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SPONGES FROM THE PARK CITY FORMATION (PERMIAN) OF WYOMING

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ABSTRACT—A new small twiglike anthaspidellid sponge, *Virgaspongiella ramosa* new genus and species, and an incrusting lithistid sponge have been recovered from silicified residues of etched limestone blocks from the Middle Permian Franson Member of the Park City Formation in western Wyoming. *Virgaspongiella* n. gen. has a skeleton of upwardly and outwardly divergent trabs formed of merged tips of runglike dendroclone spicules in ladderlike series. One to a few oxeas function as coring spicules in the trabs and project as fine spines from the dermal surface, and other monaxial spicules project from pores of the canals.

The incrusting sponge, *Incrustatospongia superficiala* new genus and species, forms a distinct, thin, uniform lithistid skeletal layer, composed largely of X-shaped dendroclones, incrusted on both the inner and outer surfaces of productoid brachiopod valves. Separated monaxial spicules locally protrude from the sponge's dermal surface apparently as spinose defensive elements.

INTRODUCTION

SEVERAL EXAMPLES of siliceous sponges have been recovered from residues of limestone blocks, from the Franson Member of the Park City Formation, that were etched to recover their paleontological content. The rarity of sponge body fossils in Permian strata of western Wyoming and adjacent states is in striking contrast to the abundant petrographic evidence for prolific populations of siliceous sponges on sea floors of that time and in that region. The evidence is provided by spicular chert, long recognized as a common lithology in the strata in question (e.g., Mansfield, 1927; Andersson and Sauvagnat, 1998). After studying thin sections of this rock, Cressman and Swanson (1964) concluded that sponge spicules account for at least half the silica in the chert. Faunas of the stratigraphic units involved, primarily the Phosphoria and Park City Formations, are well known from decades of collecting by geologists from industry, academia, and the U. S. Geological Survey (USGS). Following an exhaustive review of some 1,500 collections made by USGS personnel, Yochelson (1968) could report no sponge body fossils other than one species previously reported from a single locality (Finks et al., 1961). The apparent ease with which the sponge skeletons disarticulated before burial makes our discovery of well-preserved specimens of special interest. In this report we describe unusually preserved detailed skeletal structure of two new species.

The fossils in question are part of a selectively silicified assemblage found by Boyd and N. D. Newell in 1968 while prospecting for silicified Permian pelecypods. The locality (Fig. 1.1) is on the east flank of the Wind River Range, at the west end of Bull Lake (SE¼, SW¼, sec. 1, T2N, R4W, Bull Lake West 7½′ quadrangle, Wyoming). Large blocks of the host limestone were transported by boat to the east end of the lake, then trucked to the University of Wyoming, where they were dissolved in dilute hydrochloric acid. The insoluble residues yielded a diverse molluscan fauna accompanied by many specimens of the productoid brachiopod *Sphenalosia* Muir-Wood and Cooper, 1960, relatively rare cryptostome bryozoans, and the inevitable batch of ''unknowns.'' After the initial sorting, study focused on the pelecypods. Although gastropods were studied as part of a broader project (Kulas and Batten, 1997), no attention was given to the rest of the collection until the summer of 2002, when Boyd undertook a review of cabinets housing such ''bypassed'' material. While attempting to identify the productoid brachiopods, he noticed that many of the convex valves hold accumulations of well-preserved spicules, randomly arranged in most cases, but with evidence of organization in others. This prompted a microscopic examination of the ''unknowns'' and recognition of the specimens described here.

STRATIGRAPHIC SETTING

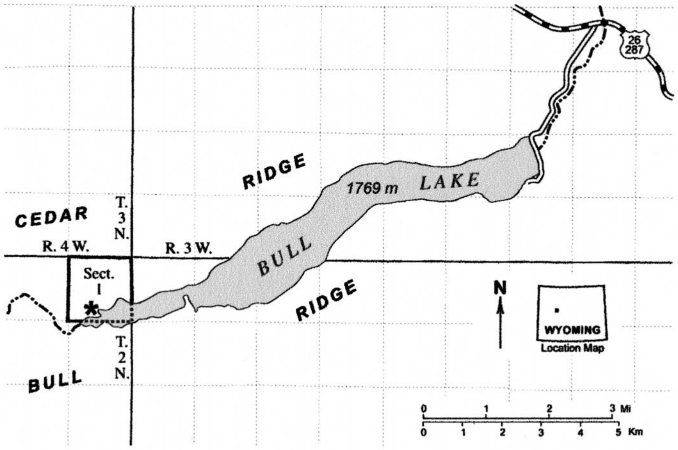
At the locality in question (Fig. 1), east-dipping beds of the Middle Permian Park City and Phosphoria Formations form a succession of low ridges and intervening swales. The Park City Formation, primarily carbonate rock and light-colored shale, and the Phosphoria Formation, consisting of dark shale, phosphorite, and chert, intertongue in such a way that members of the two formations alternate in any one vertical section (Sheldon, 1963, fig. 9). Limestone blocks containing the silicified fossils described here were obtained from the basal ledge of a low hogback formed by cherty carbonate strata of the Franson Member of the Park City Formation (Fig. 1.2). The fossiliferous ledge overlies a thin (0.5 m), resistant, phosphatic sandstone containing fragmental orbiculoid brachiopods and fish teeth, typical components of the Meade Peak Member of the Phosphoria Formation. The depositional environments represented by these members were envisioned by Wardlaw and Collinson (1986, p. 110) to involve a west-sloping ramp where buildup of a fringing carbonate bank complex was twice interrupted by migration of a deeper ramp phosphatic facies across the bank. Yochelson (1968) provided detailed discussion of the fossil content of these deposits.

PRESERVATION

Insoluble residues from blocks collected at the Bull Lake locality yielded 30 small sponges. Most are broken specimens of the new twiglike species; the others represent the new incrusting taxon.

Some of the twiglike specimens show well-preserved skeletal structure throughout their thickness, whereas many have such preservation limited to a thin outer zone. In these, the spicular aspect grades abruptly inward into dense cryptocrystalline silica, which forms the bulk of the specimen. Yet another mode of preservation is represented by 50 irregularly cylindrical objects originally interpreted by Boyd as silicified burrows or worm tubes. They consist of a thin outer layer of tiny beekite disks and/or microcrystalline quartz. This fragile rind encloses space partially filled with botryoidal silica. Subsequent microscopic study of the outer layer shows that, in a few specimens, patches of the microcrystalline material grade laterally into vestigial spicular fabric. Thus, these objects probably represent an advanced stage of diagenetic destruction of precursor twiglike sponges.

The relatively rare specimens of the incrusting sponge are of special interest for the contrast in style of preservation between incruster and host. In these specimens, the original skeletal structure of the thin crust is preserved at microscopic scale. In each case, this delicate spicular fabric is in contact with a *Sphenalosia* valve in which silicification not only changed the chemical composition of the shell but also replaced its original microstructure



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Series		Stages	Rock Units at Sponge Locality*
M. Permian	Guadalupian	Capitanian	
		Wordian	* Franson Member of Park City Fm.
		Roadian	Meade Peake Mbr. of Phosphoria Fm.

2

FIGURE *1*— Location map and stratigraphic terminology. *1,* Asterisk indicates the site of the sponge collection at the western end of Bull Lake, Wind River Mountains, Wyoming. *2,* Stratigraphic position of the productive sponge-bearing beds within the Franson Member of the Park City Formation is indicated by the asterisk. Series and stages from Jin et al. (1997); ages of rock units from Wardlaw and Collinson (1986) and rock unit terminology from Sheldon (1963).

with a diagenetic one of laterally linked beekite disks. Dissolution of sponge spicules has often been suggested as the source of silica involved in silicification of Paleozoic calcitic shells, yet in the present case, a spicular network retained its identity during (and after) replacement of subjacent calcite.

Repository.—The figured specimens are housed in the collection of fossil invertebrates, Department of Geology and Geophysics, University of Wyoming, Laramie (UW).

SYSTEMATIC PALEONTOLOGY

Class DEMOSPONGEA Sollas, 1885
Order LITHISTIDA Schmidt, 1870
Suborder ORCHOCLADINA Rauff, 1895
Family ANTHASPIDELLIDAE Miller, 1889
Genus VIRGASPONGIELLA new genus

Type species.—*Virgaspongiella ramosa* new species.

Diagnosis.—Small twiglike branching to palmate sponges that lack a distinct spongocoel but may have axial exhalant canals; upwardly divergent skeleton of ladderlike elements consists of prominent trabs cross-connected by runglike I- and X-shaped dendroclones, whose branched tips unite to form rodlike prominent trabs; trabs cored by one or possibly more axial oxeas, at any level, that project outward as spines on dermal surface.

Etymology.—*Virga,* L., twig, branch, rod, or wand; *sponge,* sponge; *ella,* small.

Discussion.—Only a few small twiglike sponges are known in the Anthaspidellidae. For example, *Brianispongia* Pickett and Rigby, 1983, from the Lower Devonian of Australia, is described as a slender branching sponge, that lacks a spongocoel or an axial cluster of excurrent canals, somewhat like the sponge described here, and has a skeleton composed of trabs and interconnecting dendroclones that diverge upward and outward from the axial region, as does the sponge here. *Brianispongia* has numerous inhalant ostia or pores and scattered exhalant exopores, as in the Wyoming sponge. We have not extended that genus into the Permian of North America because the Australian form apparently lacks the prominent coring monaxial spicules in the trabs, and does not have palmate sections. Furthermore, its exhalant exopores are less uniformly distributed and less common in its dermal structure. *Virgaspongia* Rigby and Manger, 1994, a Pennsylvanian anthaspidellid sponge from the Ozark Mountains of Arkansas, has much the same skeletal and canal pattern as *Virgaspongiella* n. gen., but is a much larger sponge and, like *Brianispongia*, lacks the monaxial coring spicules in the trabs and has associated inserted spicules in the canal pores.

Cauliculospongia Rigby and Chatterton, 1989, from the Silurian of Canada, is a form much like *Brianospongia* and *Virgaspongiella* n. gen. in being a small branching twiglike form without a spongocoel, and in having a skeleton with trabs and ladderlike series of dendroclones that arch upward and outward from the sponge axis to meet the dermal surface at high angles. However, *Cauliculospongia* has irregular vertical canals through its skeleton, structures not found in the Permian *Virgaspongiella* n. gen. A somewhat similar Permian sponge, *Pseudomultistella* Deng, 1981, was described from the Upper Permian of Guangxi, China, as a ramose sponge lacking a spongocoel, but with canals that diverge upward toward the surface. It is significantly larger than *Virgaspongiella* and has a considerably less well-organized skeleton. Although it may have trabs and horizontal dendroclones, those series may be either vertical or radial and spokelike. It also has horizontal canals that connect the upward divergent ones, in a relation unlike the canal system in the new Wyoming genus.

The Permian *Dactylites* Finks, 1960 is a digitate sponge, but it has terminal oscules at the tips of its branches and has a few surficial grooves as well. Of more significance, it has spicule layers parallel to the dermal surface, in a skeletal structure quite unlike the Wyoming form described here. *Jereina* Finks, 1960, also from the Permian of West Texas, is a cylindrical to branching form, but it has a central spongocoel that extends the full length of its branches, and thus is clearly distinct from the new sponge described here. The Ordovician *Lissocoelia* Bassler, 1927 is also a branching form, but like the Permian genera discussed above it has an axial spongocoel, and also has a skeleton of irregularly arranged dendroclones, unlike the organized skeleton in the new Wyoming genus.

VIRGASPONGIELLA RAMOSA new species
Figs. 2.1–2.4, 3.1, 3.3

Diagnosis.—As for genus.

Description.—Four well-preserved examples of the species are in the collection. The holotype, UW4022, is a tall irregularly bladed to branching small sponge (Fig. 2.2). It is 41 mm tall, from the broken elliptical base that is 3×4 mm across up to the forked bladed summit that is 7 mm wide, just below the divergence of

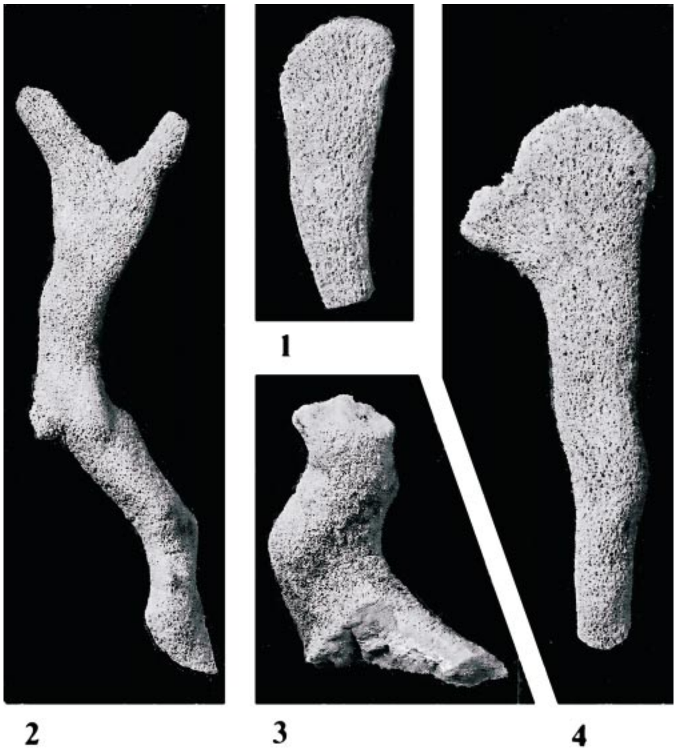


FIGURE 2—Type specimens of *Virgaspongiella ramosa* n. gen., n. sp., from the Permian Park City Formation, west-central Wyoming. All figures ×2. *1,* paratype, UW4023, with palmate form; *2,* holotype, UW4022, with twiggy form; *3,* paratype, UW4025, curved form with massive siliceous replacement of interior; *4,* paratype, UW4024, twiggy to palmate form.

two short branches, each 2–3 mm in diameter. It has a relatively smooth surface marked by numerous, closely spaced, fine inhalant ostia (Fig. 3.1, 3.3) that are commonly approximately 0.08 mm in diameter, and which connect to discontinuous inhalant canals that extend irregularly inward between skeletal trabs and the coarser exhalant canals. The somewhat coarser exopores (Fig. 3.1, 3.3) are commonly 0.10–0.12 mm in diameter, but range up to approximately 0.20 mm in largest openings. These exopores are dermal termini of the upwardly and outwardly divergent, curved, exhalant canals that approximately parallel trabs of the skeleton. Exhalant exopores are generally 0.12–0.4 mm apart over the dermal surface of the sponge. A distinct spongocoel or axial cluster of coarse exhalant canals is not developed.

The upwardly and outwardly divergent, gently curved, rodlike trabs of the skeleton are 0.06–0.10 mm in diameter and are spaced 0.08–0.20 mm apart where most evident at the dermal surface. They are formed by the merger of digitate tips of the dendroclone spicules and, with those spicules, form the ladderlike skeletal elements distinctive of the family (Fig. 3.3).

Both I- and X-shaped dendroclones are present in the skeleton. They are generally in vertically stacked, runglike, series and are spaced 0.04–0.06 mm apart in those series. I-shaped dendroclones are 0.10–0.14 mm long with subcylindrical to gently tapering shafts that are 0.01–0.02 mm in diameter. They have bifurcating rays that are approximately 0.01 mm in diameter, where they diverge, and that expand into flaring digitate termini that are 0.02–0.03 mm across. These digitate terminations merge with those of adjacent series of dendroclones to form the trabs. X-shaped dendroclones have somewhat thicker shafts that are only 0.03–0.04 mm long and 0.02–0.03 mm in diameter. Rays at both ends of the shafts are 0.03–0.04 mm long and 0.01–0.02 mm in diameter. These rays also flare into terminal tips that merge with flared tips of adjacent spicules to form the trabs.

Oxeas and possibly styles occur as coring elements in the trabs (Fig. 3.3), where usually only one axial spicule projects from dermal ends of the trabs. These spicules both have maximum diameters of 0.02–0.03 mm and may range up to 0.8–1.0 mm long. The oxeas taper to sharp tips in both directions, and styles in only one direction. However, most exposed coring spicules have broken ends and unless their taper can be observed, their nature is uncertain. Complete oxeas and styles are rare but do occur scattered as weathered elements on exposed etched surfaces. In addition to their presence as coring elements, similar spicules project from pores of both inhalant and exhalant canals, increasing the apparent spinosity of the dermal surface.

Loose fragments of larger monaxial spicules are scattered on the etched dermal surface. These range up to 0.08 mm in diameter and most certainly are transported bits and are associated with other elements of the fauna.

Two associated paratypes, UW4023 and UW4024, (Fig. 2.1, 2.4) are somewhat more simple bladed forms, widening upward from subcylindrical bases, 3.5 mm in diameter, to widths of 7–8 mm and thicknesses of up to 2.5 mm. UW4024 expands upward to a width of 9.5 mm but it is branched near the tip. Both these paratypes lack a spongocoel, but prominent exhalant ostia 0.12–0.14 mm in diameter occupy most of the axial area where a section can be seen in the broken base. Inhalant and exhalant ostia in dermal surfaces of both are of dimensions and spacing like those in the holotype.

Both paratypes have trabs that are 0.08–0.12 mm in diameter and that arch upwardly and outwardly, to meet dermal surfaces at up to 60 degrees. Trab and spicule dimensions are like those of the holotype.

An associated subcylindrical, curved, paratype, UW4025 (Fig. 2.3), has a questionable shallow osculum at the upper end of one small branch, but it is filled with debris and its true nature is uncertain. The lower end of this specimen shows the massive siliceous replacement characteristic of some specimens in the collection, where the skeletal structure was completely replaced and destroyed. However, the outer part of this paratype does show the typical skeletal and canal structure of the genus and species.

Etymology.—*Ramosa*, L., branched.

Types.—The holotype, UW4022 (Figs. 2.2, 3.1, 3.3), and paratypes, UW4023 (Fig. 2.1), UW4024 (Fig. 2.4), and UW4025 (Fig. 2.3), were collected from the Franson Member of the Park City Formation in west-central Wyoming. An additional five twiggy specimens are probably of the same species, but their definitive skeletal structures have been largely destroyed by dense silicification.

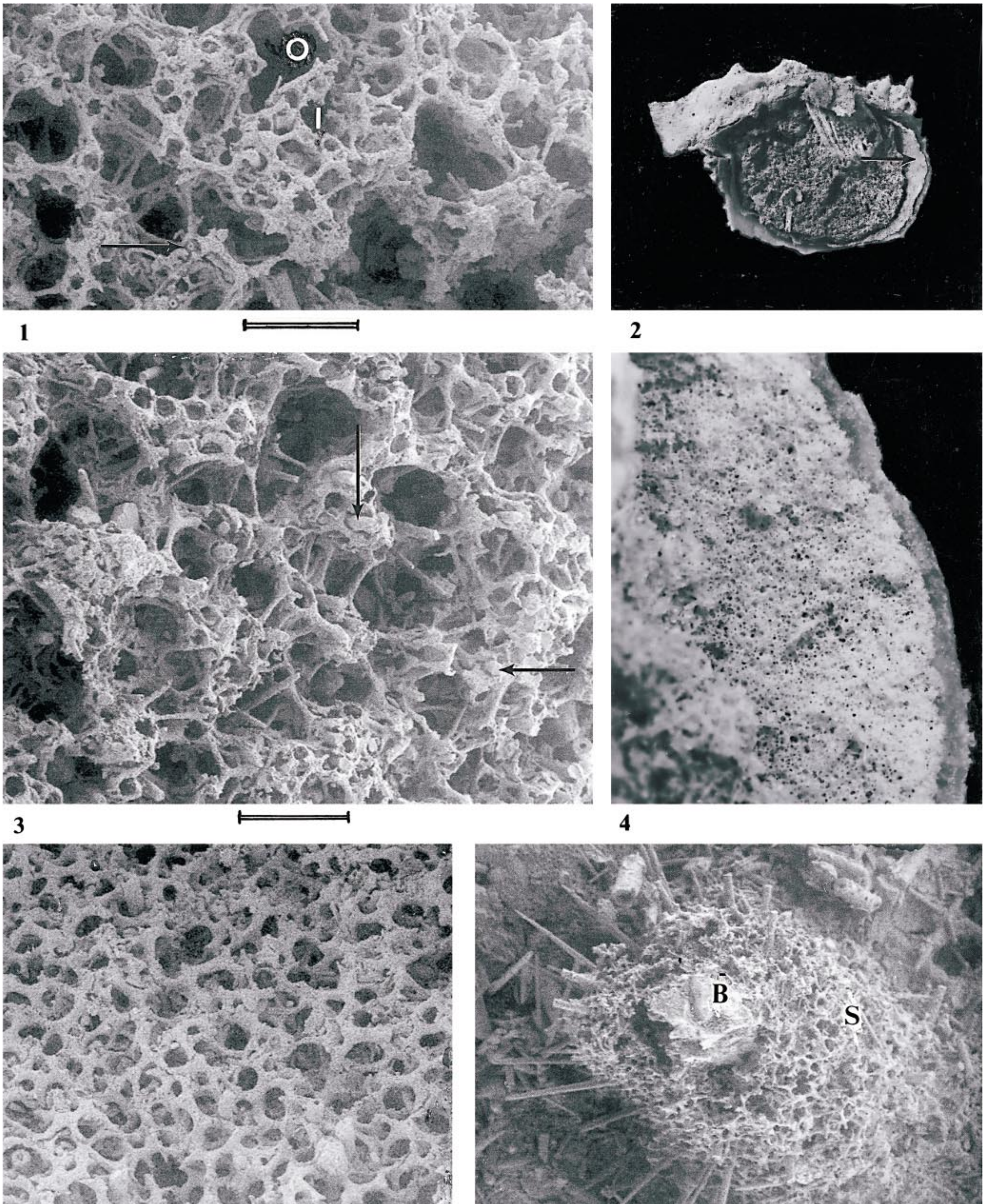
Occurrence.—Franson Member (Middle Permian) of the Park City Formation, SE¼, SW¼, sec. 1, T2N, R4W, Bull Lake 7½′ quadrangle, Wind River Range, Wyoming.

Discussion.—Comparisons with related and somewhat similar sponges have been discussed in treatment of the genus above.

Genus INCRUSTATOSPONGIA new genus

Type species.—*Incrustatospongia superficiala* new species.

Diagnosis.—Thin sheetlike incrusting sponge with skeleton of unbundled, distinct, X-shaped dendroclones, and rarely I-shaped ones, fused at mutual junctions of digitate ray tips, in indistinctly layered structure; isolated monaxial spicules locally common as erect spinose armoring elements; small skeletal pores occur between rays of dendroclones and larger exopores are separate or rarely in small irregular clusters; exhalant canals extend outward through approximately half of sponge thickness to dermal surface;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less evident small inhalant canals also extend irregularly to mid-sponge thickness.

Etymology.—*Incrustatus*, L., cover with a coat of something; *spongia*, sponge.

Discussion.—Incrusting sponges are relatively rare forms in the Anthaspidellidae and related sponges. *Velellospongia* Liu, Rigby, Jiang, and Zhu, 1998, is the only incrusting sponge described to that date in the Anthaspidellidae. It was collected from the Middle Permian Maokou Formation of Hubei Province, China, and is sheetlike, assuming the general shape of its substrate, but it has low shield-volcanolike mounds on its dermal surface, toward which internal or parenchymal canals converge and arch outward to produce exhalant clusters in craterlike depressions in the mounds. Unlike the new genus described here, it has a skeleton of I-shaped dendroclones and a distinct convergent exhalant canal system.

Heliospongia Girty, 1908 may have an incrusting base, but it has a crudely reticulate skeleton of spiculofibers of oxeas and, thus, contrasts sharply with the unbundled skeleton of the new Wyoming genus.

Sponges in the Anthracosyconidae Finks, 1960 have a layered skeleton, but they are built of superimposed layers of dendroclones arranged with their long axes perpendicular to the dermal surface of the sponge, in a structure distinctly different from that in the genus described here. The related *Collatipora* Finks, 1960, from the Permian of Texas, may be incrusting with a layered skeleton, but its typical form is hemispherical rather than a thin sheet, as in the new genus described here. In addition it has a well-defined series of internal canals, and anastomosing cleftlike grooves on its dermal surface.

INCRUSTATOSPONGIA SUPERFICIALA new species
Fig. 3.2, 3.4–3.6

Diagnosis.—As for genus.

Description.—The holotype, UW4026, and paratype, UW4027, are thin, uniform, spiculiferous incrustations 0.2–0.3 mm thick on productoid brachiopod ventral valves, mainly over the concave interior of the valve (Fig. 3.4), but extending as more discontinuous crusts onto parts of valve exteriors in both specimens. The holotype (Fig. 3.2) probably covers an ovate area of approximately 15 × 18 mm on the concave surface and extends up to 3 or 4 mm onto the beak area and around bases of some spines on the exterior. Much of the thin incrusting sponge is buried beneath 2–3 mm of spiculitic and brachiopod debris in both type specimens, which may have helped preserve their delicate spicule structure.

Principal endosomal spicules are dominantly X-shaped dendroclones that have short cylindrical shafts 0.03–0.04 mm long and 0.015–0.02 mm in diameter (Fig. 3.5, 3.6). They have forked rays at both ends that are up to about the same length and diameter as the shafts. These rays flare into digitate tips that merge with tips of adjacent spicules to form a uniform, fine-textured, delicate skeletal network.

A few rare I-shaped to Y-shaped dendroclones also occur in the skeletons. They are of about the same proportions as the X-shaped forms, but have only very short rays on one end, which merge with each other and with tips of adjacent spicules in the fused skeleton.

Parts of the dermal surfaces of both the holotype and paratype have separated small erect monaxial spicules as spinose armoring elements (Fig. 3.6). These spicules are 0.05–0.10 mm apart where most prominently developed. Whether these spicules include both oxeas and styles is uncertain because the nature of their internal tips is not known, but oxeas of the same general dimensions are common as loose spicules on etched surfaces of both the type specimens. These spicules are up to 0.03 mm in diameter and taper to sharp tips. They are up to 1.5 mm long and commonly extend up to 0.5–0.6 mm above the dermal surface, although some isolated long ones extend up to 1 mm above the dermal surface.

Coarsest openings (Fig. 3.5) are considered to be exopores of short, subcylindrical exhalant canals that extend from the dermal surface inward to about mid-thickness of the crustose sponge. These exopores are mostly about 0.06–0.10 mm in diameter. They are spaced moderately irregularly approximately 0.2 mm apart, but locally may form small clusters 0.3–0.4 mm across (Fig. 3.5).

Fine inhalant ostia are numerous and are dermal openings of small inhalant canals that locally extend from the dermal surface into the sponge for about half its thickness. They are 0.02–0.03 mm in diameter, the same size as the numerous skeletal pores formed between rays of adjacent dendroclones and that are the dominant openings throughout the uniform skeleton.

Discussion.—The holotype of *Incrustatospongia* has coated much of the concave inner surface, and some of the outer surface of the host brachiopod valve. It is mainly a uniform crust 0.2–0.3 mm thick, or perhaps 5 or 6 spicules thick, but on the exterior of the beak area, the sponge is only 1 or 2 spicules thick. The crust on the interior of the valve is partially buried by a thick, compact, layer of spiculite composed mainly of transported monaxon fragments (Fig. 3.2). The incrusting paratype also forms a thin layer over much of the interior of the host brachiopod valve, but it also has thickly coated spine bases and other parts of the exterior of the valve. These crusts over the spine bases in the paratype (Fig. 3.6) provide the most spectacular examples of the projecting monaxons that armor the dermal surface.

Comparisons with related and somewhat similar sponges have been presented in treatment of the genus, above.

Etymology.—*Superficialis*, L., on the surface, in reference to the thin crustose surficial form of the sponge.

Types.—Only the holotype, UW4026 (Fig. 3.2, 3.4, 3.5), and

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FIGURE 3—Skeletal details of *Virgaspongiella ramosa* n. gen. and sp., and illustrations of *Incrustospongiella superficiala* n. gen. and sp., from the Permian Park City Formation, west-central Wyoming. *1, 3, Virgaspongiella ramosa* n. gen. and sp., holotype, UW4022, with scale bars 200 microns long, *1,* SEM photomicrograph of skeletal structure of upper part of holotype showing dendroclone structure of skeleton with oxeas (arrow) coring trabs; and with larger exhalant exopores (O) and smaller inhalant ostia (I), as seen from the dermal surface; *3,* SEM photomicrograph showing prominent I-shaped runglike dendroclones, particularly prominent in the central part of the photomicrograph, with their rays combining with rays of adjacent spicules to form rodlike trabs, which are cored with larger monaxons, now commonly broken (arrows). *2, 4–6, Incrustospongiella superficiala* n. gen. and sp., *2, 4, 5,* holotype, UW4026, *2,* view of thin, lighter gray, incrusting sponge (arrow) coating concave surface of productoid brachiopod valve, on the right, and part of the hinge area and outer surface of valve, on the left, ×2; *4,* photomicrograph of part of incrusting holotype on right margin of *2*, showing uniform skeletal structure and abundant small inhalant ostia and rarer, somewhat larger, exhalant exopores in the dermal surface, ×18; *5,* SEM image of part of holotype dermal surface showing dominance of X-shaped dendroclones in the uniform skeletal structure, with small inhalant ostia and larger, more irregular, exhalant exopores; scale bar 200 microns long; *6,* SEM image of paratype, UW4027, showing uniform X-shaped dendroclones of the encrusting sponge (S) coating a central, light-colored, massive brachiopod spine (B), and with prominent monaxial spicules radiating from the dermal surface of the sponge; scale bar 500 microns long.

paratype, UW4027 (Fig. 3.6), represent the new *Incrustatospongia superficiala* in the collection from the Franson Member of the Park City Formation.

Occurrence.—Franson Member (Middle Permian) of the Park City Formation, SE¼, SW¼, sec. 1, T2N,R4W, Bull Lake 7½′ quadrangle, Wind River Range, Wyoming.

ACKNOWLEDGMENTS

N. D. Newell participated in the discovery of the fossiliferous ledge at Bull Lake and in collection and transport of the blocks from it. That work, as well as acid processing at the University of Wyoming, was supported by NSF grant GB-6905x to Boyd and Newell. We thank J. S. Gardner and M. Standing of the Brigham Young University Microscopy Laboratory for preparing the SEM images of skeletal structures and for their help in preparation of final figures of the sponges. We appreciate the helpful reviews of C. W. Stock and A. Pisera.

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