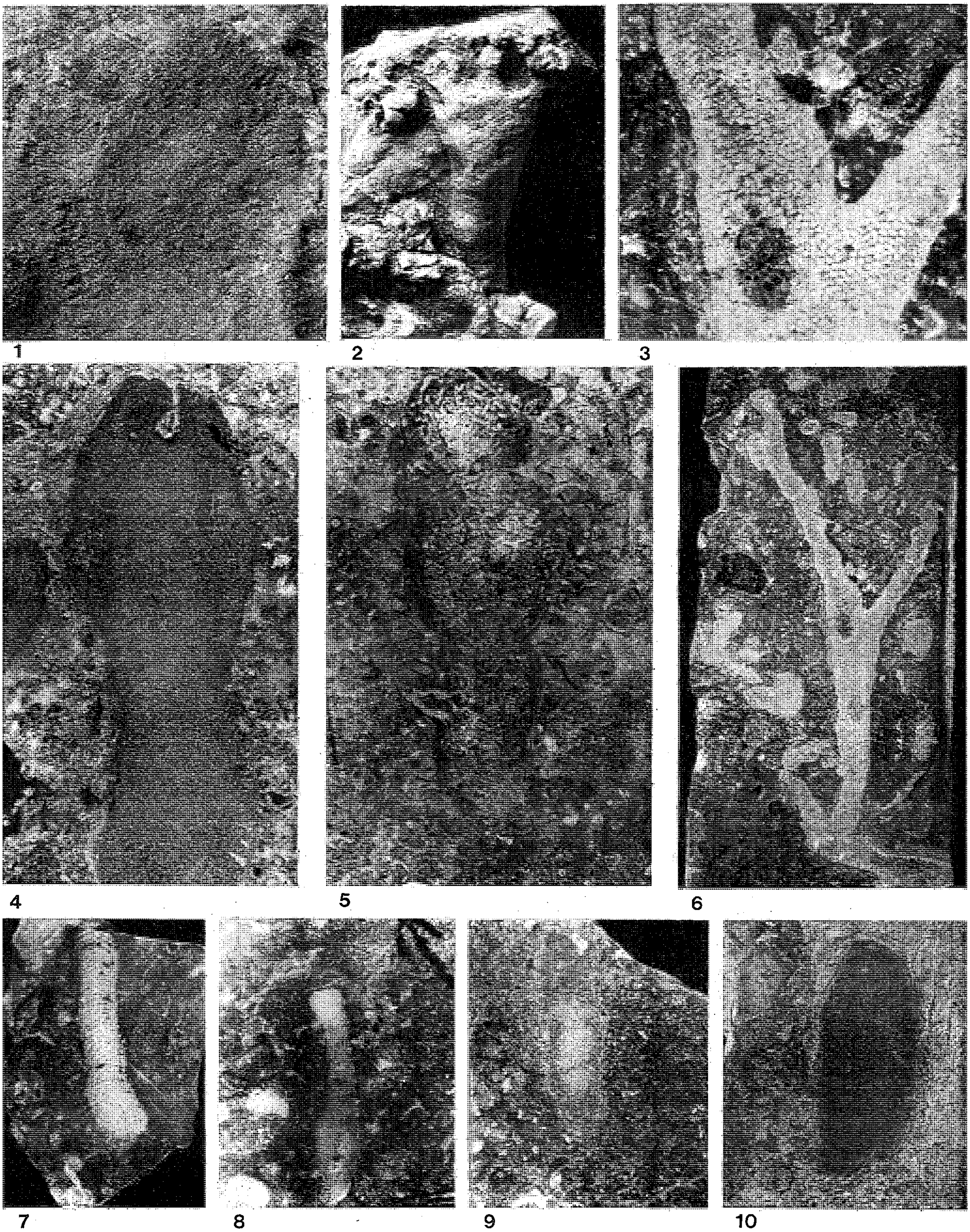
Figures *3, 6, Lemonea cylindrica* (Girty, 1908a), well preserved branched specimen with broad attachment base, section cut tangentially so axial spongocoel is not intersected, but the honeycomb-like skeletal wall is well preserved, particularly in areas where matrix has filled the chamberlets near the area of most prominent branching, UNSM 35035, from the Chinaberry Draw locality, *3,* x2, *6,* x 1/2.

Figure *4,* Form A, possibly a hydrozoan, section shows growth lines and faint tube-like skeletal structure, somewhat reminiscent of solenoporid algae, UNSM 34618, from the Dark Canyon locality, x2.

Figure *5,* Form B, irregular conical-cylindrical fossil with coarse skeletal structure interrupted by what appears to be fungal filaments that have penetrated through the dark outer wall, perhaps best shown in the lower left exterior of the specimen; the fossil may have been an inozoid sponge whose skeletal structure is now largely destroyed, UNSM 34639, from the Dark Canyon locality, x2.

Figures *7, 8, Heliospongia ramosa* (Girty, 1908a); *7,* vertical section through a cylindrical stem showing the upperward arcuate, regular, horizontal tracts and less well-defined vertical and radial tracts, UNSM 35232, from the Rattlesnake Canyon traverse, x1; *8,* less well-preserved example with faint skeletal tracts most evident near the middle, above the small spongocoel intersected in the lower part of the sponge, UNSM 35185, from the Hackberry Draw locality, x1.

Figure *9, 10, Neoheliospongia* cf. *N. typica* Deng, 1981, *9,* diagonal section through the dense skeletal net characteristic of the species, UNSM 35168, from the Dark Canyon locality, x2; *10,* diagonal section through the dense skeleton, somewhat coarser textured than the specimen in Figure 9, UNSM 35122, from the Dark Canyon locality, x2.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