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Middle Devonian Sponges from the Northern Simpson Park Range, Nevada

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ABSTRACT

An extensive Middle Devonian (Givetian) hexactinellid sponge fauna is described from the Red Hill beds, from Red Hill in the northern Simpson Park Range, central Nevada. Most are preserved as hematite replacements and occur with a major fish fauna. The new genera *Taleolaspongia, Rufuspongia,* and *Bulbospongia* are based on the new species *T. modesta, R. triporata,* and *B. bullata.* Additional new species described include *Dictyospongia*(?) *robusta, D.*(?) *amplia, Actinodictya nevadensis, A. lamina, Cyathophycus simpsonensis, Cyathophycella minuta, C. grossa, Teganiella ovata,* and *Rufuspongia* sp. 1. *Protospongia conica* Rigby and Harris, 1979, is represented by a single specimen. Three types of root tufts are also described.

INTRODUCTION

Middle Devonian (Givetian) sponges have recently been recognized in association with a diverse Devonian fish fauna (Gregory, Morgan, and Reed 1977; Murphy, Morgan, and Dineley 1976; Reed 1985, 1986) from Red Hill in the northern Simpson Park Range, Eureka County, Nevada (fig. 1). The sponge locality is near the south base of Red Hill, a promontory at the northern end of the Simpson Park Range in east central Nevada. The moderately diverse sponge assemblage is dominated by hexactinellid sponges and occurs through approximately one and one-half meters of moderately homogenous-appearing limestone (fig. 2.2). The fossil sponges and fishes occur within a relatively narrow band of well-bedded, light gray, locally dolomitic lime mudstones that occur approximately 80 m below the base of the Devils Gate Limestone (figs. 2.1, 3.1–3.3). The fossils occur in a sequence of carbonates locally and informally known as the Red Hill beds.

Sponges are second in abundance only to the diverse fish assemblage and together with other invertebrates occur scattered throughout the quarried interval. The principle fish-bearing and sponge-bearing beds occur 3.0–4.5 m above a distinctive intraformational conglomerate (fig. 2.1). Associated articulate brachiopods, *Leiorhynchus* cf. *L. hippocastanea,* occur with somewhat more common linguloid brachiopods (?*Barroisella*), conularians, stylasterans, crinoid debris, and abundant specimens of *Polygnathus cristatus* (Murphy, Morgan, and Dineley 1976, p. 467). The assemblage is of Givetian age, as based on conodont zones (Johnson, Sandberg, and Poole 1988, p. 163; Sandberg, Poole, and Johnson 1988, p. 186). Johnson (1978, p. 121) concluded that the fish-sponge beds are of late upper Givetian age (lowermost *asymmetricus* Zone). In samples from recent quarry operations by H. P. Schultze and others, the occurrence of conularids among the invertebrates is second to the sponges, followed by the linguloid and rhynchonellid brachiopods, corals, coiled and straight cephalopods, gastropods, and fragments of plants. Murphy (1977, fig. 5) considered the environment of the Red Hill area as open marine near the Middle-Upper Devonian transition.

This mixed assemblage, although not diagnostic of any particular environment, does suggest marginal marine to open marine accumulations. Fossil filamentous algae, some branching plant fragments, and *Equistum*-like plant debris also occur. In general the sponges, algae, and plant debris have been replaced by iron oxides and probably represent secondary replacements of organisms that were at one time pyritized. Rocks of this section accumulated during a minor transgressive eustatic pulse (Johnson, Sandberg, and Poole 1988).

Reed (1985, p. 1181) reported that the age of the Red Hill fish fauna is near the Middle-Upper Devonian boundary, and that correlation with the fish-bearing rocks of the Soviet Baltic (Estonia) indicates a lowermost Late Devonian age for the Nevada assemblage. Reed also noted that conodonts indicative of the lowermost *Polygnathus asymmetricus* Zone also occur with the fishes and indicate an age near the Middle-Late Devonian boundary. Johnson (1977, p. 27) included the fish- and sponge-bearing beds in his brachiopod Inverval 25, characterized by brachiopods of the *Leiorhynchus hippocastanea* Zone, which includes the lowermost *asymmetricus* Zone.

Murphy, Morgan, and Dineley (1976, p. 467–68) reported that the stratigraphic section exposed on Red Hill is over 130 m (440 ft) thick and includes the lower part of the Devils Gate Limestone and the Red Hill beds, below, that are in part equivalent to the Nevada Limestone in areas to the east and south.

The principal sponge-bearing layers were the sequence quarried by Schultze and his associates during 1983 and 1987 (figs. 3.2 and 3.3). The collections reported here are largely from the 1987 collections of Schultze's field party. They opened up two extensive quarries in adjacent outcrops, presumably at University of California Riverside locality 7528, reported by Murphy, Morgan, and Dineley (1976).

As far as the sponge record is concerned, only sponge spicules have been reported previously from the region (Gregory, Morgan, and Reed 1977; Murphy, Morgan, and Dineley 1976, p. 468), but no mention has been made of the extensive and varied sponge fragments that occur with the fishes in the principal fish-bearing beds. The sponges described here were assembled by Schultze and his party as part of a collection of all of the fossils evident in approximately 3 meters of beds that were peeled away, layer by layer, in the quarry.

Each sample was labeled in the field according to the bed from which it came. Individual beds range in thickness from approximately 2 cm to 10 cm and were identified by bed numbers 1 through 21, from the top down (figs. 2.2 and 3.2). The fossil sponges and fish commonly do not occur at major diastems and do not appear as turbidite or storm accumulations, but occur scattered throughout the lime mudstones. A few occur in argillaceous partings between the limestone units. Many of the sponges appear, thus, to have been essentially in place, although some of the larger sponges are represented only by fragments and probably were transported at least short distances. The hexactinellid sponge skeletons were composed of unfused spicules, and at least the large specimens would not suffer long distance transportation without dissociation. Some of the sponges appear to have been flattened in place, along with clusters of conularids and some fish materials. Fossil sponges and fishes occur in close association in these peculiar beds.

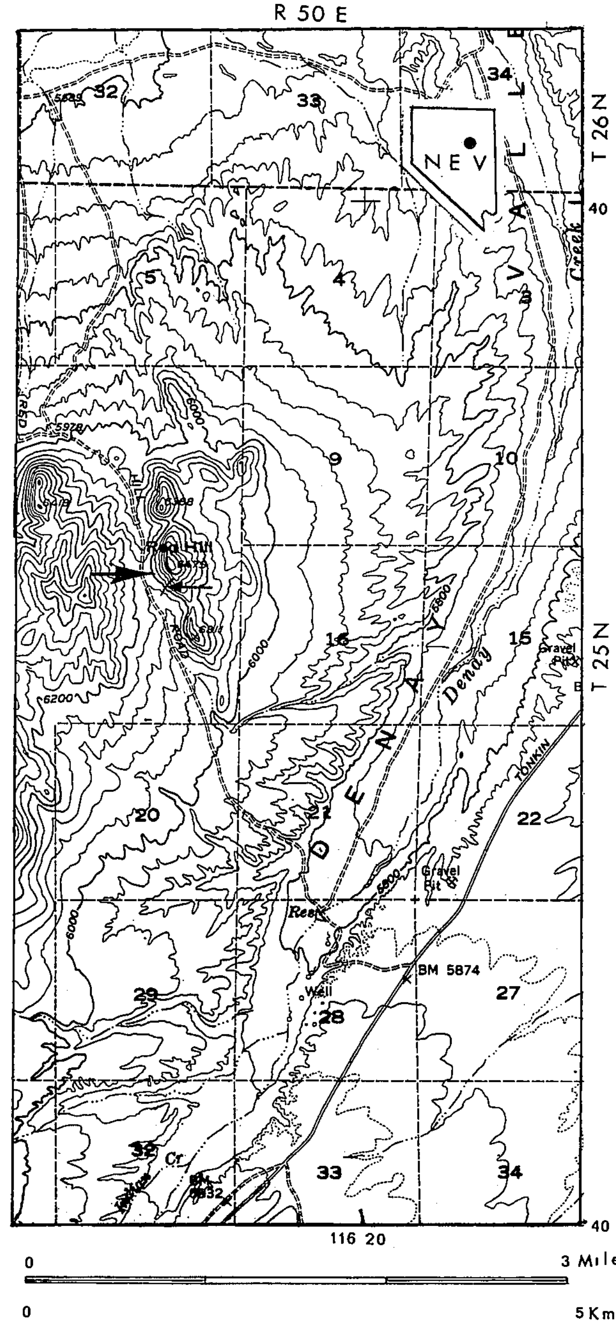


FIGURE 1.—*Index map to the sponge locality at Red Hill (large arrow) in the northeastern end of the Simpson Park Range, in the Horse Creek Valley 15-Minute Quadrangle in Eureka County, Nevada. The small arrow indicates the approximate position of the measured stratigraphic section shown in figure 2.1.*

ACKNOWLEDGMENTS

The sponge fauna was first recognized by Arthur Boucot, who gave articulated specimens from the region to the senior author in 1986 at meetings of the Geological Society of America in Reno. These included two large and some smaller blocks that were apparently sponges set aside by Schultze and his associates in their 1983 quarry operation. Most of the fossils described here, however, were collected by the Schultze field party in 1987. That crew consisted of Hans-Peter Schultze, John Chorn, and a graduate student, Mike Gottfried, all from the University of Kansas Natural History Museum, Lawrence, Kansas, and Peter Brühn, from Essen, and Erich Thomas, from Witten-Herbede, Germany. Their work was supported by National Geographic grant 3516-87 to Schultze. Lloyd and Val Gunther of Brigham City, Utah, trimmed the fossils to reduce the bulk of storage and did minor preparations on some fossil. To these workers, we express our gratitude for gift of the specimens and the care with which they collected and prepared the material and related each fossil to the detailed stratigraphy of the quarry. D. R. Nylen of the Nevada State Museum, Carson City, loaned the large specimen of (?)*Dictyospongia robusta* n. sp. for study. L. T. Bird of Brigham Young University aided in figure and manuscript preparation. Mehl's stay in the United States was financed by Deutsche Forschungsgemeinschaft within the DFG-Project Ke 322/5-3.

LOCALITY

The Red Hill locality is near the exposed bottom of a sequence of reddish, yellow, and greenish gray silty lime mudstones, approximately 60 m (200 ft.) thick, at the base of the southwest flank of Red Hill (figs. 1 and 3.1). The hill is an isolated promontory at the north end of the Simpson Park Range, in NW 1/4, NE 1/4, section 17, T. 25 N, R. 50 E, on the Horse Creek Valley 15-Minute Quadrangle in Eureka County, Nevada. The locality is at 40°03′34″ N and 116°2′07″ W, at an elevation of approximately 6220 ft.

Type and reference materials are deposited in the U.S. National Museum (USNM), except for a large part and counterpart of (?)*Dictyospongia robusta*, which are in the Nevada State Museum (CM), Carson City, Nevada.

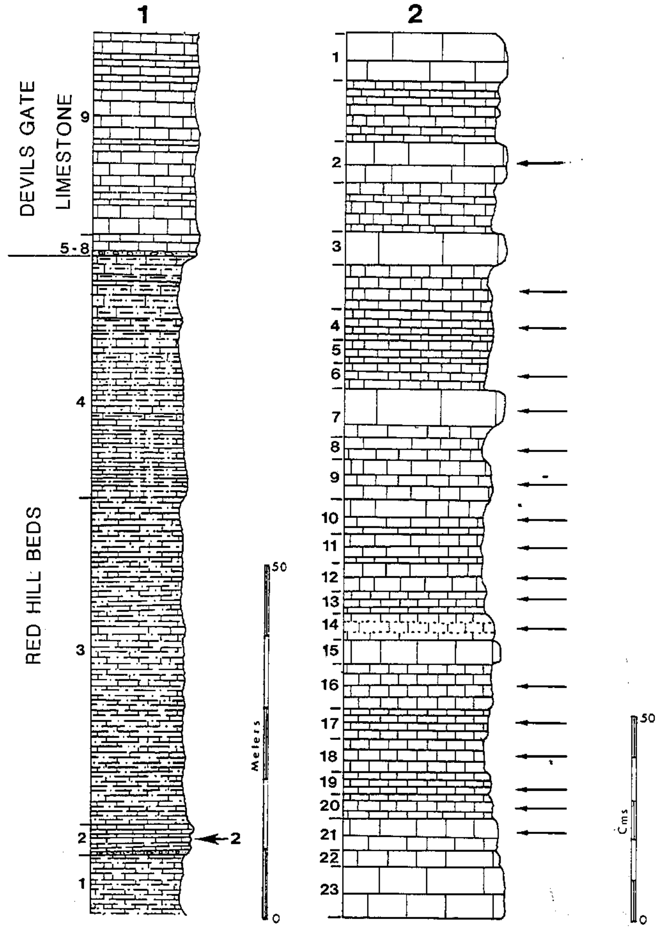


FIGURE 2.—*Stratigraphic sections exposed in the Red Hill area and in the Red Hill quarry.* 1, *Generalized stratigraphic section of Middle and Upper Devonian beds exposed on Red Hill (modified from Murphy, Morgan, and Dinley 1976). The moderately resistant Devils Gate Limestone at the top of the section forms the prominent ledges near the top of Red Hill in figure 3.1. Numbered arrow at the right, near the bottom of the section, shows the position of the detailed stratigraphic section shown in figure 2.2.* 2, *The detailed stratigraphic section of the Red Hill quarry, with numbered beds, was prepared by Schultze and coworkers during 1987. Arrows at the right show positions of sponges within the stratigraphic column, through approximately one and one-half meters of beds exposed in the quarry (figs. 3.2 and 3.3).*

SYSTEMATIC PALEONTOLOGY

Class HEXACTINELLIDA Schmidt, 1870
Subclass AMPHIDISCOPHORA F. E. Schulze, 1887
Order RETICULOSA Reid, 1958
Superfamily PROTOSPONGIOIDEA Hinde, 1887
(nom. trans. Finks, 1960)
Family PROTOSPONGIIDAE Hinde, 1887

Genus PROTOSPONGIA Salter, 1864

PROTOSPONGIA CONICA Rigby and Harris, 1979
figs. 4.1–4.3 and 5

Protospongia conica RIGBY AND HARRIS, 1979, p. 974–76, pl. 1, fig. 1, pl. 2, figs. 1, 5, text figs, 2, 3; MEHL, RIGBY, AND HOLMES, 1993, p. 109–13, figs. 2.2, 4.1, 6.3, 7.3–7.5 and 9–10.

Description. Complete larger specimen 11 mm high, with maximum width at midheight of 3.5 mm. Smaller fragment of mainly basal 1.5 mm, expands to 0.5 mm wide, with root spicules projecting 4.5 mm beyond sponge body; all spicules replaced by hematite. Larger specimen conicocylindrical with thin wall essentially only one spicule thick, expands upward from obconical base, becomes subcylindrical above 2–3 mm and narrows in upper 1.5–2.0 mm to incompletely preserved osculum.

Well-ordered skeleton with horizontal-vertical stauracts in at least two orders forming regular quadrules approximately 1.2–1.4 mm high in most of skeleton, although smaller in lower and upper 1–2 mm. First-order quadrules 0.6–0.8 mm wide, less regular than height; second-order quadrules less consistently preserved and 0.6–0.8 mm high and 0.3–0.5 mm wide; small third-order quadrules locally defined and approximately 0.3 mm wide and 0.2 mm wide.

First-order spicules appear to increase in size toward top of sponge, most with vertical rays 1.0–1.2 mm long and horizontal rays 0.8–1.0 mm long and with basal ray diameters of approximately 0.08 mm. Second-order spicules with vertical rays approximately 0.7 mm and horizontal rays 0.4–0.5 mm long and with basal ray diameters of approximately 0.04 mm. Third-order spicules with vertical rays approximately 0.3 mm and horizontal rays approximately 0.2 mm long and 0.02 mm basal ray diameter.

Proximal parts of few (3–5) possible anchoring spicule ghosts project 0.2–0.3 mm into base of sponge. Spicule diameters may have been enlarged during diagenesis and replacement, because most of these spicules have irregular outlines.

Discussion. Two specimens are identified as *Protospongia conica* Rigby and Harris, 1979, described from the Silurian of British Columbia. The species has also been reported by Mehl, Rigby, and Holmes (1993) from the Lower Devonian(?) part of the Silurian-Devonian Roberts Mountains Formation from Starvation Canyon in the Independence Mountains.

Rigby and Harris (1979, p. 106) observed that the holotype of *Protospongia conica* has only two preserved orders of spicules, but the Nevada specimens from the Independence Mountains, as well as these from the north end of the Simpson Range, have at least three spicule

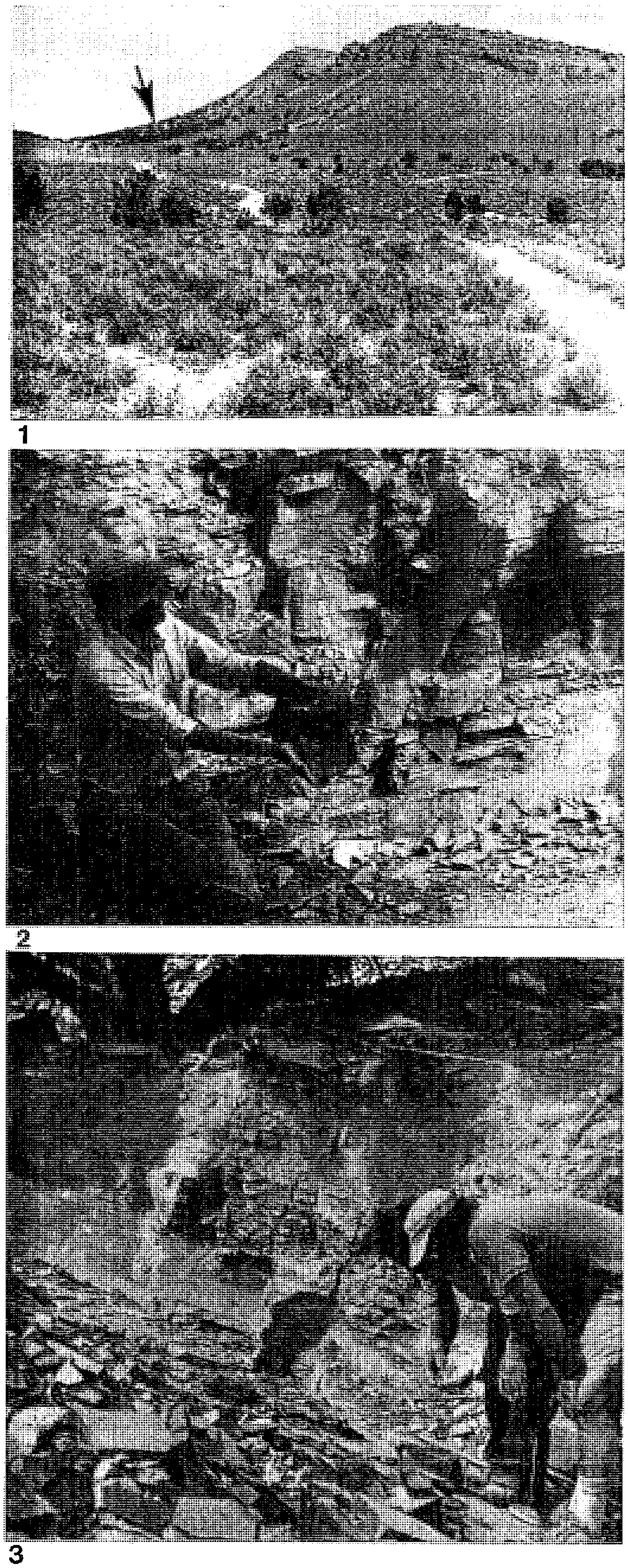


FIGURE 3.—*Position and exposures in the Red Hill quarry.* 1, *Red Hill as seen from the southeast; the arrow shows the approximate position of the Red Hill quarry in the lower part of the slope-forming Red Hill beds; ledge-forming Devils Gate Limestone caps the cuesta.* 2, *Erich Thomas in the upper Red Hill quarry, with the holotype of* Capillospongia modesta *from bed 7; painted numbers mark beds 3–10 exposed in the quarry wall behind; beds 15–17 are exposed below the sponge, near the base of the quarry wall (see fig. 2.2).* 3, *Lower or eastern quarry in which beds of the lower part of the quarry are exposed near the base of the juniper tree in the upper left; Peter Brühn and Mike Gottfried examine specimens from the thin-bedded, gray limestones.*

orders preserved, but their dimensions are in agreement with those of first- and second-order structures in *Protospongia conica.*

Protospongia spina Mehl, Rigby, and Holmes, 1993, has a quad-ruled skeleton of essentially the same dimensions as that seen in *Protospongia conica,* but in addition, *P. spina* has prominent, hooklike distal rays on coarse first-order spicules. These kinds of spicules are not developed in *P. conica,* either from British Columbia or from the Silurian-Devonian of Nevada, and are certainly not present in the small specimens seen here. *Protospongia* sp. 1 and *Protospongia* sp. 2 of Mehl, Rigby, and Holmes (1993) both have very coarse skeletal nets at least twice as large as any observed in *P. conica* and, thus, are clearly separable, and the distinctive specimen described here would certainly not fit into those coarse species.

Material. Figured specimen, USNM 463520, from bed 10, Red Hill quarry.

Superfamily DICTYOSPONGIOIDEA
Hall and Clarke, 1900
(nom. transl. Finks, 1960)
Family DICTYOSPONGIIDAE Hall and Clarke, 1900
Subfamily DICTYOSPONGIINAE Hall, 1882
Genus DICTYOSPONGIA Hall and Clarke, 1900

Diagnosis. "Elongate vaselike, with root tuft of long hairlike spicules; reticulate skeleton formed by longitudinal strands about 5 mm apart, crossed by transverse spicules 10–15 mm apart, with secondary much smaller reticulation. Well-preserved specimens may show loose spicules resembling those of living 'hyalosponges'" (de Laubenfels 1955, p. E71).

Type species. Dictyophyton sceptrum Hall, 1890.

DICTYOSPONGIA(?) ROBUSTA n. sp.
figs. 4.4–4.6, 6.2–6.4

Diagnosis. Coarse, subcylindrical dictyosponge with first-order quadrules 24–30 mm high and 16–21 mm wide; size increases upward. Skeletal straps produce second-order quadrules 15–16 mm high and 10–11 mm wide; third-order quadrules mostly 7–8 mm high and 5 mm across; fourth-order quadrules 3–4 mm high and 2–3 mm wide, locally preserved. First-order skeletal straps 1.8–2.1 mm wide and composed of bundled small, long, hairlike spicules approximately 0.05 mm in diameter.

Description. Largest fragment of coarse species is flattened impression, 28 cm tall, and ranges to 9.5 cm wide, consists of hematite replacement of pyritized skeleton, with impressions of numerous spicules in skeletal straps as hematite-stained incomplete rods. Three orders of straps and quadrules recognizable throughout most of specimen, and fourth-order in one small area; quadrules generally somewhat higher than wide and bounded moderately sharply by skeletal straps. Separate upper and lower walls of flattened specimen suggested in a few areas, with thin spongocoel fill, perhaps 0.2–0.3 mm thick, preserved in middle part; sides of specimen not clearly defined, so total width and height of sponge not defined, but coarseness of skeletal net suggests sponge may have been several times larger than preserved in even largest fragment.

First-order quadrules range 24–30 mm high, with sizes increasing toward what is considered as upper part of sponge; same quadrules range 16–21 mm wide, with sizes increasing slightly upward; most first-order quadrules 18–19 mm wide in lower and middle part, but increase to 19–21 mm wide in upper part; all moderately regular and bounded by prominent wide straps.

Second-order quadrules slightly higher than wide, range 13–16 mm high with most 15–16 mm high; quadrule sizes in upper part slightly larger than in middle and lower part; same quadrules range 8–12 mm wide, with most approximately 10 or 11 mm wide with moderate uniformity.

Third-order quadrules range 6–11 mm high, with most approximately 7 or 8 mm high, and range 4–7 mm wide, with most approximately 5 mm across. Fourth-order quadrules 3–4 mm high and 2–3 mm wide preserved as few quadrangles in lower, better preserved part of specimen.

Vertical and horizontal first-order straps range 1.8–2.1 mm wide in narrower part but flare slightly in intersections, where hairlike spicules and spicule rays obviously interdigitate while maintaining essentially straight courses and probably produced slight knobs or nodes at intersections, but these not apparent in either specimen, although individual straps show as slight ridges when viewed in low-angle tangential light.

Both vertical and horizontal second-order straps approximately 1.5 mm wide; in some areas as many as 20 spicules moderately clearly identified in limonite-stained replacements, but these must represent only small part of spicules in individual tracts.

Third-order straps approximately 1 mm wide with both horizontal and vertical straps of essentially same dimensions. In these, 10–15 spicules can be identified in single cross sections in a few areas where microscopic details best preserved.

Fourth-order tracts 0.5–0.6 mm wide where spicules preserved essentially only as series of small hematite dots representing positions of spicules.

All tracts appear composed of small, long, hairlike spicules, and none include clearly defined hexactines, but details largely destroyed in two or three replacements; where bits of spicules preserved they appear to be 0.05

mm in diameter as segments a few millimeters long, but total lengths of spicules impossible to determine because of tress- or ropelike nature of skeleton; spicules evident only as hematite-stained impressions.

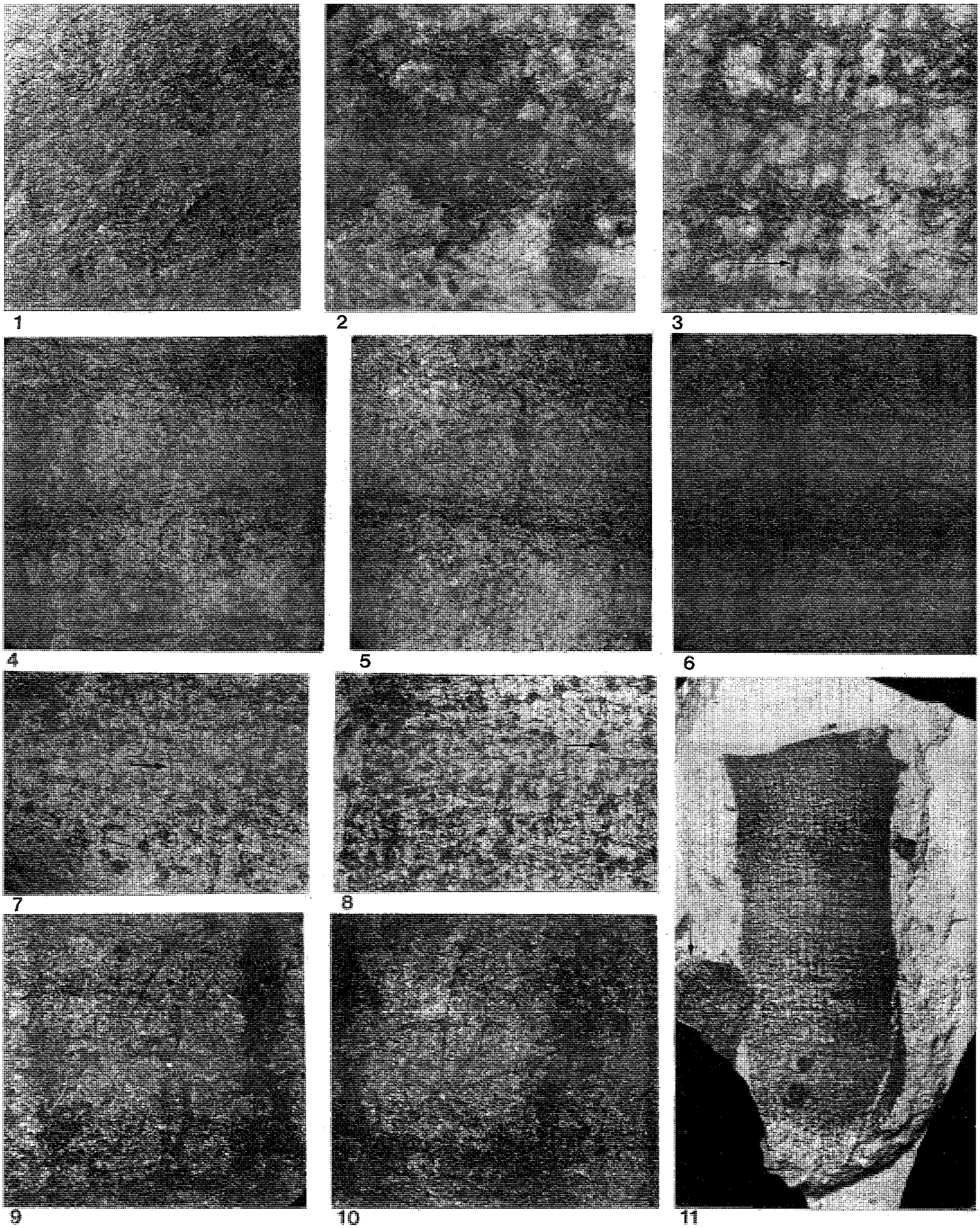
Spicules moderately widely spaced in most straps so perhaps only 50% of volume of any individual strap cross section represented by spicules. Relationships uncertain, however, because of cycles of replacement and diagenesis, plus flattening. Intensely hematite-stained section of specimen may include complete margin; composed of numerous subparallel hematite-replaced spicule impressions essentially same size as impressions within reticulate skeleton, but side region lacks evidence of reticulation and appears more like root tuft arranged moderately parallel to reticulate part of sponge skeleton; whether different structures related or "by chance" juxtaposition remains uncertain. As with spicules within body of sponge, total dimensions of spicules in presumed root tuft not preserved, some sections of tuft with spicules to 0.05 mm in diameter and fragments to 2–3 mm long, although most appear as much shorter loglike impressions in moderately compact and closely spaced, hematite-replaced structure.

Additional smaller fragment with same general quadrule and spicule strap dimensions, except some first-order straps to 2 mm wide. Hematite blebs suggest smaller spicules in fourth-order quadrules but obscure. Fragment also with thin lens of spongocoel filled traceable to preserved edge, suggests wall only approximately 1 mm thick at folded, flattened upper margin. No marginalia or sculpture shown on edge.

Discussion. De Laubenfels (1955, p. E71–E74) recognized two subgroups within the Dictyospongiidae; the subfamily Dictyospongiinae Hall, 1882, characterized by lack of a prismatic shape; and the subfamily Prismodictyinae de Laubenfels, 1955, with polygonal transverse sections. Although our specimen is flattened, it appears to belong in the Dictyospongiinae and to be part of a tubular or upright cylindrical sponge. *Dictyospongia* Hall and Clarke, 1900, is an elongate, vaselike cylindrical form throughout most of its length. *Cyathodictya* Hall and Clarke, 1900, also has a tubular central section, but has a tapered base and an upper oscular margin. Because the sponge from Nevada shows only a gentle upward expansion, we have included it, with some reservation, within *Dictyospongia.*

Hydriodictya Hall and Clarke, 1900, is an upward-obconical expanded form, and obviously has a shape different from our specimen. *Lebedictya* Hall and Clarke, 1900, may have a subcylindrical section, although it, too, appears more commonly as an upward-expanding obconical form. The flaring thistle tubelike shape of *Thamnodictya* Hall, 1884, and the radial lobate form typical of *Cleodictya* Hall, 1884, are distinctly different from the smooth tubular cylindrical sponge seen here.

FIGURE 4.—*Specimens of* Protospongia, Dictyospongia *(?), and* Cyathophycella *from the Red Hill quarry.* 1–3, Protospongia conica *Rigby and Harris, 1979, USNM 463520, bed 10;* 1, *Small, nearly complete specimen with typical conicocylindrical form and well-ordered skeleton of horizontally and vertically arranged stauracts forming quadrules of at least two orders in lower center; undetermined sponge fragments in upper right, X2;* 2, *Rounded base of sponge shows convergence of vertical rays of stauracts toward rounded, somewhat pointed base; proximal part of anchoring spicule(?) indicated by arrow, but such spicules do not project beyond the base, X12;* 3, *Photomicrograph of middle wall, with surface wet with water, shows at least two orders of quadrules of regularly arranged stauractines; second order (arrow) well defined in quadrules formed by somewhat more coarsely preserved first-order elements, X12.* 4–6, Dictyospongia*(?)* robusta *n. sp., holotype, photomicrographs of CM-4205-H-1 from Red Hill quarry; all pictures show bundled tracts of small, long, hairlike spicules in moderately open tracts, in reticulate quadruled skeleton; most show to fourth-order quadrules and third- and fourth-order straps, except fig. 4.6, which shows a prominent first-order vertical and horizontal strap in the skeleton.* 7, 8, 11, Cyathophycella minuta *n. sp., holotype, USNM 463531, Red Hill quarry; and paratype, USNM 463532, small partial skeletal element in left of figure 11, from bed 21.* 7, 8, *Photomicrographs of skeletal net of microreticulate nature in which tracts are composed of rectangularly arranged small hexactines or hexactine-derived spicules that commonly produce knots of limonite replacement where aligned in first- and second-order tracts; hexactine nature of spicules shows best by arrow in figure 7 and knots of limonite replacement shows best by arrow in figure 8; figure 7 from near the central base of the holotype; figure 8 from approximately the middle of the left wall on holotype,* 7, 8, *X5.* 11, *Entire holotype and paratype; holotype subcylindrical, thin-walled sponge with reticulate quadruled skeletal structure defined by limonite-replaced spicules arranged in microreticulate tracts rather than bundles; neither exact base nor oscular margin preserved in holotype, but somewhat convergent margin does show in paratype along the left, which also includes a thin lens of spongocoel filling matrix and documents that the walls were thin (arrow).* 9, 10, Cyathophycella grossa *n. sp., paratype, USNM 463534, both X5, show microreticulate, quadrule-arranged spicules in skeletal tracts rather than bundled fine fibers; hexactine-based parallel, oriented spicules, in the central part of quadrules, divide them somewhat irregularly, unlike regular pattern of* Protospongia, *bed 16; both views are of upper left of skeleton as figured in 8.7, X5.*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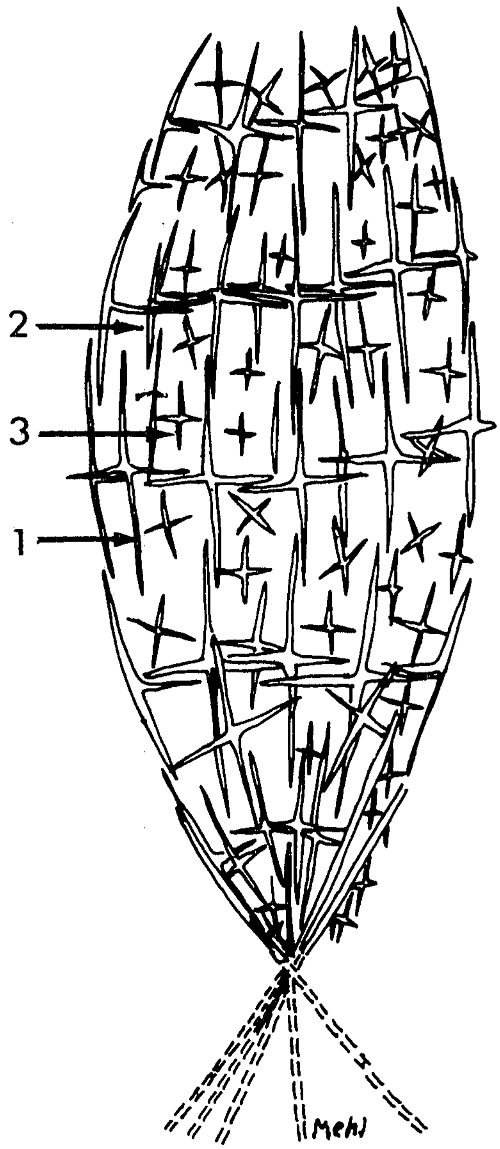


FIGURE 5.—*Diagrammatic reconstruction of a fairly complete specimen of* Protospongia conica. *Inferred projection of anchoring spicules shows beyond the base of the sponge. First-, second-, and third-order spicules are indicated by numbered arrows. Based on USNM 463520, shown in figures 4.1–4.3, from bed 10, Red Hill quarry, approximately X5.*

Among the sponges described by Hall and Clarke (1900), *Dictyospongia sceptrum* (Hall 1890) is a tubular form, but is considerably smaller in diameter and in overall mesh relationships than *D.*(?) *robusta* described here. The same could be said for *D. euromorpha* Hall and Clarke, 1900, *D. charita* Hall and Clarke, 1900, and *D. lophura* Hall and Clarke, 1900, all of which are small species, at least an order of magnitude smaller than the Nevada form.

In some ways *Thysanodictya rudis* (Hall 1863) may be somewhat similar. However, *Thysanodictya* has a three-dimensional reticulate skeleton that produces prominent nodes and an almost scalloped appearance in its skeletal pattern. In addition *T. rudis* has first-order quadrules only about the same size as second-order quadrules in the Nevada form. *Thysanodictya apeleta* Hall and Clarke, 1900, appears to be a section of a large sponge that may have first-order quadrules of essentially the same size as those in the Nevada form, with three well-preserved orders of quadrules and straps, but again the scalloped depressed areas between the major quadrules are not evident in the Nevada specimen.

A coarser skeletal net, somewhat similar to the Nevada *Dictyospongia*(?) *robusta,* was recorded by Hall and Clarke (1900) as *Thysanodictya hermenia* Hall and Clarke, 1900, but that latter form has only indented, scalloped, first-order tracts preserved in the holotype for that species. A better specimen figured by Hall and Clarke (1900, pl. XL, fig. 3), does show quadrate subdivisions of the large quadrule and a skeleton net not vastly different from our Nevada specimen.

Clathrospongia caprodonta Hall and Clarke, 1900, has moderately large first-order quadrules and coarse first-order straps, but the quadrules are not subdivided by clearly defined orders of reduced size, so that its first-order quadrules are filled with a gridlike net, rather than an ordered reticulation.

The Nevada material is, thus, considered to constitute a new species of *Dictyospongia*(?), based on its overall sponge size and dimensions of the skeletal net. Because the complete form is not known, the generic assignment is questionable.

Available material. The part and counterpart holotype of the large sponge, CM-4205-H-1a,b in the Nevada State Museum, was collected from Red Hill quarry, but its stratigraphic position within the Red Hill section is uncertain. A smaller paratype fragment and partial counterpart, USNM 463521, are from bed 19, and it is probable that the larger specimen came from the same bed in the Red Hill quarry section. A less well preserved and exposed part and counterpart from bed 20 may also belong in this species.

Etymology. Robustus, L., strong and hard like oak, referring to the strong, robust skeleton of the species.

DICTYOSPONGIA(?) AMPLIA n. sp.
fig. 6.1

Diagnosis. Dictyosponge with very large quadrate reticulate grid with first-order quadrules 30–40 mm high and 23–28 mm wide; bounded by wide tracts 2–3 mm wide; smaller ranked second-, third-, and fourth-order quadrules each approximately one-half size of the larger orders; shape of sponge unknown.

Description. Two moderate size fragments show very large quadrate grids in reticulate skeleton; larger fragment, approximately 18 cm high and to 10 cm wide, shows coarse reticulate grid in massive hematite replacement; direction of growth indicated by upward branching of first-order tracts and quadrules, suggest tubular or conicocylindrical coarse sponge. First-order quadrules 30–40 mm high and 23–28 mm wide, measured center-to-center of coarse, wide straps; vertical first-order straps range 2.0–2.5 mm wide and horizontal ones 2.0–3.0 mm wide, both apparently composed of numerous, long rays, but details of skeletal structure lost in coarse replacement, but impressions of rodlike rays show.

Second-order openings 15–20 mm high and 12–15 mm wide; defined by vertical and horizontal second-order straps 1.0–1.5 mm wide. Third-order quadrules to approximately 10 mm high and 8 mm wide, with moderate irregularity, more apparent in coarser openings with straps approximately 1 mm wide, but only irregularly preserved. Fourth-order quadrules range 4–7 mm high and 4–5 mm wide, even more irregularly preserved and with more irregular dimensions. Smaller quadrules not preserved, but small blebs of hematite occur throughout irregular openings and suggest perhaps even finer spicules originally present, but not preserved.

Vertical tracts branch upward, become subparallel in 2–3 first-order quadrules, so overall tendency for distinct, vertical parallelism. Available fragments probably flattened diagonally because quadrules generally rhomb-shaped, at least in part.

Rare irregular diagonal tracts present on one fragment and partial counterpart; relationship to principal skeleton unknown. Lateral margins, bases, and oscular margins not preserved, hence total dimensions of coarse sponge unknown, but probably large.

Discussion. In terms of skeletal dimensions, this is the coarsest textured sponge in the Red Hill collections, for its quadrules are largest and spicular straps are the widest. Because of this, these fragmental specimens have been assigned to a species distinct from *Dictyospongia*(?) *robusta* n. sp., even though both show some vertical change in quadrule size, particularly evident in *Dictyospongia*(?) *robusta.* Overall dimensions, however, are very different, and therefore we have separated them as distinct species. Even though quadrule measurements and strap size may increase upward in the juvenile areas in dictyospongid skeletons, they change less in middle and upper areas. Specimens of both species described here are from the more or less cylindrical "mature" parts of skeletons. Because of consistent differences in dimensions of skeletal structures, they are unlikely to represent only ontogenetic differences in a single species. Uncertainty, however, can be removed only by discovery of more nearly complete specimens. Both taxa are named in spite of their fragmental nature because they are so much coarser than previously described species.

Comparisons of coarse textured dictyosponges had been made with similar coarse textured *Thysanodictya* and *Clathrospongia* in discussion of *Dictyospongia*(?) *robusta.* The same comparisons and ways of differentiation could be made with the coarse textured form described here.

Material. Holotype, USNM 463522, and, paratype, USNM 463523, and partial counterparts, all from bed 19 of the Red Hill quarry.

Etymology. Amplius, L., larger, in reference to the large size of the reticulate skeletal grid.

Genus ACTINODICTYA Hall, 1890

Revised diagnosis. Explanate, somewhat irregularly grown dictyosponges, surface low convex, perhaps with broad oval outline; surface of specimens crossed in all directions by interlaced spicular bands in conspicuous irregularity, but with certain degree of rectangular reticulation among both coarser and finer bands; coarse bands comparatively few; differences in size in coarse and fine reticulation gradational; irregular intersections of spicular bands give skeleton somewhat stellate aspect; one layer with more or less parallel and regularly arranged stauractines or hexactines.

Type species. Actinodictya placenta Hall, 1890.

ACTINODICTYA NEVADENSIS n. sp.
figs. 7.3, 7.4, and 8.1

Diagnosis. Irregularly palmate to funnel-shaped dictyosponges with skeleton composed of variously sized stauractines and hexactines irregularly oriented and spaced. Largest spicules with rays 10–20 mm long and 0.04–0.05 mm in basal diameter. Irregularly oriented smaller, possible second-order spicules to fourth-order approximately half the size of larger orders. Rays may overlap to form small discontinuous irregular fibers.

Description. Somewhat rhomboidal-shaped fragments up to 8 X 10 cm across composed of moderately irregularly oriented and spaced, variously sized stauractines and possible hexactines; rays of largest spicules thin, 15–20 mm long, and generally arranged at mutual 90°, most moderately straight, although several gently curved C- and S-shaped; major first-order spicule ray junctions irregularly approximately 5 mm apart; ray junctions commonly marked by small hemispherical hematite masses up to 0.5 mm in diameter, may represent proximal-distal rays or possible clusters of organic bonding material. Rays overlap and 2–4 subparallel in cross sections of fibers.

Central canals to approximately 0.08 mm in diameter, evident in many spicules; canal fillings and cylindrical calcareous rods, most with basal diameters to approximately 0.04–0.05 mm, and 0.02–0.03 mm in diameter at approximate midlength; fillings gently taper and surrounded by irregular hematite rind, either coating around initial small spicule, or spicules irregularly replaced by pyrite now altered to hematite.

Numerous, smaller, perhaps second-order spicules with rays to 10 mm long, and basal ray diameters of approximately 0.04 mm. Smaller possible third-order spicules with rays approximately 5 mm long and basal ray diameters of 0.02 mm; what appear as relatively small fourth-order spicules with rays 2–3 mm long and basal ray diameters of approximately 0.01–0.02 mm as smallest preserved. Most spicules at least superficially stauractines; some hematite hemispheres at ray junctions appear with axial canals 0.02–0.04 mm in diameter, oriented approximately at right angles to four tangential rays parallel to stratification, indicating at least some spicules are hexactines because of presence of proximal-distal rays. Skeletal net extends through approximately 3–4 mm of limestone, indicates moderately thick, but open-textured skeleton for species.

Discussion. Actinodictya placenta Hall, 1890, as figured in Hall and Clarke (1900, pl. 30, figs. 1–3; pl. 31, figs. 1, 2), has a general appearance similar to our species, but Hall and Clarke's species is significantly coarser textured. *A. placenta* has major coarse spicules several times the size of similar spicules in the Nevada *A. nevadensis* n. sp., both in terms of diameters of the coarse stauractine spicules, as well as in ray lengths of spicules of thin diagonal tracts. Both species show a basically obscure, but certain, rectangular placement of the small spicules, which indicates that in both Nevada and New York species the irregular skeleton is not merely a strew of dissociated spicules, but part of a skeletal net showing some irregularity. It is primarily differences in sizes of skeletal elements that separates the two species discussed above, with *A. nevadensis* n. sp. having the distinctly finer texture of the two.

In the material from Red Hill, *Actinodictya nevadensis* n. sp. is considerably coarser than *A. lamina* n. sp., which also has more numerous, fibrous-appearing tracts composed of longer spicule rays than those in *A. nevadensis* n. sp. *A. nevadensis* n. sp. also lacks the crude horizontal and vertical fibrous tracts evident in *A. lamina* n. sp.

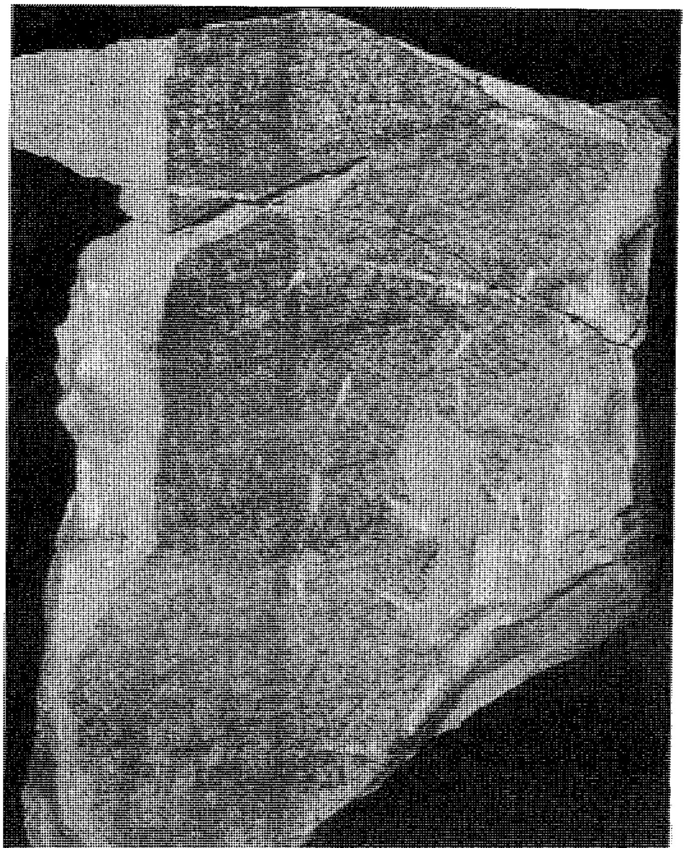
Material. Holotype, USNM 463524, part and counterpart, specimen 1–3 from bed 16; paratype, USNM 463525, from bed 5, and an unnumbered reference specimen 4 from bed 10. The paratype is an approximately rhombic-shaped fragment, 5 X 6 cm, and the small reference specimen 4 is a rectangular fragment 2.5 X 6 cm across, all from the Red Hill quarry.

Etymology. Nevadensis, for Nevada, where the species was first found.

ACTINODICTYA LAMINA n. sp.
figs. 7.1, 7.2, 8.2, 8.3, 8.5, 8.6

Diagnosis. Steeply obconical, cylindrical(?) dictyosponge, inner(?) skeletal wall a protosponge-like layer of distinctively separated, but well-oriented stauractines;

FIGURE 6.—*Species of* Dictyospongia(?) *from the Red Hill quarry.* 1, Dictyospongia(?) amplia *n. sp., holotype, USNM 463522, bed 19; very large reticular grid shows first-order quadrules 30–40 mm high, and with coarse straps; these quadrules are subdivided into second-, third-, and fourth-order openings by smaller tracts; full dimensions of sponge not known because of fragmentary preservations; somewhat rhombic pattern to reticular grid probably a result of diagonal flattening during burial and diagenesis, X1.* 2–4, Dictyospongia(?) robusta *n. sp. from bed 19; 2, 4, Holotype, CSM-4205-H-1b, largest fragment of the sponge known, shows the moderately coarse quadruled skeletal net outlined by first-order straps approximately 2 mm across; general parallel form of skeletal net suggests a coarse, subcylindrical dictyosponge, but neither top, bottom, nor the complete width is preserved in the fragment collected; skeleton preserved as relatively massive hematite locally with gentle molds of the skeletal impression, X0.5; 4, Skeletal structure of well-preserved part of the holotype fragment, approximately three first-order quadrules wide, with wide prominent vertical and horizontal straps; quadrules subdivided to second, third, and fourth order by smaller straps best shown near the middle of the photograph; counterpart to figure 2, X1; 3, Paratype, USNM 463521, bed 19, shows same general size of quadrules and skeletal structure as seen in the holotype, although with hematite-replaced skeletal structure not preserved with moldlike arrangement, but flattened during burial and diagenesis, X1.*



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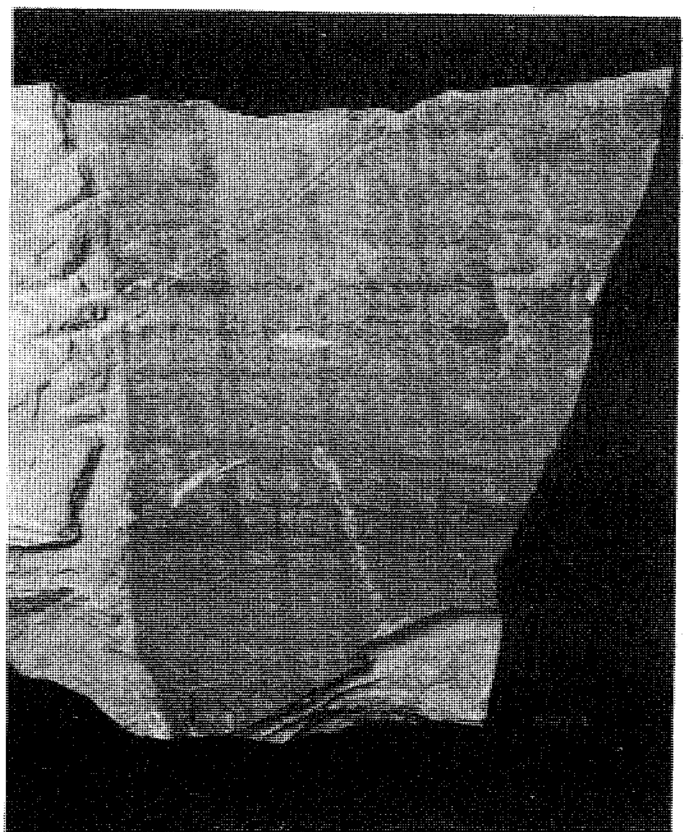

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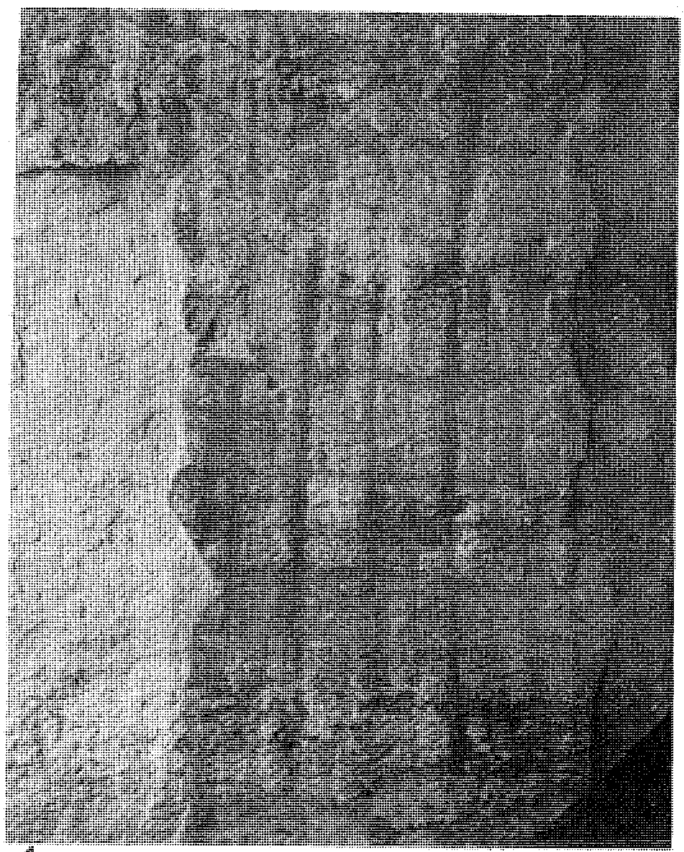

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and overlying(?) layer of tracts of two kinds; one weakly defining large quadrules and the other irregularly oriented and spaced. Inner large quadrules 2.0–2.5 cm wide and approximately 1.5 cm high. Spicules of tracts with long rays 40–50 mm long; tracts usually with coarse hexactines or stauractines in tract junctions.

Description. Steeply obconical cylindrical(?) sponge with skeleton of at least two parts, an underlying(?) protosponge-like layer composed in large part of distinctive separated and well-oriented stauractines; overlying(?) layer of tracts of two kinds, one, essentially weakly defining moderately large quadrules, and other intimately associated layer of variously oriented and irregularly spaced tracts.

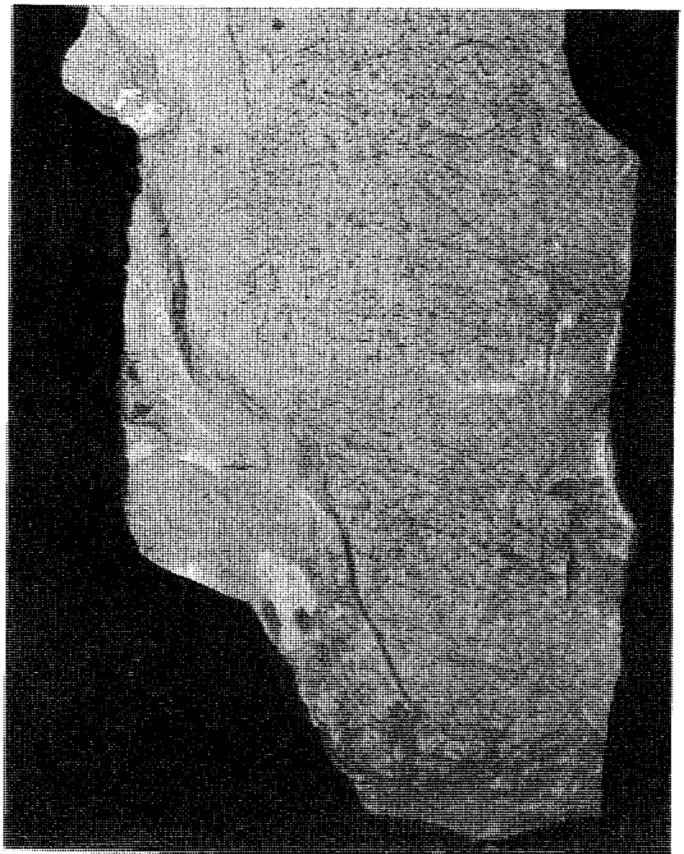
Holotype fragment 4 cm high and 7 cm wide, with orientation based on general upward divergence of tracts and spicule dimensions in associated somewhat larger, though less well preserved, specimen; larger quadrules in holotype 2.0–2.5 cm wide and approximately 1.5 cm high; bounded by weak bundles of long-rayed, thin, delicate spicules in orientation parallel to protosponge-like stauractine layer of skeleton. Vertical and horizontal tracts weakly defined, clusters may be discontinuous but certainly composed of thin spicules 10–20 mm long in tracts up to 1.0–1.5 mm wide, with considerable irregularity, most usually narrower; tracts may be offset 2–3 mm and arranged en echelon as one tract becomes discontinuous and another offset and overlapped several millimeters.

Tracts usually with coarse hexactines or stauractines in tract junctions but not consistently; rays range to 40–50 mm long, and perhaps longer, with very gentle taper, overlapping, and distinctively subparallel in many areas, but may splay horse-tail-like in both reticulated and diagonal tracts. Diagonal tracts of essentially same general dimensions as those in more regular part of skeleton; composed of 10–20 long rays, irregular diagonal arrangement without particular spacing or orientation, but apparently integral part of rectangular tract system, overlying and underlying reticular tract, and may interdigitate with them.

Long, hairlike spicules range to 0.06–0.10 mm in diameter, but most spicule segments 0.02–0.04 mm in diameter, with long smooth taper to sharp tips; delicate spicules rarely traceable for entire length because of incomplete replacement. Somewhat coarser-appearing stauracts with rays to 10 mm long and with basal ray diameters to 0.2 mm; relatively coarse rays taper quickly and become fine spicules at midlength, essentially like those of tracts of skeleton. Many stauracts with preserved central canals approximately 0.02–0.03 mm in diameter, most noticeable in proximal parts of rays. Nodes or remnants of axial canals suggest some spicules hexactines, but evidence inconclusive. Numerous, small circular blebs of hematite occur on bedding planes, but most concentrated within sponge impression, suggesting hematite replacements of proximal-distal rays, but exposures along fractured sides show no certain proximal-distal rays. Small stauractines of that part of skeletal layer with rays 2–3 mm long and with basal ray diameters of 0.05–0.10 mm, irregularly preserved and commonly only irregularly replaced hematitic structures. Smallest spicules have rays approximately 0.2–0.3 mm long with basal ray diameters maximum of 0.02 mm. Small spicules generally oriented parallel to intermediate and coarsest stauracts in protosponge-type layer within skeleton.

Less well preserved paratype somewhat rectangular fragment, approximately 13 mm high and to 6 mm across, shows same general skeletal structure of well-oriented stauractines in protosponge-like layer, with overlying layer composed of moderately well organized tracts that define quadrules, now distorted to rhombic openings apparently by diagonal flattening; this layer associated with numerous tracts of irregular orientation as in holotype. Vertical tracts diverge upward from separation of

FIGURE 7.—*Species of* Actinodictya *from the Red Hill quarry.* 1, 2, Actinodictya lamina *n. sp.* 1, *Paratype fragment with prominent irregular tracts composed of spicules with long rays forming crude large quadrules, in addition to other variously oriented and irregularly spaced tracts, over a protosponge-like layer which shows prominent regularity in orientation of the hexactine-based spicules; tracts show best along the right and the associated protosponge-like layer shows best along the left, USNM 463530, bed 19, X1;* 2, *Holotype shows characteristic double-layered skeletal structure of irregular tracts composed of long spicules and underlying, more regular, protosponge-like layer of the skeletal net; tracts prominent in middle and right, and the protosponge-like layer prominent in the lower left; Y-shaped impressions near the bottom is a plant fragment, USNM 463526, bed 11, X1.* 3, 4, Actinodictya nevadensis *n. sp., holotype, part and counterpart, USNM 463524, bed 16; skeleton composed of variously sized stauractines and hexactines with irregular orientation; rays may overlap, as for example, in the center to produce weak irregular fibers that included some of the coarsest hexactine-based spicules observed in the collection; smaller spicules occur between coarse elements in the hematite replacement; figure 3 rotated 90° from figure 4, X1.*



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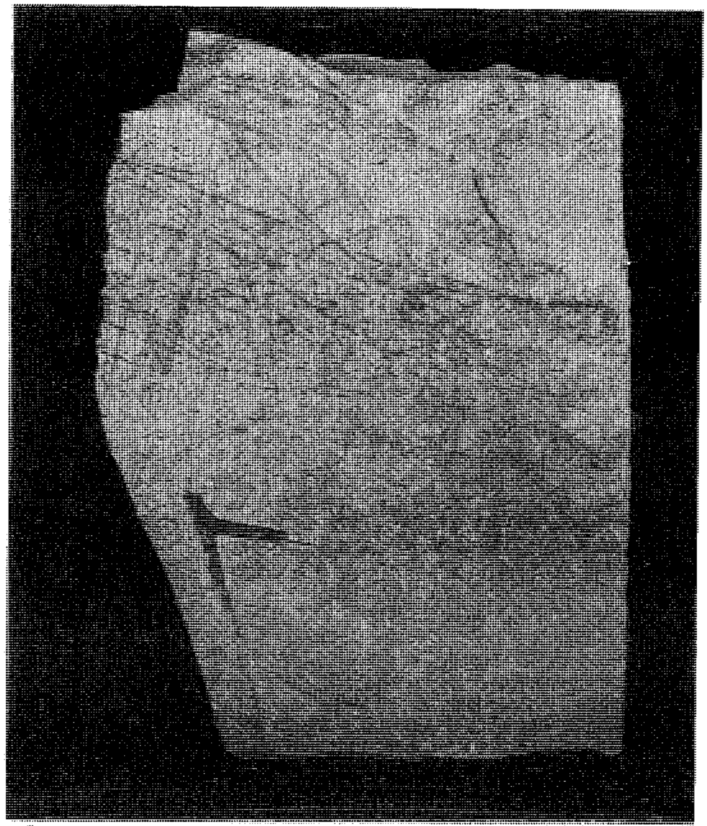

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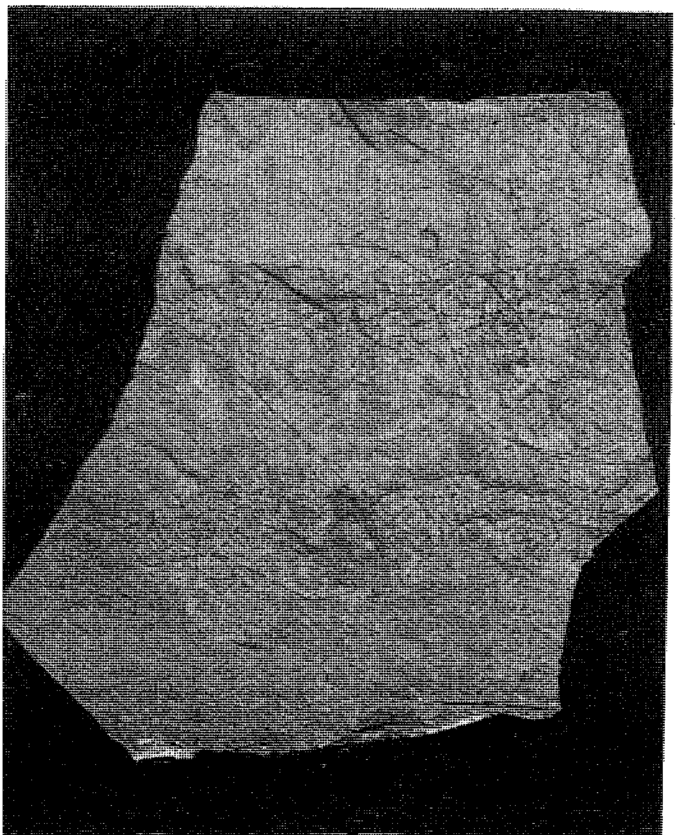

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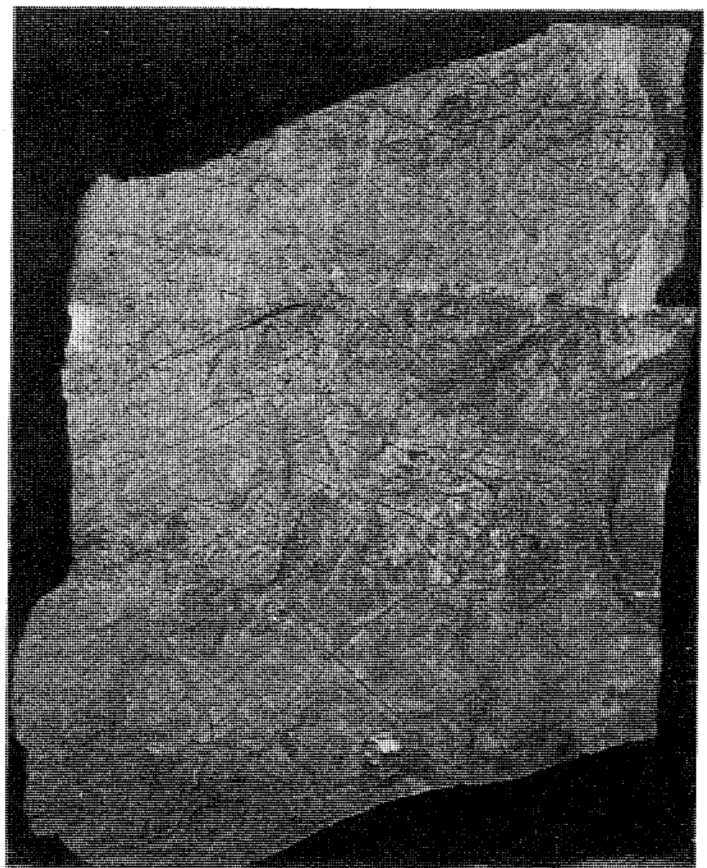

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approximately 1 cm in lower part of sponge to approximately 1.5–2.0 cm across in upper part of fragment; produce quadrules approximately 1.2–1.8 cm high with considerable variation; only first-order tracts developed. As in holotype, tracts approximately 1–3 mm wide, with most approximately 2 mm wide, and apparently composed of several, moderately widely spaced, subparallel, long spicules. Details largely destroyed in coarse hematitic preservation, but gross fabric moderately well preserved in spotty hematite replacement.

Discussion. This species of *Actinodictya* from the Red Hill quarry is most similar to *Actinodictya placenta* Hall (Hall and Clarke, 1900, pl. 30, figs. 1–3; pl. 31, figs. 1, 2), except spicular bands in the New York Devonian Chemung species are considerably coarser than in the Nevada species. In addition, the faint reticulate quadrule-defining tracts developed in *Actinodictya lamina* are not evident in the New York species, although both have the irregular tracts above a moderately uniformly developed protosponge-type layer. Hall and Clarke (1900, p. 950) concluded that the species *A. placenta* may be a broadly convex expansion with a definite suboval marginal outline. This seems unlikely, and it appears to us that the Devonian fragments figured by them are considerably more incomplete than they initially considered. Indeed, the Nevada species appears to have been a steeply obconical form, based on the gradual and moderately uniform upward expansion of the irregular, though discontinuous, reticulate net. That structure is best seen in the paratypes.

Comparisons with *Actinodictya nevadensis* n. sp. have been presented under treatment of that species.

Material. Holotype, USNM 463526, from bed 11, and associated paratypes, USNM 463527–463529, samples 2, 3, 4 from bed 11; paratype USNM 463530, part and counterpart from bed 19 and two unnumbered reference specimens questionably referred to the species from bed 10.

Etymology. Lamina, L., a thin sheet or plate, referring to layered nature of the skeleton.

Genus CYATHOPHYCELLA Rigby and Stuart, 1988

Diagnosis. "Thin-walled dictyosponges in which vertical and horizontal tracts are composed of latticelike rectangularly arranged hexactines and hexactine derivatives occurring in ranked arrangements within individual tracts" (Rigby and Stuart 1988, p. 135).

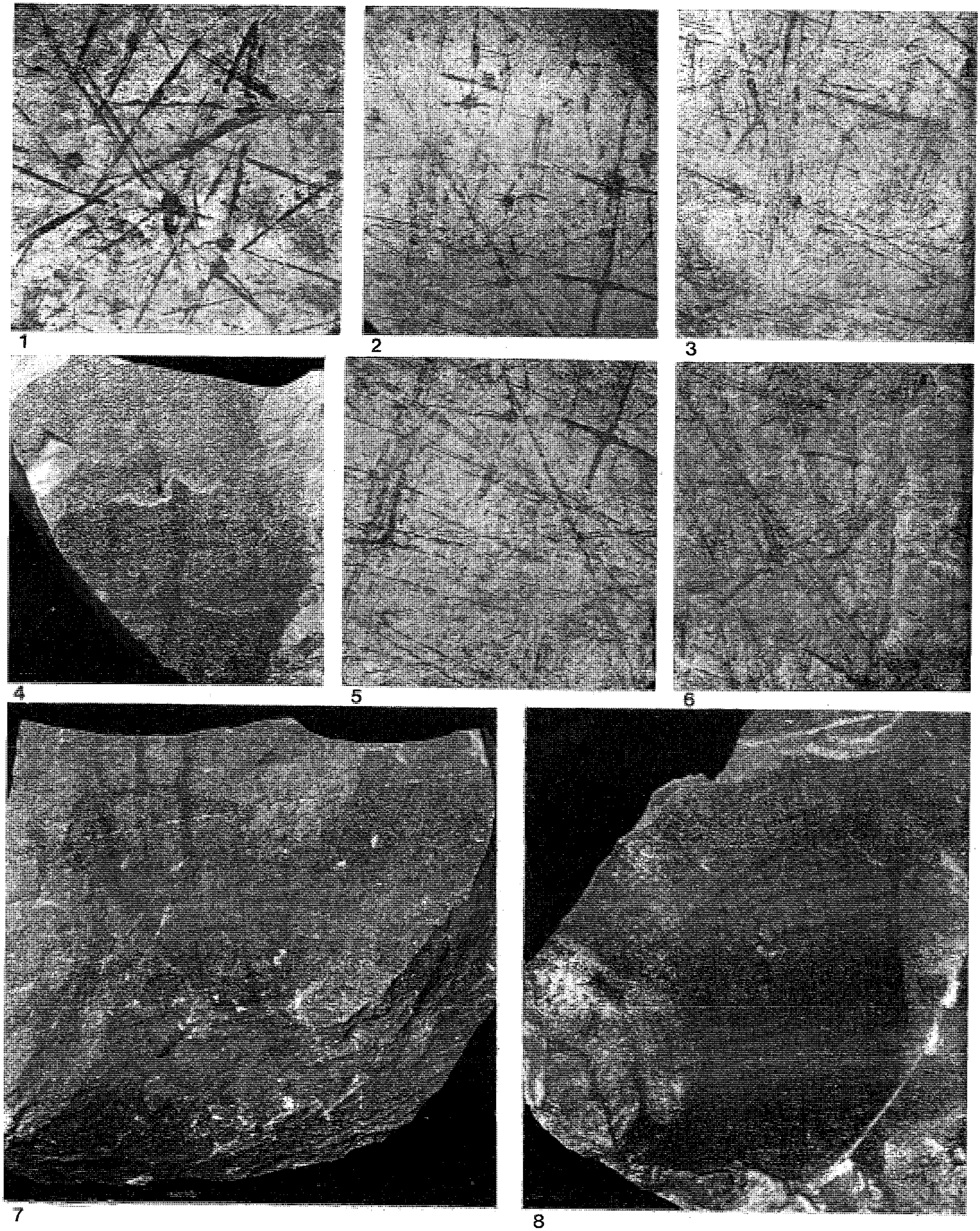
Type species. Cyathophycella quadrata Rigby and Stuart, 1988.

CYATHOPHYCELLA MINUTA n. sp.
figs. 4.7, 4.8 and 4.11

Diagnosis. Cylindrical, thin-walled dictyosponges with skeletal net tracts composed of microreticulate structure, characteristic of genus, and skeleton in ranked orders to the third order; first-order tracts separated approximately 2 mm near base, but diverge upward to approximately 4 mm apart and with tracts 0.4–0.8 mm wide. Coarsest spicules hexactines or hexactine-derived with rays to 1 mm long and basal ray diameters of 0.10 mm. Most common spicules stauracts with rays to 0.8 mm long, and basal diameters to 0.08 mm form microreticulate tracts, rather than protosponge quadrules with simple rays; lacks long bundled rays of dictyospongiids. Spicules spaced generally regularly 0.05–0.10 mm apart in skeletal tracts.

Description. Generally cylindrical thin-walled sponges with deep open spongocoel; rounded base, may flare in

FIGURE 8.—*Photomicrographs of* Actinodictya *species and natural-size specimens of* Cyathophycella grossa *n. sp. from Red Hill quarry.* 1, Actinodictya nevadensis *n. sp., holotype, USNM 463524, X5, from bed 16; relatively coarse hexactine-based spicules clearly show their long coarse rays and irregular orientation; circular dark dots appear to represent proximal-distal rays of shallowly buried spicules, but may be only artifacts of preservation; expanded masses of hematite at ray junctions are typical of many sponges from the Red Hill quarry, X5.* 2, 3, 5, 6, Actinodictia lamina *n. sp., photomicrographs show the general skeletal structure with bundled tracts of long hairlike spicules above a more regularly organized protosponge-like layer of the skeleton; the later perhaps shows best in* 2 *and along the right of* 6; 2, 3, 5, *holotype, USNM 463526 and* 6, *paratype USNM 463527, all from bed 11, X5.* 4, 7, 8, Cyathophycella grossa *n. sp., all from bed 16;* 4, *paratype, USNM 463535, shows general curvilinear nature of skeletal tracts with skeleton now preserved only as a series of hematite dots; more closely spaced where microreticulate skeletal tracts occur; a light-colored thin matrix lens near the middle, arrow, separates upper and lower walls of the flattened sponge; right margin essentially complete; specimen shows the thin nature of the walls of the species, X1;* 7, *paratype shows curvilinear nature of quadruled skeletal elements and general gradation from a skeleton of clearly coarse tracts on the left to less-pronounced tracts on the right; neither oscular margin nor probable stemlike lower part preserved; lateral variation in curved skeletal quadrules characteristic, USNM 463534, from bed 16, X1;* 8, *holotype, USNM 463533, from bed 16, shows apparent stemmed to upward-flaring asymmetrical gobletlike sponge with reticulate grid of at least three orders; dimensions of the grid vary laterally, as well as vertically; tracts composed of fine microreticulation, from bed 19, X1.*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upper 1 cm or have convergent tracts to smooth oscular margin. Holotype fragment approximately 8 cm high and 3 cm wide. Skeleton well-ordered reticulation of tracts of three obscure orders forming quadrate appearing skeleton.

First-order vertical tracts approximately 0.5–0.8 mm wide, extending locally to 1 mm, where small circular blotches of intense hematite replacement mark tracts. Vertical first-order tracts separated approximately 2 mm at base and diverge upward to approximately 4 mm apart at top, with gradually widening pattern particularly prominent in rounded base and in uppermost 2 cm; horizontal tracts 0.4–0.6 mm wide and produce first-order quadrules 4–5 mm wide at the top. Discontinuous second-order tracts subdivide first-order quadrules into openings approximately 2 mm wide and high at midheight and upper height. Vertical tracts 0.2–0.5 mm wide and horizontal tracts 0.2–0.3 mm wide. Third-order tracts, 0.1–0.2 mm wide, locally, subdivide second-order quadrules, but are discontinuous and appear more as aligned expanded junctions rather than complex tracts of long spicules. Second- and first-order tracts similarly preserved; not composed of long spicules as in other dictyosponges, but microreticulate mesh produced by short rays of small hexactines and hexactine-derived spicules.

Coarsest spicules hexactines or hexactine-derived with rays 0.8–1.0 mm long with basal ray diameters of approximately 0.10 mm, some spicules with distal-proximal rays at ray junctions, but relatively rare; even more rare coarser spicules with rays to 2 mm long and basal ray diameters of 0.12 mm, but may be foreign, because almost consistently oriented at angles to principal vertical-horizontal tracts.

Most common coarse spicules stauracts or hexactines with rays 0.6–0.8 mm long and basal diameters of 0.05–0.08 mm; rays taper quickly so spicules appear relatively robust. Finer, more abundant spicules with rays 0.2–0.4 mm long and basal ray diameters of 0.02–0.03 mm; commonly 0.2–0.3 mm apart in fairly regular reticulate net. These are principal spicules of microreticulate tracts and combine with smallest spicules, with ray lengths of 0.1–0.2 mm and basal ray diameters of 0.005–0.010 mm, to produce fine skeletal structure. Many such spicules spaced fairly regularly 0.05–0.10 mm apart, but locally, particularly in open quadrules, may be spaced 0.15–0.20 mm apart. Smallest spicules rarely preserved, but apparent as series of small dots, with relatively coarse dots at ray junctions, and where small spicule tracts superimposed on somewhat coarser rays of spicules.

Small fragment of same species on same block with holotype, approximately 1.7 cm high and 2 cm wide, with convergent tracts that sweep from subparallel to convergent at smooth oscular margin; a margin not preserved on holotype.

Possible root tuft on holotype extends 7–8 mm from basal part of skeleton into matrix and to 2–3 mm into rounded lower part of basal skeleton; spicules of possible root tuft to 2.0–2.5 mm long, smooth diactines 0.02–0.03 mm in diameter; extend below projected hemispherical base of sponge, as somewhat convergent, although irregularly preserved cluster.

Discussion. The Devonian form described here appears to be distinctly coarser textured than the type species *Cyathophycella quadrata* Rigby and Stuart (1988, p. 135–36), from the Roberts Mountains Formation in the Independence Mountains of northeastern Nevada. That species has a quadrate skeletal mesh with first-order openings approximately 1 mm across and somewhat less high. Vertical tracts, which may include both first- and second-order tracts, are spaced so that 10–11 occur per 1 cm in the type species and have widths of up to 0.5–0.6 mm, but most are about 0.3 mm wide, but within the 0.5–0.8 mm range of the Red Hill species. Horizontal tracts are discontinuous in the type species, but prominent in the Red Hill species. In the Red Hill species first-order tracts are approximately 4 mm apart through most of the sponge; this is four times the separation observed in the type species, the only other previously described species of *Cyathophycella.* Sizes of spicules appear essentially similar in the two species, but the considerably coarser nature of the quadrate skeleton suggests separation of the Red Hill specimen as a new species.

Rigby and Stuart (1988, p. 136) noted that there may have been an open spicular gridwork over the quadrules between the horizontal and vertical bundles, but such a covering was only suggested because spaces between tracts in the holotype of that species are essentially spicule free. However, such a gridwork is evident within quadrules between tracts on the holotype of the Red Hill species.

Comparisons with *Cyathophycella grossa* are made in discussion of that species. Within other Paleozoic hexactinellids, however, only *Dictyophytra*(?) *walcotti* Rauff, 1894, from the Ordovician Utica Shale has been reported to have a relatively well-defined boxwork of parallel hexactines and hexactine-derived spicules within individual tracts of the skeletal net. Rigby and Stuart (1988), after reexamination of the type specimen (USNM 25348), concluded that a microreticulate skeletal structure does not exist within tracts of *D.*(?) *walcotti,* but rather that the tracts are made of parallel bundles of closely spaced small spicules. Rauff's species was considered by them as a junior synonym of *Cyathophycus reticulatus* Walcott, 1879.

Plectoderma scitulum Hinde (1884, p. 132–33) has a gross skeleton somewhat like the species described here with clustered spicules in vertical tracts of overlapping rays, but it has separate spicule rays occurring as almost single runglike horizontal elements, rather than tracts.

Cyathophycus Walcott, 1879, has a skeleton of weakly bundled hexactines and hexactine-derivatives, but it does not have a skeleton of reticulate microstructure, like that described here. The small *Norfordia* described by Rigby and Harris (1979) may have been a similarly shaped sponge, but it too has a skeleton of bundled spicules, principally small diactines, that contrast sharply with the microreticulate net of *Cyathophycella.*

Material. Holotype, USNM 463531, and two small fragments, one of which appears to show an oscular margin and is designated as a paratype, USNM 463532, occur on a single block from bed 21 in the Red Hill quarry; counterpart shows only the lower part of the holotype on a block associated with other nondescript fragments of sponges.

Etymology. Minuta, L., small, in reference to the small skeletal texture of the species.

CYATHOPHYCELLA GROSSA n. sp.
figs. 4.9, 4.10, 8.4, 8.7, 8.8 and 9.11

Diagnosis. Stemmed cylindrical to upward-flaring asymmetrical hemispherical to goblet-shaped, moderately thin-walled dictyosponges with reticulate grid outlining quadrules of at least three orders of gradational size, both vertically and laterally as result of asymmetric growth; skeletal straps moderately closely spaced fine microreticulation of stauractine or hexactine spicules within tracts, with moderately short rays parallel to vertical and horizontal tracts; quadrules between with protosponge-like fine dermal layer of hexactines and stauractines; many spicules with spherical masses at ray junctions.

Description. Three fragmented specimens with counterparts, occur in collection, with flattened, hemispherical, or gobletlike appearance, fragments to 8 cm high and 10 cm wide; neither oscular margin nor base preserved, base apparently lost during collection, but one lateral margin with coarse net clearly defined in coarse asymmetrical skeletal grid. Holotype stemmed, cylindrical to upward flaring, gobletlike, fragment and counterpart, with neither base nor summit preserved; skeleton composed of thin, quadrately reticulate, net preserved as coarse hematite replacement; cylindrical stem approximately 5 cm wide with torn base, flared slightly at base as attachment, but obscure; stem widens abruptly upward somewhat asymmetrically, to an expanded upper part; one side stem approximately 3 cm high and other side 7 cm high between same horizontal skeletal structures in quadrate skeletal mesh; quadrules on one side, thus, significantly higher than on other, i.e., 0.4–0.5 vs. 1.0 cm in lower part and 1.0 vs. 1.8 cm high in upper part.

Stem approximately 7.0–7.5 first-order quadrules wide and about 8 quadrules high to base of abrupt funnel-like expansion. First-order quadrules in middle part of stem 8–9 mm high and 6–7 mm wide; subdivided into 5 moderately well-defined orders by tracts in stem, each quadrule order approximately one-half size of next larger order, so quadrules approximately 8, 4, 2, 1, and 0.5 mm high and somewhat less wide with considerable variation.

Quadrules and straps larger on one side than other; both quadrule sizes and strap widths vary in systematic way laterally and also increase in size vertically from fragment base. Vertical and horizontal straps curved, indicating curved growth in both specimens; for example, first-order quadrules range laterally from 9 mm to 22 mm high, increasing in one direction, and from approximately 11 mm to 16 mm wide, with definition of straps obscure on side where smallest. Only three orders of quadrules and straps recognizable in upper sponge, best defined in middle of fragments; each order subdivides quadrules into smaller order, so in coarse-textured areas quadrules approximately 20, 10, and 5 mm high and 16, 8, and 4 mm wide. Space between straps in quadrules filled with parallel stauractines or hexactines, with coarsest filling spicules with rays to 4 mm long and with basal diameters of 0.10–0.15 mm, rays robust and taper to tips. Most common spicules small, with rays approximately 0.4 mm long producing fine dermal net or grid with quadrules 0.3–0.4 mm across; all spicules in parallel arrangements. Spicules range down to tiny ones with rays 0.1–0.2 mm long and basal ray diameters of 0.01 mm or less.

Coarsest first-order vertical straps range 1.0–2.5 mm wide and horizontal ones approximately 3 mm wide. Second-order vertical straps to 1.5 mm and horizontal straps to 3.0 mm wide; with both vertical and horizontal third-order straps approximately 1 mm wide. All straps a fine reticulate structure produced by stauractine or hexactine rays, up to 4 mm long, and with basal diameters of 0.2 mm. In mesh between these stauract-appearing spicules, smaller ones with rays to 0.3–0.4 mm long parallel to tract axis, but same spicules with shorter rays, 0.2–0.3 mm long, at right angles to tract axis. Spicules within the tracts range down to small forms same general size as tiniest elements in quadrule-filling mesh.

Tracts generally appear moderately open with to one-quarter of space filled with matrix and with spicule rays 0.2–0.3 mm apart; tracts appear more dense than quadrule fill, perhaps because tracts thicker than essentially single layer of quadrule net, but rays also appear somewhat more closely spaced, perhaps a result of compaction of three dimensional net so more spicules appear compressed into same area.

Poorly defined major skeletal net on one side of sponges may be only apparent because bedding plane surfaces not at uniform levels within skeleton and dermal(?) layer more extensively preserved where robust tracts more obscure in the holotype.

Paratype with similar dimensions and structures, but also with thin lense of spongocoel filling partially removed, so both upper and lower levels of skeleton exposed. Continuation of spongocoel-filling lense to near preserved margin suggests original wall only a few millimeters thick, at most, as indicated by differences between edge of filling lense and edge of exterior of sponge.

Many spicules of several sizes with spherical hematite mass at ray junctions; consistent occurrence must indicate some original structure, probably not in mineralized skeleton because hemispheres are not uniformly developed, but perhaps related to secondary mineral precipitation by decomposition of organic masses present at ray junctions. Such hemispheres common in several genera and species in collection, but reasons for their development remain obscure.

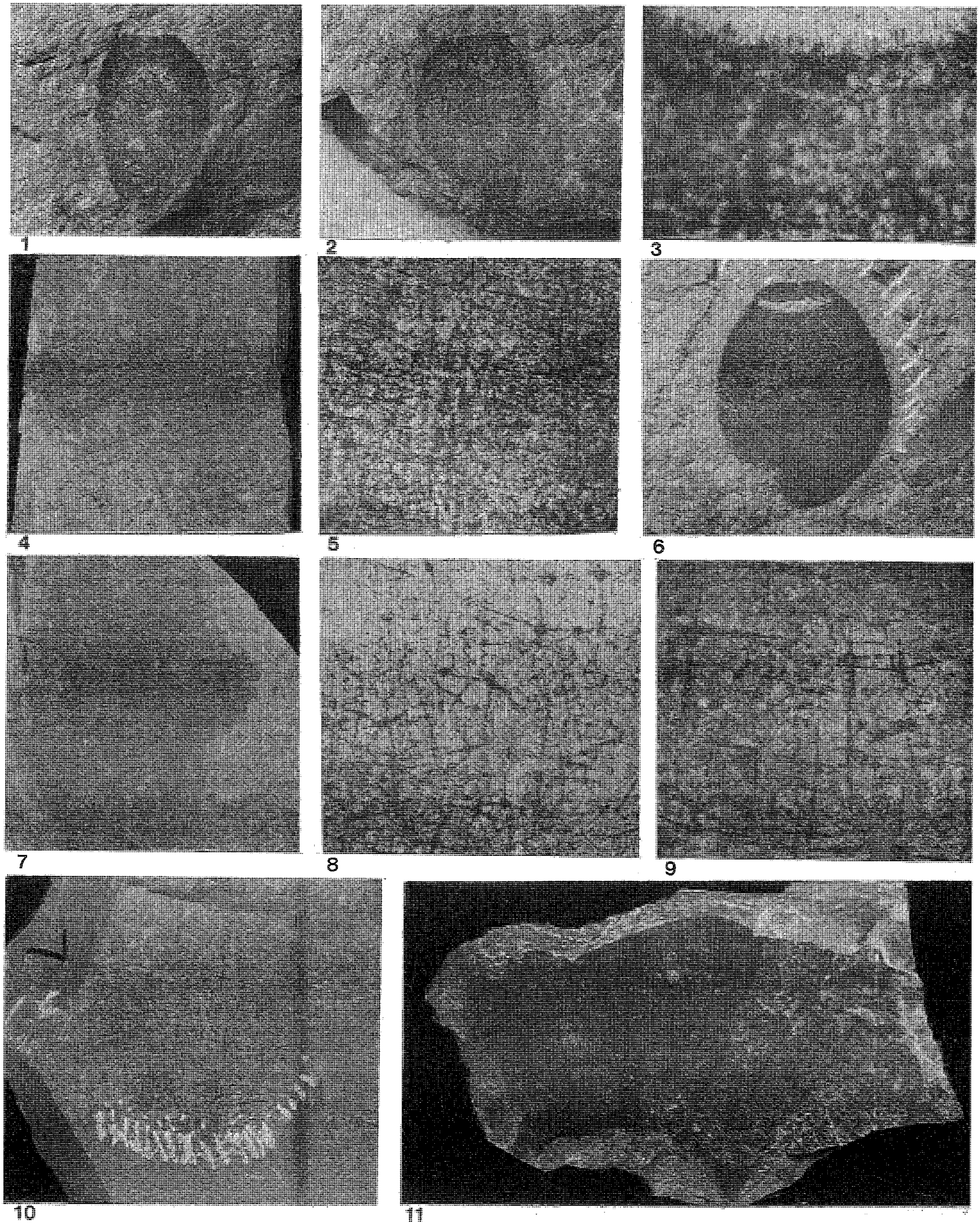
Discussion. The species is placed within the genus *Cyathophycella* because of the microreticulate network of fine spicules that make up the coarse straps, in contrast, to the long-rayed, hairlike bundled spicules developed in most dictyospongiids. That difference in skeletal structure was the reason that Rigby and Stuart (1988) differentiated the genus. The type species, *C. quadrata* Rigby and Stuart, 1988, and the cylindrical, relatively fine textured species *C. minuta* n. sp. described herein from the collections of Red Hill quarry, are the only other species known within the genus. The very coarse, gross nature of the quadruled bounding straps and sizes of quadrules immediately differentiate this species from others in the genus.

The two larger fragments are probably from slightly different parts of skeletons, but within the same species, with the coarser specimen from somewhat higher in the goblet. Both show the same asymmetry and there is an overlap in sizes of grids in the lower part of coarser specimens and the upper part of the finer one.

The three specimens represented by parts and counterparts are distinct and not fragments of the same specimens, so the known record of the species consists of at least these three sponges.

Material. Holotype, USNM 463533, part and counterpart, and paratypes, USNM 463534 and 463535, parts and counterparts, all from bed 16 from the Red Hill quarry.

FIGURE 9.—Teganiella, Cyathophycus, *and* Cyathophycella *specimens from the Red Hill quarry.* 1–3, 6, Teganiella ovata *n. sp., all are hematite-replaced specimens;* 1, *paratype, USNM 463540, shows general oval outline with flattened oscular margin at the top and prominent curved root tuft at the base; reticulate small tracts of hexactines and hexactine-derived spicules show parallel arrangement in the upper and lower part, but diagonal arrangement in the middle part of the sponge, bed 6, X2;* 2, *paratype, USNM 463543, shows characteristic flat but fringed oscular margin, oval form, and well-defined root tuft of hairlike spicules at the base, bed 7, X2;* 3, 6, *holotype, USNM 463539, from bed 6;* 3, *photomicrograph of the oscular margin shows a fringe of short, small prostalia around the oscular margin, and the moderately regular skeletal structure of the upper part of the holotype, X10;* 6, *characteristic oval form of laterally flattened sponges, here with well-preserved skeletal structure, more or less parallel to the oscular margin in the upper part, but diagonally oriented in the middle and lower part of the sponge; light-colored lens in the upper part is flattened matrix that filled the spongocoel, which has been partially removed to show the inner or gastral surface of the wall in the uppermost part, X2.* 4, 5, 7–10, Cyathophycus simpsonensis *n. sp., from the Red Hill quarry;* 4, *paratype, USNM 463538, fragment with characteristic skeletal structure in parallel pattern, but not in ranked quadrules, with clusters of railroad-track-like parallel rays of longer spicules in quadruled patterns, from bed 9, X1;* 5, *same paratype shows details of skeletal structure with parallel, but unbundled, rays of hexactine-based spicules in railroad-track-like arrangement, with smaller, somewhat parallel-oriented, hexactine-based spicules filling in quadrules between, in a more or less irregular way, but with orientation similar to the long-rayed spicules, X5;* 7, *paratype, USNM 463537, fragment with marked parallel arrangement of long, thin-rayed spicules in quadrule-like arrangement, characteristic of the species and with coarser hexactines filling between in parallel, but not quadruled, fashion from bed 7;* 8, *paratype, USNM 463538, shows relatively coarse protosponge-like appearance with only limited railroad-track-like fine rays in the lower left, from bed 9, X5;* 9, *holotype, USNM 463536, shows relatively coarse spicules of the main parallel part of the skeletal net, with masses of hematite at ray junctions, suggestive of hexactines in spicules of various orders, ranging from those with rays up to 2–3 mm long down to those with rays only 0.2 mm long, X5, from bed 9;* 10, *holotype, USNM 463536, fragment shows characteristic spicule structure with moderately coarse hexactine-based spicules in parallel orientation, although not in quadruled pattern nor in railroad-track-like rays of longer, fine-rayed spicules, X1.* 11, Cyathophycella grossa *n. sp., counterpart of holotype, USNM 563533, rotated 90° from figure 8.8, extends upward toward the right beyond that figure; shows curved skeletal patterns and lateral variation in sizes of quadrules between the expanding tracts of the skeletal net, X1, from bed 16.*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Etymology. Grossa, L., big, coarse, thick, referring to the coarse appearance of the skeletal tracts.

Superfamily HINTZESPONGIOIDEA Finks, 1983
Family HINTZESPONGIIDAE Finks, 1983
Genus CYATHOPHYCUS Walcott, 1879

Emended diagnosis. Thin-walled, obconical to conicocylindrical hintzespongiids with deep spongocoel and wide osculum; skeleton of two layers; outer composed of thin-rayed hexactines and perhaps stauractines with rays at right angles or nearly right angles; rays overlap to produce loose, open horizontal and vertical tracts around slightly vertically elongate quadrules; rhabdodiactines or monaxons also included in tracts with smaller stauracts, the tracts may be multiple rayed; quadrules filled with distinctively smaller stauracts, mostly in horizontal-vertical arrangement, divide quadrules somewhat irregularly, not in regular quadruled pattern of *Protospongia;* inner thin layer of slender-rayed hexactines or hexactine-derivatives in nonparallel arrangement around circular gaps covered by the more dermal layer; upper part of wall near oscular margin with irregular and tightly packed skeletal pattern; may include prominent oscular fringe; root tuft uncertain.

Discussion. Walcott (1879) described *Cyathophycus* initially as an algal fragment. Whitfield (1881) alluded to its similarity with *Dictyophyton*, which had also been called an alga by Hall (1863b), but Whitfield also noted the similarity of those forms to the Recent sponge *Euplectella.* Walcott (1881, 1883) also recognized that relationship and described the skeleton of *Cyathophycus* as consisting of vertical and horizontal bundles of thread-shaped spicules. Hall (1884) listed *Cyathophycus* within the family Dictyospongidae without referring to Walcott's discussion. Dawson (1888, p. 56) described the skeletal net as a trelliswork of vertical and horizontal bundles of long simple spicules. Hinde (1888, p. 66) observed that the skeleton was made essentially of stauractines with long rays forming vertical and horizontal bundles. Dawson, in Hinde (1888, p. 67), suggested that the name *Cyathospongia* should replace the name *Cyathophycus* because the ending indicates a plantlike organism, but *Cyathospongia* was preoccupied by another sponge (Hall 1890, p. 234).

Rauff (1894, p. 250–51) emended the diagnosis of the genus and redescribed the type species, *Cyathophycus reticulatus* Walcott, 1879, and *C. quebecensis* Dawson, 1888, as part of his major study of fossil sponges. Rauff's work was by far the most definitive to date. He redescribed the Ordovician species from the Utica Shale of Oneida County, New York, in some detail, and more briefly Dawson's species from Little Métis Bay on the Lower St. Lawrence of southeastern Quebec.

In several ways *Cyathophycus* is a transitional form between protospongiids, with simple, regular, largely unbundled skeletons, and dictyospongiids, with quadruled, thicker, more complex skeletons (Rigby 1986b, p. 12). It is also a transitional form with the hintzespongiids that have a major well-organized principal skeleton and a second less-organized skeletal layer that is composed of irregularly oriented hexactines and hexactine-derivatives (Finks 1983). Rigby (1986b) concluded that the *Cyathophycus* lineage may have been the line that evolved into the important Devonian and Carboniferous dictyosponges.

Type species. Cyathophycus reticulatus Walcott, 1879.

CYATHOPHYCUS SIMPSONENSIS n. sp.
figs. 9.4, 9.5, 9.7–9.10

Diagnosis. Steeply obconical, thin-walled hintzespongiids with parallel and upward-divergent skeletal structure indicated by railroad-track-like subparallel spicule rays of largest spicules 5–7 mm apart, with rays to approximately 5 mm long and basal diameter generally 0.02–0.03 mm. Spicules ranked to fifth-order with ray lengths 0.10–0.15 mm and 0.02–0.03 mm in diameter; hexactines with nodes and some with curved C- or S-shaped rays. Spicules in overlapping, distinct parallel structure, but not in regular, typical protosponge quadruled pattern; lacks major tracts and clusters; main skeletal openings several millimeters across; inner irregular layer ill defined.

Description. Numerous specimens, but no complete individual in collection; largest fragment approximately 5 cm tall and 6.5 cm wide, with upward-expanding skeletal structure of apparently obconical lower part of sponge; skeletal structure basically parallel, although divergent upward as indicated by railroad-track-like structures of subparallel spicule rays.

Largest spicules spaced approximately 5–7 mm apart in crude quadrule corners, with somewhat overlapping distinctly parallel rays, but not in regular typical protosponge quadruled pattern; structure lacks major tracts but coarsest spicules occur with parallel rays, both horizontally and vertically, in tracklike structure; coarsest spicules overlain(?) by successively smaller spicules until fine-textured, essentially quadrate dermal layer developed.

Largest spicules essentially first-order spicules with both vertical and horizontal rays to approximately 5 mm long, but most 3.5–4.0 mm long, with tips generally poorly preserved in hematite replacement; basal diameters 0.2–0.3 mm, rarely to 0.5 mm with latter perhaps produced by ray overlap obscured in hematite preservation. Central canals evident locally, irregularly preserved; most

0.02–0.03 mm in diameter, although a few irregularly to 0.06 mm in diameter.

Smaller spicules of second-order size with ray lengths 2.0–2.5 mm and basal ray diameters of approximately 0.10 mm, in parallel orientation although not defining second-order quadrules. Spicules of third-order size with rays 1.0–1.5 mm long and basal ray diameters of approximately 0.02 mm, spicules spaced approximately 0.8–1.0 mm apart, although may occur as part of tract development or with rays close to larger spicules. Spicules of fourth-order size with rays 0.3–0.5 mm long and basal ray diameters 0.05–0.10 mm, spaced approximately 0.1 mm apart in a moderately regular spacing. Small spicules of fifth-order with ray lengths 0.10–0.15 mm long and 0.02–0.03 mm in diameter, tiniest spicules preserved, arranged subparallel and spaced 0.02–0.04 mm apart, with moderately regular pattern; smallest elements apparently form dermal layer.

Most spicules with four tangential rays; some hexactines with nodes of proximal-distal rays as well. Most spicules with rays at right angles, but some with other angles as well, particularly rays curved C- or broadly S-shaped. Triactine-appearing spicules with rays approximately 120° apart, and triactines appear as prodienes with U-shaped appearance of two ascending rays rare and irregularly oriented in skeleton.

Railroad-track-like structures of "first-order" spicules with vertical rays subparallel, offset 2–3 mm, with ray centers diagonally offset same distance. "Tracks" separated approximately 3 mm at base, but diverge upward to 4–5 mm apart near fragment top; some new "tracks" inserted by branching in lower part of preserved skeleton. Similar, crude, horizontal tracks spaced approximately 1 cm apart, but less well defined than vertical elements.

Smaller spicules with rays parallel those of first-order spicules, irregularly placed in larger orders, but more regularly in spicules of smaller orders. Many spicule centers with hemispherical expansions of hematite; small hemispheres or cylindrical structures of hematite also elsewhere, suggest proximal-distal rays in moderately three-dimensional, but still thin, skeletal structure; original wall thickness indeterminable because of compression related to compaction of lime mud matrix.

Discussion. The Nevada species *Cyathophycus simpsonensis* n. sp. differs from the New York type species, *C. reticulatus* Walcott, 1879, and the Quebec species, *C. quebecensis* Dawson, 1888, in lacking a prominent reticulation that forms pronounced quadrules, with tracts composed of several spicule rays. In addition, the main skeletal openings of the Nevada species are several millimeters across, in contrast to the somewhat smaller and moderately well defined rectangular mesh with quadrules approximately 2 mm wide and 3 mm high in some of the largest specimens of *C. reticulatus* Walcott, 1879. In addition Rauff (1894, p. 252) reported that the skeleton of *C. reticulatus* has a reticulated quadruled structure where intersecting tracts diminish in size, step-by-step, and produce progressively smaller orders of quadrules. Such a distinct pattern is not developed in the Nevada species.

Cyathophycus quebecensis Dawson (1888, p. 54, and 1890, p. 44–47) has a prominent reticulate net of vertical and horizontal bundles that may be composed of long rods or perhaps of long rays of stauractines or hexactines. Prostalia were shown on the side of the tubelike, steeply obconical form in a generalized reconstruction by Dawson. The skeletal structure is obviously more well defined than in the Nevada species, although the restoration by Dawson does show the prominent vertical bands composed of essentially two subparallel rays, somewhat like the "tracks" seen in the Nevada species. He also showed prominent horizonal bands, in contrast to the considerably more obscure horizontal structures in the Nevada species. No sponges were figured by Hall and Clarke (1900) with a skeletal structure like that shown in these Devonian sponges from Nevada. Because of that we have placed the new species within *Cyathophycus*, a genus known until recently only from the Ordovician of eastern North America.

A new species, *Cyathophycus mackenziensis*, has been described by Rigby and Chatterton (1994) from the Silurian Road River Formation, Mackenzie Mountains, Northwest Territories, Canada. It has crudely ranked quadrules that are generally 2 mm high and 1 mm wide in a skeleton considerably finer textured than *C. simpsonensis*. The Canadian species lacks the railroad-track-like pattern of coarser spicules characteristic of the new species *C. simpsonensis* described here and, overall, is a smaller, more fine textured sponge.

Phormosella Hinde, 1887, from the Ordovician of England, has a more protosponge-appearing, unbundled skeletal net than seen in the Nevada material, but *Phormosella* does have smaller orders of spicules in subparallel arrangement in quadrules between major elements of the skeleton. However, *P. ovata* Hinde, 1887, the type species, is a globular small form, whereas the material from Nevada suggests this species was a steeply obconical sponge.

The skeletal structure lacks a distinct tract development like genera and species within the dictyospongiidae, although it does appear transitional from the protospongiids to the dictyospongiids in having moderate tract development.

Material. Holotype, USNM 463536, specimen 6, and paratype USNM 463537, part and counterpart, specimens 2 and 3, all from bed 7; and paratype USNM 463538, specimen 1 from bed 9. Additional specimens include one reference specimen, a fragment 5.5 X 7 cm across, from bed 4, one fragment 3 X 5 cm across and another rectangular fragment 2 X 3 cm across from bed 6, and a rectangular fragment 3.5 X 7 cm across from bed 9, representing 7 different specimens in all, generally from the upper part of the stratigraphic section at the Red Hill quarry.

Etymology. Simpsonensis, in reference to the type locality in the northern Simpson Park Range.

Family TEGANIIDAE de Laubenfels, 1955
Genus TEGANIELLA Rigby, 1986
TEGANIELLA OVATA n. sp.
figs. 9.1–9.3, 9.6, 10, 11.1–11.5, and 16.8

Diagnosis. Small globular to egg-shaped teganiellid sponges to 23 mm high and 16 mm in diameter with moderately dense but thin wall around large simple spongocoel; wall apparently perforated by small pores 0.3–0.4 mm in diameter; large, round osculum at summit bordered with fringe of small prostalia; other marginalia lacking except for long hairlike root tuft at rounded base. Skeleton of reticulate small tracts of hexactines and hexactine-derived spicules, tracts may be irregularly oriented in various parts of sponge, tracts to 0.1 mm wide around first-order quadrules 0.2–0.4 mm wide and high; smaller orders present in quadrules.

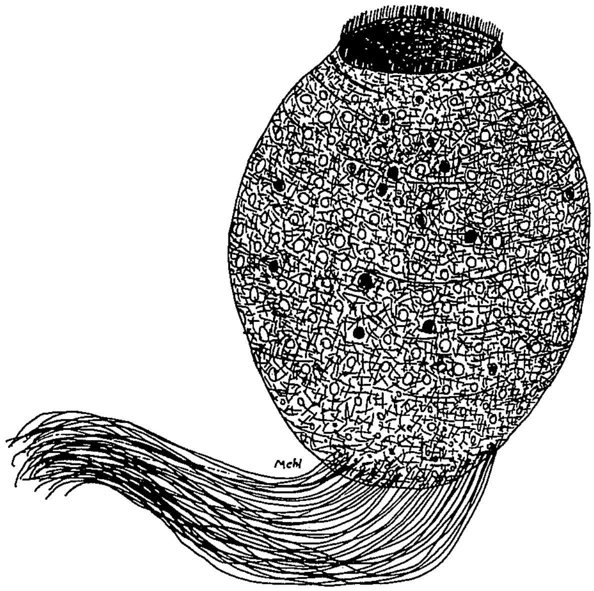


FIGURE 10.—*Reconstruction of* Teganiella ovata *n. sp. shows globose form, well-defined root tuft, and fine prostalia around the spongocoel margin; skeletal structure characteristically subparallel to the oscular margin in the upper part, but more or less diagonally arranged, but still in reticulate pattern in the middle and lower part of the sponge. Scale approximate for only coarse structures, not fine textures, X4.*

Description. Spherical to egg-shaped sponges in collection 3–23 mm high, with maximum diameters to 16 mm at approximately midheights to three-fourths height above rounded base; summit with circular osculum where flattened vertically, or lenticular when flattened laterally or diagonally; wall around large open and deep spongocoel thin but dense for upper 0.5–1.0 mm at oscular margin, but less dense and open porous reticulation in lower parts, generally only few spicules thick toward base; main wall only single tract thick, perhaps with much thinner poorly preserved dermal and gastral layers. Fringe of prostalia to 0.5 mm long borders oscular margin; smooth spicules 0.005–0.010 mm in diameter, taper upward to sharp tips, lower ends obscured in dense skeleton of rim, spicules spaced irregularly 0.02–0.10 mm apart, not in clusters.

Wall consists of principal tract reticulate layer and irregularly preserved thin dermal and possible gastral layer; fairly regular quadrate latticework of narrow tracts of stauractine (or hexactine) rays forms main part of wall (fig. 11.1); spicule details largely lost in coarse hematite replacement, but small spicules locally identifiable; latticework may be variously oriented in different parts of sponge, but commonly essentially horizontal-vertical near oscular margin and irregularly diagonal in midheight (figs. 9.1, 9.6, and 11.2). First-order tracts to 0.1 mm wide, range from 1–2 spicules, where small, to perhaps 6–10 spicule rays, where wide or thick; define rectangular openings 0.2–0.4 mm wide and high; may be locally subdivided to half that size by second-order spicules, but latter essentially lacking on most specimens, perhaps lost during diagenesis; most spicules first-order elements with rays approximately 0.05–0.08 mm in diameter; ray lengths of first order to at least 0.4 mm common; second-order spicule rays to 0.2 mm long and 0.005 mm in diameter and smaller third-order spicules with rays to 0.1 mm long and only approximately to 0.002 mm in diameter. Meshwork overlain on both dermal and gastral sides by irregularly oriented tiny stauractines and probably diactines; latter spicules irregularly oriented to tangential around circular ostia in walls.

Round pores 0.2–0.3 mm in diameter interrupt quadruled skeleton; no noticeable differences in diameter between outer or dermal pores and those in gastral surface.

Tresslike root tuft of delicate-appearing but long diactine spicules about 75% as long as sponge body is high (figs. 9.2 and 10); root spicules project from base in clusters 0.1–0.2 mm wide and spaced 0.2–0.3 mm apart at base but unclustered 2–3 mm below base to become irregularly subparallel; tuft spicules traceable only 2–3 mm into lower part of sponge but appear to originate at tract junctions in reticulate sponge body, proximally subparallel but become somewhat twisted in distal ends; distal anchors not recognized.

Discussion. The type species, *Teganiella heathi*, was described from the Mississippian Heath Formation in central Montana by Rigby (1986a). Both the type species and *Teganiella ovata* n. sp. are small globular or egg-shaped forms, with relatively thin walls and pronounced large round oscula at their summits. The skeletal net in the type species is composed, perhaps, of a double layer of somewhat organized thin-rayed hexactines; one layer more or less diagonally oriented and the other approximately parallel and normal to the main sponge axis. Coarsest spicules in *T. heathi* have rays nearly double the length of the largest spicules preserved in the new *T. ovata; T. heathi* appears to have very limited tract development, such as is characteristic of the Nevada species.

First-order openings in *T. ovata* are approximately 0.2–0.4 mm wide and high, whereas similar rectangular, through diagonal, rectangular openings in *T. heathi* are approximately 1.0–1.3 mm across, and even intermediate size openings are 0.5–0.8 mm across in *T. heathi,* which is considerably coarser textured than the meshwork in *T. ovata.* Also missing in *T. ovata* are the distinct, long, vertically aligned spicule rays that produce somewhat linear straps in *T. heathi.*

A root tuft is not known from the type species, although in a restoration Rigby (1986a, fig. 4) showed a small brushlike root tuft. A well-defined tuft is developed in the Nevada species (figs. 9.1, 9.2, and 11.3), but such a tuft is only locally preserved and evident, as well, and would be apparent only with lateral flattening. Specimens that are vertically or diagonally flattened show no tuft. Rigby (1986a) discussed the comparison of the genus with other related forms and summarized the somewhat convoluted history of *Teganium subsphaericum* (Walcott 1879) and *Sphaerodictya* described by Hall and Clarke (1900, p. 200–201).

Globular specimens of similar sizes may occur densely packed in large numbers or are scattered isolated sponges on single bedding planes. One block 4 X 6 cm, for example, contains 35 specimens of the species, all with diameters ranging only approximately 3–5 mm (fig. 11.4). Sponges of this small species are the only ones in the collection that are essentially complete, and they commonly occur as clusters of similar-sized mature sponges. Most have been flattened vertically and now appear as rings of skeletons around oscula (fig. 11.5) Most were apparently attached by a root tuft and buried in situ, with moderately regular upright orientation, and were flattened vertically during compaction of the silty and argillaceous lime mud, so now each shows a wide simple osculum. Such compaction ultimately produced apparent strong horizontal orientations to all collapsible structures during early diagenesis, so skeletons now show poor current orientation. They appear to be clusters of mature, generally vertically oriented sponges of single generations rather than current transported and sorted accumulation. Those flattened laterally were more likely transported, for several show horizontally flattened root tufts. Most of the sponges show only as flattened "rings" or as outlines of sponge body cavities, but a few are moderately well preserved and were not as intensely affected by the pervasive diagenesis and pyritization that led to alteration to hematite of the skeleton.

Material. Holotype USNM 463539, and paratypes USNM 463540–463542 from bed 6, paratypes USNM 463543 and 463544 from bed 7, paratypes USNM 463545–463547 from bed 16; and additional unnumbered reference specimens from beds 6, 7, 9, 10, 11, 17, 18, 19. The collection includes about 53 blocks, including many parts and counterparts, that contain more than 200 specimens of this species. The species is particularly abundant in samples from beds 6, 7, 9, and 10, Red Hill beds, Red Hill quarry.

Etymology. Ovatus, L., egg-shaped in reference to the common shape of the species.

Genus RUFUSPONGIA n. gen.

Diagnosis. Sheetlike or low funnel-shaped teganiid sponges with two-layered wall in which inner or gastral layer pierced by coarse pores and outer, more dermal layer by smaller pores; wall composed of hairlike diactines or possibly rhabdodiactines and stauractines with associated small stauractines. Spicules arranged in irregular clusters and tangentially around large pores or gaps; coarse hexactines or rhabdodiactines and dictyospongiid or protospongiid regular arrangement of spicules lacking in either layer.

Discussion. Comparisons are discussed in treatment of the type species, below.

Type species. Rufuspongia triporata n. sp.

Etymology. Rufus, L., red, referring to the Red Hill type locality of the type species, and the red hematite preservation of many of the sponges of the genus.

RUFUSPONGIA TRIPORATA n. sp.
figs. 11.6–11.11, 12.1, 12.3–12.8, 13, and 16.3

Diagnosis. Moderately large sheetlike or low funnel-shaped teganiid sponges with two-layered wall composed of hairlike diactines, or possibly long, thin-rayed stauractines, with associated small stauractines; spicules arranged in gastral layer in irregular clusters and tracts around moderately large gastral pores to 10 mm in diameter outlined by tangential elements. Dermal layer with smaller pores, 1.0–1.5 mm in diameter, separated by small tracts of same-size hairlike spicules, all approximately 0.02 mm in diameter and to 4–5 mm long.

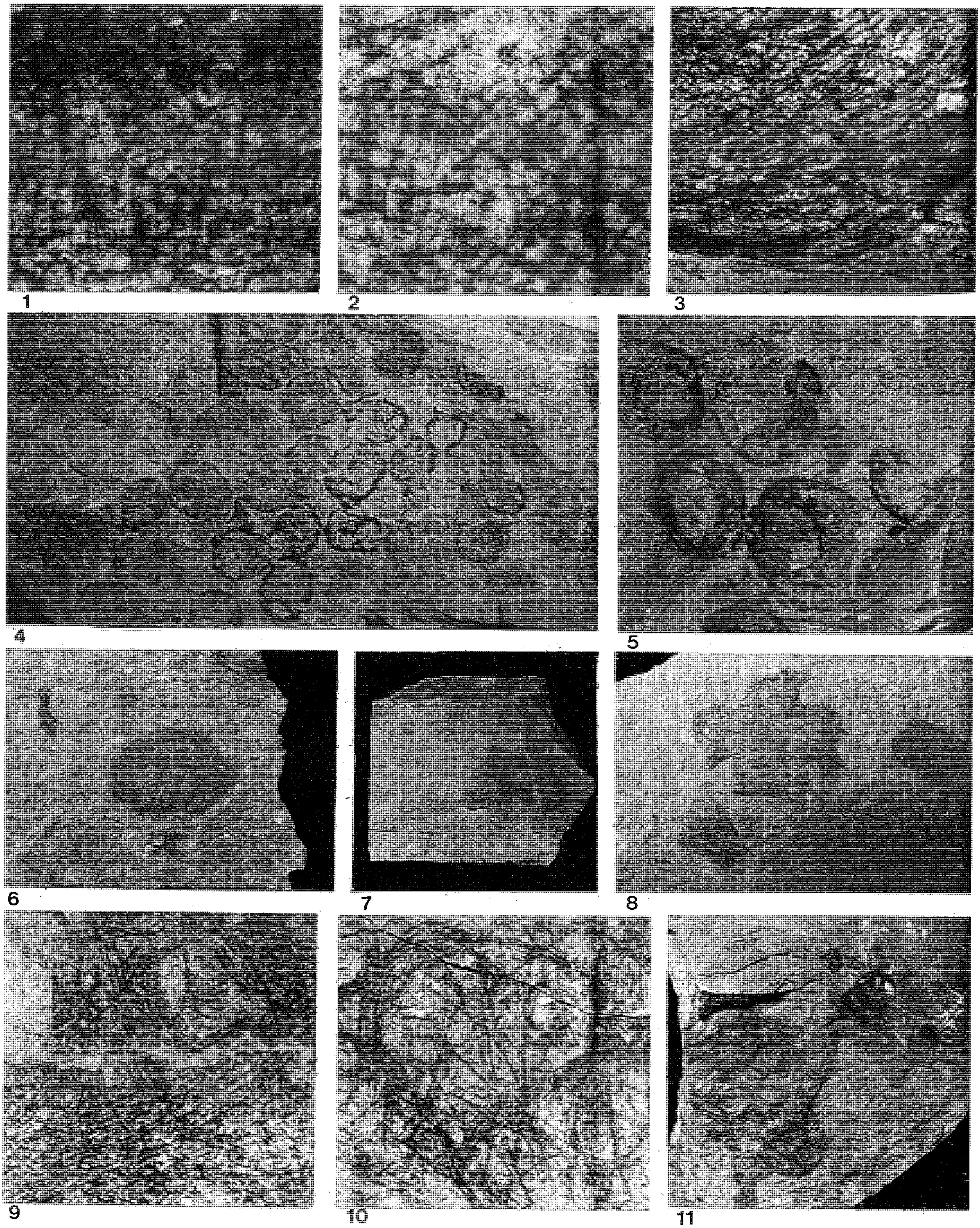
Description. Material ranges from large fragment 9 X 11 cm down to small bits identifiable largely because of distinctive spicules and pores; several approximately 3 X 4 cm. Spicules replaced with limonite or massive hematite in varying details. Large holotype with one complete margin, but otherwise shape generally not defined, other than broad, sheetlike.

Smaller fragments show more skeletal detail in two-layered wall, with inner or gastral layer defined by moderately large gastral pores; pores circular to oval and 5–10 mm in diameter, where circular, or approximately 8–10 mm long and 5–6 mm across, where oval; pores separated by tracts 0.5–1.0 mm across of hairlike, irregularly oriented, sweeping spicules. Pores defined by more densely packed tangential curved spicules than in thatch of irregularly oriented, isolated elements or curving tracts. Dermal pores 1.0–1.5 mm in diameter, circular, surrounded by spicules of essentially same size as in gastral layer; separated by smaller spicule clusters 0.1–0.5 mm wide, with most approximately 0.1–0.2 mm wide and with 4–5 spicules in a cross section.

Spicule clusters of skeleton generally straight to weakly curved and up to 0.3–0.5 mm apart, where more regular; elsewhere clusters separated by irregular, widely spaced thatch of small spicules of varying orientation. Spicules in both layers may be en echelon in clusters or flare to form discontinuous elements in subreticulate pattern or in triangular irregular patterns around pores. Dermal layer extends across gastral pores, so two-layered skeleton commonly shows well; in other areas only dermal or gastral layer preserved and defined by skeletal net and dimensions of pores. Gastral pores generally arranged virtually side-by-side, and where oval with long dimensions roughly parallel and probably horizontal, based on orientation of similar-sized openings in specimen with moderately complete, probably oscular margin.

Spicules generally long, smooth, doubly tapering diactines or rhabdodiactines, perhaps to 10 mm long, but

FIGURE 11.—*Specimens of the new species* Teganiella ovata *and* Rufuspongia triporata *from the Red Hill quarry.* 1–5, Teganiella ovata *n. sp. from the middle part of the Red Hill quarry;* 1, 2, *photomicrographs of holotype, USNM 463539, show general reticulate parallel orientation of hexactine-based small spicules in the thin-walled skeleton;* 1, *is of the upper part of the skeleton, with principal structures parallel or at right angles to the spongocoel margin;* 2, *midwall shows parallel arrangements on the left and diagonal arrangements of the reticulate, almost dictyid, structure in the upper right, from bed 6, both figs. 1 and 2, X12;* 3, *segment of the root tuft, near bottom of sponge shown in fig. 9.1, shows long, hairlike spicule fibers and weak clustering near the bend in the lower center, paratype, USNM 463540, from bed 6, X12;* 4, *relatively closely packed cluster of small specimens, some of which were essentially vertical before compaction, and others which were diagonally or laterally flattened, the latter have lenticular-appearing to circular-appearing oscula; individual sponges outlined by hematite rinds of the flattened edges of the skeleton; sponges apparently essentially buried in situ, paratype USNM 463452 from bed 6, X2;* 5, *somewhat larger specimens, each vertically flattened to produce ringlike remnants of the skeletal wall around the open osculum now largely matrix filled; these specimens were buried standing essentially vertically, presumably held in position by now obscure root tufts, but vertically flattened during burial and diagenesis; paratype, USNM 463547, from bed 16, X2.* 6–11, Rufuspongia triporata *n. sp. from the Red Hill quarry;* 6, *paratype, USNM 463572, shows characteristic pores in relatively obscurely spiculed rounded fragment; layers of spicules obscure the larger opening and only intermediate-sized openings of the outer part of the wall are evident, from bed 8, X1;* 7, *paratype, USNM 463551, small fragment shows coarse upper circular gap, a characteristic of the inner layer of the skeleton, and smaller intermediate and small pores within the more outer skeletal structure lower down, from bed 6, X1;* 8, *somewhat larger fragments show all three sizes of pores, viewed presumably from the exterior; coarse probably gastral openings or gaps show as arcuate interruptions of the skeletal net on the upper and lower right; somewhat smaller intermediate- and small-sized pores outlined by tangential, long, hairlike spicules show best in the middle and left part of the specimen, USNM 463550, from bed 7;* 9, *photomicrograph of paratype, USNM 463551, shows skeleton disrupted by a small fracture along which matrix has been preserved; fine hairlike nature of long spicules of skeleton show well on both sides of fracture; large gap of the presumed gastral part of skeleton shows on left; a somewhat smaller opening subdivided into two or three smaller pores more characteristic of the presumed dermal part of skeleton shows above the fracture in upper right center, rotated 90° from fig. 11.7, from bed 6, X5;* 10, *coarse oval gap outlined by relatively compact tangential spicule bundle as seen through finer-textured, more dermal layer, with circular openings in lower right of intermediate size and smaller openings in skeleton that partially obscure the large gap in upper center and upper left, paratype, USNM 463552, from bed 11, X5;* 11, *paratype, USNM 463549, small fragment in which several of the moderately coarse probably gastral gaps are preserved in the skeleton; the smaller openings of the more dermal layer shows through the gaps in the flattened skeleton, from bed 11, X1.*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most appear 4–5 mm long within tufts, or somewhat less than that in the widely spaced thatch between clusters.

Some small hexactine or stauractine spicules preserved in margins of paratype USNM 463527, which shows two layers well. These small spicules with rays generally 0.5 mm long, or less, and with basal ray diameters of 0.02–0.03 mm, basically same diameters as principal spicules in skeletal net. Hexactines or stauractines may occur elsewhere, but identity lost in numerous intersections of small long-rayed spicules, which produce pseudostauractines in many areas, but elsewhere hematitic replacement may have obscured stauractine spicules in the irregular net. Coarse rhabdodiactines and hexactines lacking for skeleton composed essentially of spicules with uniform, small, hairlike dimensions.

Discussion. Rufuspongia triporata is similar to *Taleolaspongia modesta* n. sp. in terms of pore dimensions and spicule size of much of the dermal and gastral net. However, *T. modesta* has abundant subparallel, oriented, coarse hexactines throughout the skeleton, spicules that are missing in all of the specimens referred to *R. triporata.* Pores in the dermal layer of *R. triporata* are essentially the same size as in the principal skeleton of *T. modesta,* but are less regularly arranged than in *T. modesta. T. modesta* also lacks the coarse gastral pores so characteristic of even small skeletal fragments of *R. triporata.*

Rufuspongia sp. 1 is known from a single fragment. It has a moderately dense skeletal net and wide tracts between large pores, both much larger than present in *R. triporata.* In *Rufuspongia* sp. 1 the fine dermal layer is missing, but this could be an artifact of preservation. Skeletons of both species appear composed of irregularly oriented tufts of tresslike small spicules.

Some massive replaced fragments of *R. triporata* may appear similar to *Bulbospongia bullata* n. sp., but the latter form lacks the coarse gastral and dermal pores, and has a skeleton composed of more regularly oriented, subparallel, fine and coarse spicules, rather than spicules of uniform dimensions like those in *R. triporata.*

R. triporata may appear somewhat similar to fragments of *Actinidictya* species preserved in the Red Hill collection, but lacks the regular quadrate skeletal structure developed in some of those forms and lacks the obvious relatively coarse hexactines and stauractines of the skeleton as well. For example, *A. nevadensis* n. sp. has spicules to 0.05 mm in diameter and clearly defined smaller, perhaps second-order spicules with ray diameters approximately 0.04 mm across, spicules that are considerably coarser than any present in *R. triporata.* In addition, *A. nevadensis* lacks the obvious, well-organized pore structure seen in *R. triporata. A. lamina* n. sp. has a basic protosponge-like layer composed of large distinctive stauractines and overlying tracts that may be irregularly oriented and spaced, and could appear similar to the dermal or gastral layers of *R. triporata,* in some preservations, but differences in the basic skeletal structure immediately separates them.

Stephenospongia magnapora Rigby, 1986, from the Cambrian Stephen Formation near Field, British Columbia, has a skeletal pattern somewhat reminiscent, at least, to the gastral layer of *R. triporata.* Both have moderately large oval openings or gaps. In *Stephenospongia* these gaps range to 10–11 mm across (Rigby 1986b) and are outlined by tangential segments of spicules, like in the Devonian form described here. There is no evidence of the two-layered wall in *Stephenospongia,* however, such as is considered characteristic of *R. triporata.*

Ratcliffespongia wheeleri Rigby and Church, 1990, is also a Cambrian sponge that may appear somewhat similar to our Devonian species. *Ratcliffespongia* has a two-layered wall, with an inner layer containing large parietal gaps between tracts of irregularly oriented spicules, principally hexactines, but *Ratcliffespongia* has a regular, diagonally oriented, reticulate layer of ranked stauractines and perhaps other hexactine-based spicules as an outer layer. Consequently, the two would be easily separated, although in obscure preservations, the inner skeletal layer with large circular to elliptical parietal gaps could appear similar.

Hintzespongia bilamina Rigby and Gutschick, 1976, from the Middle Cambrian of Utah (Rigby 1983, p. 267–68), is also a hexactinellid with two distinct layers, with an inner layer of irregularly oriented hexactines and stauractines, and an outer layer to regularly oriented, quadruled, and ranked skeletal structure. *H. lamina,* too, has fairly large gaps outlined by the irregular inner spicules, but has a skeleton composed of hexactines and would be easily differentiated as *Hintzespongia,* even in coarse preservations.

Some specimens of the species show only the large gaps and others show only the smaller two sets of gaps. In several fragments, however, all three sets of openings are preserved. They overlap each other in such a way that the two sets of smaller holes can be seen through the large ones, or the larger ones can be perceived because of their wider-spaced linings of diactines underlying the smaller gaps. These overlapping occurrences show that the gaps occur differently on either side of the walls in flattened specimens (fig. 13). Comparisons with the general organization of Recent hexactinellids, in particular, as well as the general functional morphology of sponges, suggest that the larger gaps were gastral openings and the two smaller sets were dermal openings. Such gaps should not be considered identical with ostia, however, because ostia, in a soft-part sense, are much smaller, only 0.010–0.030 mm, as documented by Reiswig (1979) and Reiswig and Mehl

(1991), for example, and would be only hardly observable in even well-preserved fossil material. These smaller gaps probably represent openings of incurrent canals from some subdermal (lacunal) spaces. These sponges probably grew to become fairly tall and fairly large in diameter (20–30 cm), but appear to have been rather thin walled (fig. 13), because both dermal and gastral surfaces can be observed in one layer of the flattened specimens.

In their systems of outer and inner gaps, as well as in the general arrangement of a skeleton of compressed mainly diactine spicules, these sponges appear similar to modern rossellid hexactinellids, such as *Acanthascus* Schulze, 1887, and they may be related. By the Late Devonian, as far as the scattered fossil record shows, almost all of the Recent hexactinellid major groups were present. For example, one dictyonine group, the Hexactinosa Schrammen, has been documented by Rigby, Racki, and Wrzolek (1981) as occurring in Devonian rocks from the Holy Cross Mountains, Poland, although these sponges probably did not play an important role then, as compared with the flourishing Dictyospongiidae and Brachiospongiidae. The sponges described here might be Late Devonian representatives of the Mesozoic-Recent Rossellidae, because rossellid-like sponge architecture can be traced back as far as the Cambrian (e.g., *Stephenospongia* and *Ratcliffespongia* as discussed above).

Material. Holotype, USNM 463548, part and counterpart, from below the correlation horizon, and paratypes; USNM 463549, specimen 1 from bed 11; USNM 463550, specimen 1 from bed 7, part and counterpart; USNM 463551, specimen 1 from bed 6; USNM 463552, specimen 3 from bed 11; USNM 463572, specimen 1 from bed 8, and other specimens including figured taphonomic samples USNM 463563 and 463564 from bed 19, and numerous reference specimens from beds 6, 7, 8, 11, 12, and 13. In addition, numerous small fragments, probably belonging to the genus and species, occur from several beds scattered throughout the Red Hill quarry.

Etymology. Triporata, in reference to the pores of three different sizes recognized in the skeletal wall.

RUFUSPONGIA sp. 1
fig. 12.2

Diagnosis. Coarse *Rufuspongia* in which parietal gaps range 7–20 mm across as round, oval openings in skeleton of irregularly oriented small rodlike spicules; other layers of wall unknown.

Description. Single fragmental specimen, part and counterpart, skeleton replaced by hematite crust; about 7 X 20 cm; skeleton perforated by round to irregularly oval gaps of only one general size; range 7–20 mm, with most 10–12 mm across, gaps large when compared with those of *R. triporata.* Spicules only poorly expressed in hematite films within the sponge wall, evident in only two areas, small rodlike spicules clearly shown, closely packed and curved short segments at least 1–2 mm long and 0.03–0.05 mm in diameter, tangential to coarse gap margin; elsewhere only irregular mottled appearance like poorly preserved hexactine network like in *Teganiella ovata* n. sp but not certain; fragments possibly part of gastral surface of large *Rufuspongia.* Orientation of fragments uncertain because no preferred orientation and no systematic shift in sizes of large gaps.

Discussion. Rufuspongia sp. 1 is represented by only a single specimen, part and counterpart, but the large gaps are distinctive, and for this reason the species has been separated from *R. triporata,* where even the largest gaps of the gastral layer are somewhat smaller than the coarse openings in *Rufuspongia* sp. 1. It is also possible that this fragment is from an upper or more distal, coarser textured, part of a skeleton of *R. triporata* than any we have preserved in the collection. If so, the figured specimen of *Rufuspongia* sp. 1 represents only the relatively finely spiculed, coarse porous gastral layer of that species.

Material. Figured specimen, USNM 463553, part and counterpart from bed 19, Red Hill quarry.

Genus TALEOLASPONGIA n. gen.

Diagnosis. Broad, open, funnel-like to palmate teganiid sponges with thin wall, skeleton composed of two major elements; regularly oriented hexactine and hexactine-derived small hairlike spicules that form an irregular thatch, and coarse, prominent, upward-divergent hexactines and rhabdodiactines in midwall or perhaps as distinct layer; latter spicules not in regular protosponge or dictyosponge arrangement, but with elongate, vertical rays generally subparallel; wall pierced by circular to oval gaps or pores of moderately uniform diameter and may be in crude rows.

Discussion. Comparisons to *Rufuspongia* have been made in discussions of *R. triporata,* above, and in discussions of the type species *T. modesta,* below. In some respects, *Taleolaospongia* may appear similar to *Ratcliffespongia wheeleri* Rigby and Church, 1990, from the Cambrian of Utah. Both apparently have layered walls that contain moderately large parietal gaps. The gap-bearing layer in both is composed principally of tracts of irregularly oriented spicules that occur tangential to the gaps. However, *Ratcliffespongia* has a regular, diagonally oriented layer of the skeleton composed of ranked stauractines in a pattern distinctly more regular than that seen in the coarse hexactine spicules in *Taleolaspongia.* The latter spicules may show moderate parallelism but certainly not the well-organized, almost protosponge-appearing skeleton of the layer of *Ratcliffespongia.*

Similarly, the Middle Cambrian *Hintzespongia* Rigby and Gutschick, 1976, also has a layered wall, with an inner layer of irregularly oriented hexactines and staurac-tines, and an outer layer of regularly oriented, quadruled and ranked, hexactine-based spicules. That regularity distinguishes *Hintzespongia* from *Taleolaspongia.* In addition, the irregular skeletal layer in *Hintzespongia* is composed of moderately clearly defined hexactines with relatively robust and short rays, not of long, thin, hairlike spicules.

Stephenospongia has a skeleton with prominent gaps defined by moderately irregular tangential segments of long spicules, but it lacks the prominent subparallel coarse hexactines and rhabdodiactines characteristic of *Taleolaspongia. Stephenospongia* Rigby, 1986, was described from the Middle Cambrian Stephen Formation of British Columbia.

Actinodictya nevadensis n. sp. has a skeleton composed of irregularly oriented spicules, but lacks the obvious pores evident in *Taleolaspongia.* The coarse stauractines and possibly hexactines in *A. nevadensis* are moderately irregularly oriented and spaced, in contrast to the more or less subparallel arrangement of the coarse hexactines and rhabdodiactines in *T. modesta,* the type species of the genus. *A. lamina* n. sp. apparently has a skeleton composed of two layers. A protosponge-like layer is composed of large, distinctive, and well-oriented stauractines, certainly reminiscent of the coarse hexactines and rhabdodiactines in *Taleolaspongia. A. lamina* also has an overlying(?) layer of variously oriented spicules, but tracts of one kind in that layer weakly define moderately large quadrules, and tracts of another series are irregularly oriented and spaced, in a skeletal structure quite distinct from that seen in *Taleolaspongia.* In addition *A. lamina* lacks the prominent, well-defined skeletal pores or gaps so characteristic of *T. modesta.*

Type species. Taleolaspongia modesta n. sp.

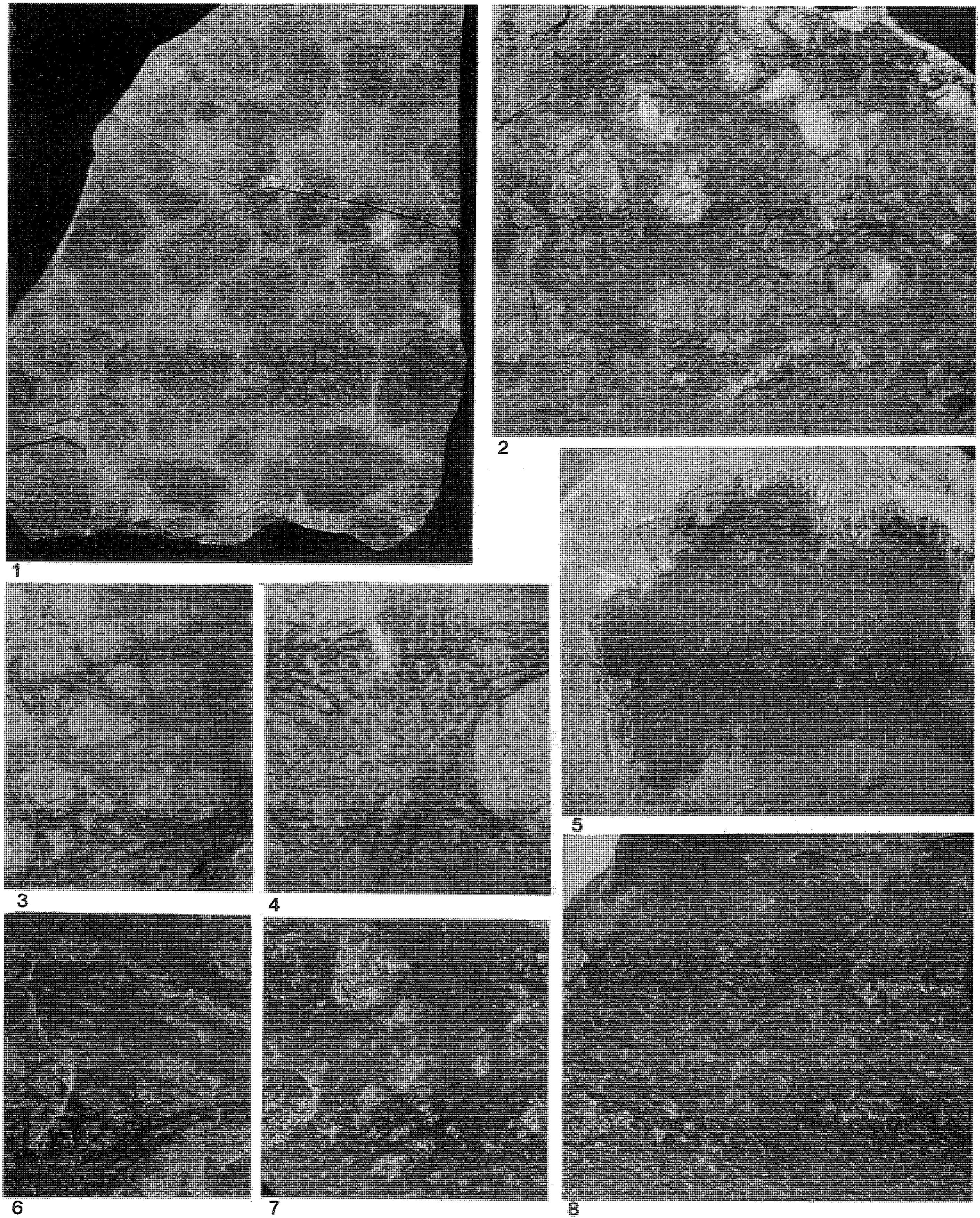
Etymology. Taleola, L., dim., slender staff or rod; *spongia,* sponges; in reference to rodlike spicules that are so prominent and distinctive in skeletons of the sponge.

TALEOLASPONGIA MODESTA n. sp.
figs. 14.1, 14.2, 14.4–14.8

Diagnosis. Broad, open funnel-like to palmate teganiid sponges with thin porous wall composed mainly of fine, irregularly oriented hexactines and hexactine-derived small, hairlike spicules but includes prominent, upward-divergent, coarse hexactines and rhabdodiactines in mid-wall; coarse hexactines spaced irregularly, but generally 1–2 mm apart in vertical rows. Long vertical hexactine rays to 50 mm, but most shorter, with short horizontal less-common rays to approximately 10 mm long. Coarse spicules not in regular protosponge or dictyosponge pattern, but irregular; fine intervening spicules similarly irregularly oriented in thin wall around circular to vertically elongate pores to 2 X 4 mm, with many smaller pores in irregular areas between ray crossings.

Description. Many fragments range from small bits 4 X 6 cm to large holotype, approximately 19 X 22 cm; all with thin porous wall of two discrete major elements; coarse prominent spicules and finer thatch around pores.

FIGURE 12.—*Fragments of* Rufuspongia *spp. from the Red Hill quarry.* 1, *Assortment of fragments of* Rufuspongia triporata *and other sponges as transported debris showing moderate size sorting, as well as fragmental nature of skeletal fragments, USNM 463563, from bed 19, X1.* 2, Rufuspongia *sp. 1, poorly preserved but very coarse-textured* Rufuspongia *with large oval to circular parietal gaps in skeleton of irregularly oriented small, rodlike spicules; figured specimen USNM 463553, from bed 19, X1.* 3–8, Rufuspongia triporata *n. sp.;* 3, *paratype, USNM 463550, shows intermediate and small openings in the more or less dermal part of the skeletal net of the paratype, from bed 7, X5.* 4, *paratype, USNM 463549, shows long, thin, hairlike spicules and their tangential arrangement around the coarse gaps in the presumed gastral part of the skeleton, and the moderately open texture with fine pores between the spicules, from bed 11, X5.* 5–8, *Holotype, USNM 463548, from bed 11;* 5, *entire fragment shows irregular fractured outline and dense hematite-replaced skeletal net interrupted by large, oval to circular gaps on the presumed gastral surface, and smaller circular gaps in the dermal part of the skeletal net; tool marks are from preparation and removal of part of the enclosing lime mudstone matrix, X0.5;* 6, 7, *photomicrograph shows the porous skeleton and relatively robust-appearing, coarsely replaced spicules that, in tangential fashion, define the pores and the relatively open-textured skeletal net, both X5;* 8, *counterpart which shows relatively open coarse gaps in the skeleton in the lower center and lower left outlined by tangential clusters of spicules, but through these are seen the dermal part of the skeleton in which intermediate and smaller pores are visible, seen through the gaps; also outlined by tangential, long, relatively fine hairlike spicules, X1.*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Coarse rhabdodiactines and hexactines distinctive features in midwall, irregularly oriented, generally with long subvertical rays to 50 mm long, in larger fragments, but most 30 mm long or less; horizontal rays somewhat shorter to 5–10 mm long; all irregularly oriented and not in rectangular grid.

Walls perforated by moderately uniform pores 2–4 mm in diameter, where circular, and 2 X 4 mm, where vertically elongate, in crude rows. Small pores 1 mm in diameter, and somewhat larger, grade up to 2 mm across; smaller pores occur in triangular openings between irregularly crossed rays. Larger pores in crude rows between prominent vertical rays of coarse spicules; rows parallel to coarse long rays and separated by bundled tracts of smaller subparallel spicules.

Coarse hexactines and rhabdodiactines irregularly spaced generally 1–2 mm apart and oriented from subparallel and vertical to diagonal as much as 45° in fabric, latter make skeletons appear rhomboidal in some areas. Main rays in smaller fragments traceable 20–30 mm, but in coarse fragments up to 50 mm from ray junctions; coarsest spicules approximately 0.6 mm in diameter, but most approximately 0.2–0.3 mm in maximum diameter, with prominent taper to sharp tips. Proximal-distal rays evident in many coarse spicules as short nodes or as fractured elements. Length of proximal-distal rays uncertain.

Most of skeleton of fragile, fine hairlike spicules irregularly oriented; most probably rhabdodiactines, but because of irregular crossings, some appear as stauractines or as hexactines, although not in regular quadruled net, but diagonally and irregularly oriented. Most small spicules range 0.02–0.04 mm in diameter, but some range to 0.06 mm across in largest coarse fragment. Small spicule rays generally traceable up to 5 mm, but most are shorter and range down to forms only 0.5 mm long. Most small rays straight, but some gently curved, particularly where small rays tangential to coarse gaps in skeletal wall. Small spicules irregularly spaced in fairly open tracts, and pack-

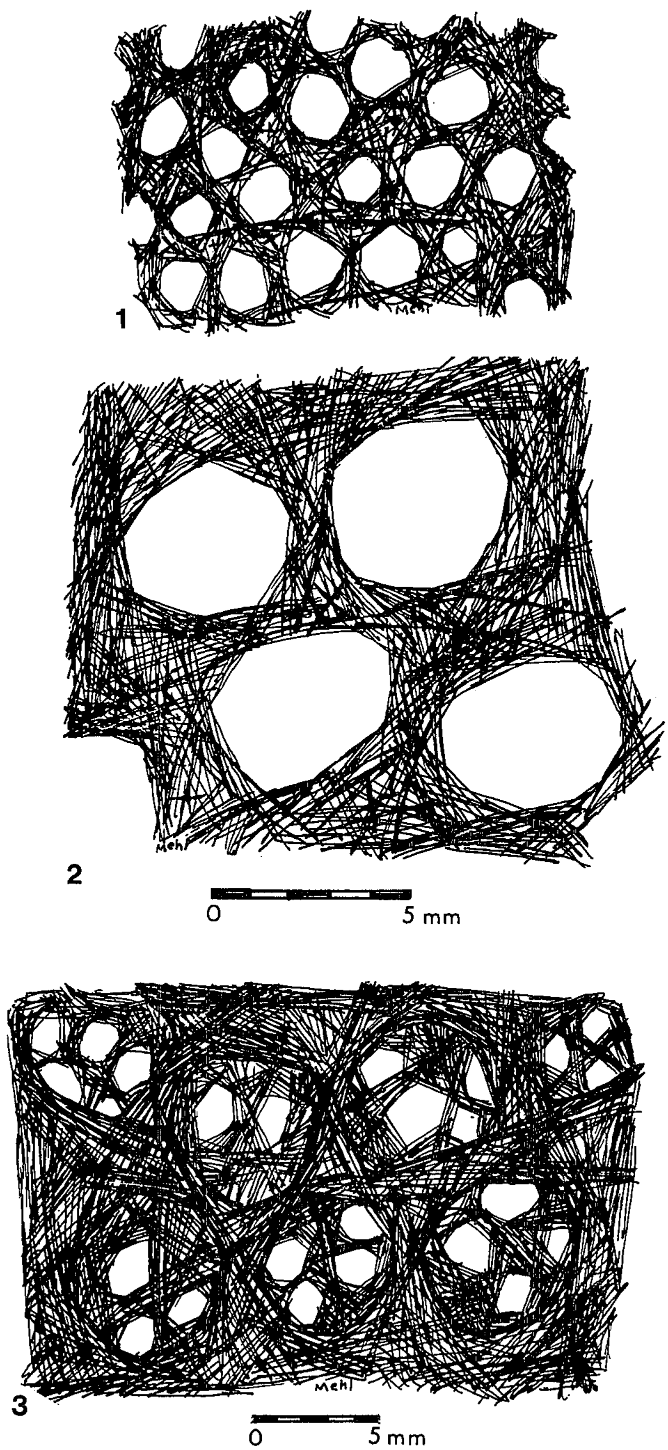


FIGURE 13.—*Sketches of part of the wall of* Rufuspongia triporata *n. sp. Approximate scales indicated by bars; 1 and 2 to same scale. All of the openings are defined by sweeping tangential clusters of long, hairlike, presumably hexactine-based spicules.* 1, *Sketch of skeleton from the dermal surface showing only the relatively fine pores and the long- and short-rayed, hexactine-based spicules that make up the structure.* 2, *Same general skeletal area seen from the gastral surface, without the dermal layers behind, shows the long, sweeping, hairlike, tangential clusters of spicules that define the major gastral gaps.* 3, *Sketch of skeletal structure of the two-layered wall with coarse, presumed, gastral gaps through which can be seen the skeletal structure of the more dermal part of the skeleton with smaller openings.*

ing may range to 10 spicules per 0.5 mm, measured at right angles to their trend, and generally spicules occupy far less than one-half volume or width of flattened tract. Many fragments have the fine spicule part of the net preserved as only dense hematite crusts, where traces of fibrous small spicules only locally preserved, or hinted at in irregular hematite, massive preservation.

In many fragments coarse root-tuft-appearing spicules preserved locally as calcite, but generally as very light gray silica; spicules underwent replacement before small spicules replaced by pyrite and altered to hematite.

Discussion. Comparisons with *Rufuspongia* have been discussed earlier, in treatment of *R. triporata. Taleolaspongia modesta* also differs from *Bulbospongia bullata* in having prominent, very coarse hexactines and rhabdodiactines in the skeletal net, made mainly of smaller hairlike spicules, and in having moderately regular, distinct, medium-sized pores. Both may have similar growth forms, but comparisons are difficult to make because of their fragmental nature.

R. triporata lacks the coarse hexactines and rhabdodiactines, and has a skeletal wall apparently composed of two layers. One layer, on the presumed gastral surface, has large gaps outlined by hairlike tangential rays, and the other layer exposed on the presumed dermal surface extends across the gaps and has finer pores outlined by spicules of essentially the same size as those in the gastral part of the skeleton. Known fragments of *R. triporata* are so small, however, that no comparisons can be made in terms of growth form, but only in the nature of spiculation and pore size.

Material. Holotype, USNM 463554, from bed 7; paratypes, USNM 463555, part and counterpart, from bed 12; USNM 463556, part and counterpart, from bed 18; and USNM 463557 and 463558, both with part and counterpart, from bed 19. Additional unnumbered reference specimens were collected from beds 2, 18, 19, and 21, from the Red Hill quarry.

Etymology. Modestus, L., moderate, gentle, unassuming, referring to the moderate-sized pores of the species.

Genus BULBOSPONGIA n. gen.

Diagnosis. Vaselike or balloonlike teganiid sponges expand upward from steeply obconical lower part to bulbous upper part; walls thin, marked with low vertical ridges, but upper part smooth; skeleton fine textured, upwardly divergent, locally plumose, mixed fine and moderately coarse long spicules, principally diactines but perhaps including stauractines; lacks coarse hexactines and rhabdodiactines; lacks coarse reticulate stauracts and prominent pores or gaps; coarse spicules more dominant in inner part of wall and fine spicules in outer part of wall.

Discussion. Bulbospongia bullata n. sp. may appear similar to *Phragmodictya catilliformis* (Whitfield 1881) in generalized growth form, with a gently ridged, lower subcylindrical part that expands upward in vaselike form. However, that species of *Phragmodictya* has nodes along the weak ridges, sculpture which is not evident in the flattened Devonian form from Nevada. In addition, *Phragmodictya* generally has a moderately well defined reticulate skeletal structure, characteristic of the dictyospongiids, in contrast to the upward subparallel to plumose skeletal structure seen in *Bulbospongia.*

Similarly, *Pyruspongia* Rigby, 1971, also has a bulbous or upward-expanding balloonlike form, but *Pyruspongia* has a moderately dense skeletal net composed of irregularly oriented hexactines instead of the more dominant thatch of diactines characteristic of *Bulbospongia. Pyruspongia, Phragmodictya,* and *Bulbospongia* are similar, however, in lacking prominent pores in their thin walls, but in some flattened preservations they could appear similar in general growth form.

These sponges might be included within the order Hadromerida Topsent, 1898, in the classification of de Laubenfels (1955), but there is no Middle Paleozoic genus that would include them. The Epipolasida Sollas, 1888, have a radiate architecture instead of a bulbous thatched structure. Tetraxial spicules are not apparent as major elements in the parallel thatch of the sponges described here, so the genus is not included in the Choristida Sollas, 1888, or among the more structured demosponges. The genus is included here in the Hexactinellida with some question, because of its association and because the skeletal structure is not well preserved.

Type species. Bulbospongia bullata n. sp.

Etymology. Bulbus, L., a swelling of fleshy, usually underground, bud or tuber; *spongia,* sponge; referring to the balloonlike appearance of the sponge.

BULBOSPONGIA BULLATA n. sp.
figs. 14.3, 14.9, 15.1–15.3, 16.1, 16.2, 16.4–16.8

Diagnosis. As for the genus, which is monotypic.

Description. Large, upward-expanding, vaselike to balloonlike sponges with rapidly expanding lower stemlike part; and upper more globose or vaselike appearance; base on holotype and paratypes torn and oscular margins not preserved on vaselike forms, but is preserved on single, flattened large block. Walls thin, perhaps with low vertical ridges approximately 1 cm apart in lower stemlike part of sponge, but widening to about 2 cm apart in upper, expanded vaselike globose form; walls lack coarse gaps or pores.

Large holotype approximately 8 cm across at torn base, but expands uniformly upward, lower approximately 4 cm a uniform obconical expansion, but flares above to widths of approximately 9 cm, as preserved one-half width, at 8 cm above base and to 10 cm, in one-half width, at approximately 10 cm above base. Above this, margins lost either by collecting or torn prior to burial.

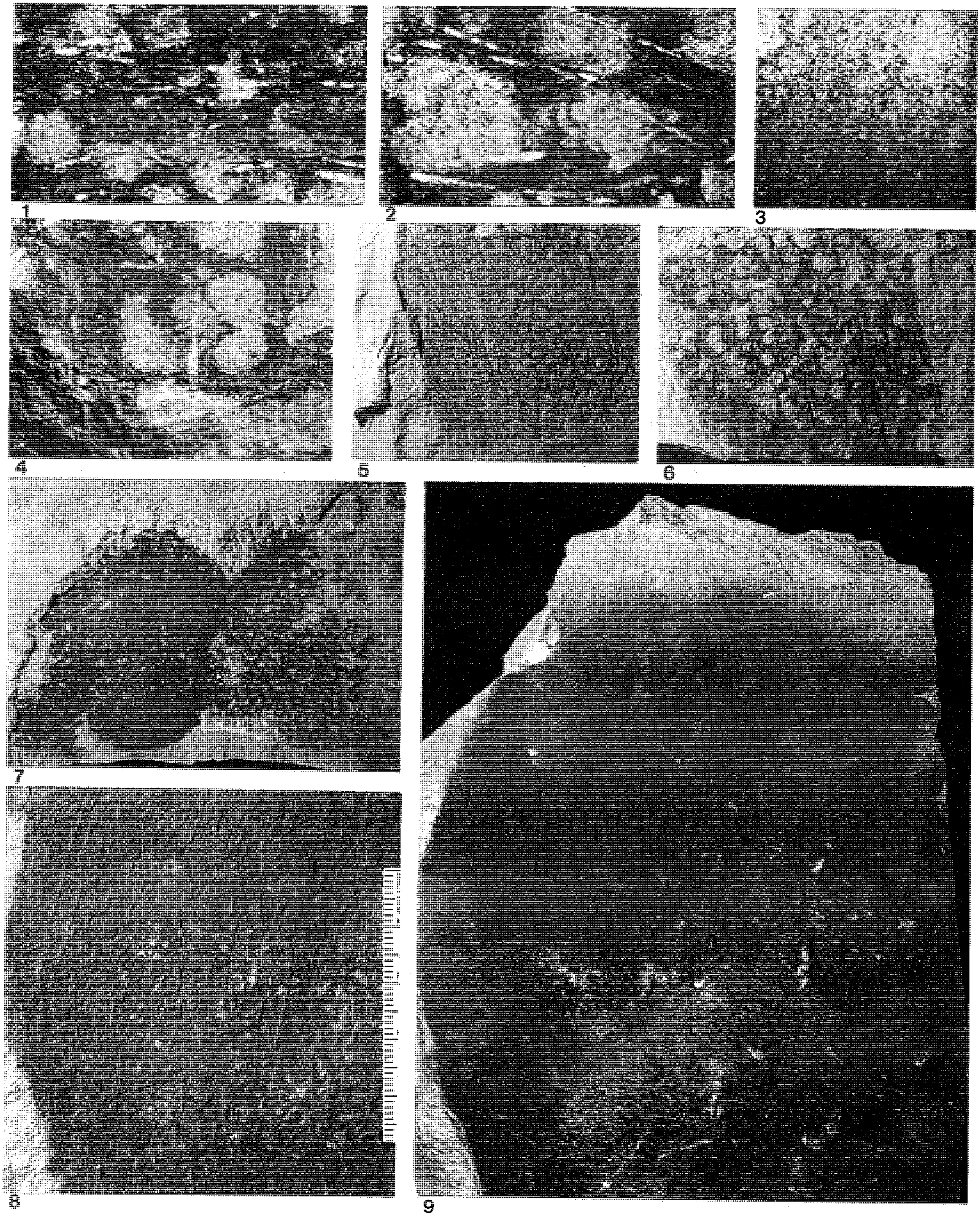
Skeletal structure upward plumose of mixed fine and moderately coarse, long spicules, with suggestion of plumose areas up along ridges that function as axes of divergence of skeleton; entire skeleton fibrous upward and outward, but thin and apparently pliable so in some areas low ridges folded to produce ribbed impressions in holotype and some paratypes, as well as in reference specimens.

Skeleton a mix of coarse, apparently diactine spicules with rays up to approximately 3 mm long and 0.10–0.20 mm in diameter; most spicules 1–2 mm long and approximately 0.10 mm in diameter, at midlength; no marked quadrate arrangement, although spicules crudely parallel, and a few possible stauractines may be present, but these questionably part of skeleton and may be foreign spicules. Finer spicules in plumose or thatched skeleton approximately 0.02 mm in diameter and appear as relatively long, thin, hairlike spicules; more prominent in paratype, USNM 463561 than in large holotype where skeleton dominated by coarse spicules. Coarse spicules may form inner principal skeleton, and fine spicules dominate in outer, finer-textured dermal skeleton; differentiation gradational and uncertain because of flattened nature of sponges. Holotype, however, with thin lense of spongocoel filling, so both upper and lower walls partially differentiated and separated by thin, relatively spicule-free, gray matrix lense. Coarse spicules most characteristic immediately below lense as inner surface of lower wall and fine spicules most prominent in upper part of upper wall, in dermal(?) layer, although elsewhere in same sponge relationships not as clearly shown.

Smaller paratype with distinct conical stem, approximately 3 cm across at base, widens up from torn base to approximately 5 cm wide, 3 cm above base, and then more rapidly expands in globose fashion so upper part approximately 12 cm across at 9 cm above base; full width not preserved in torn fragment and broken edge fractured and lost during collection. Wall with prominent, low, ridgelike ribs as areas of moderately dense skeletal development, with same general spacing as in holotype. Minute dotlike hematite replacement of paratype suggests microreticulate part of skeleton, but no clear tracts nor straps, nor clearly defined horizontal spicules at right angles or at high angles to apparently plumose structure of main part of skeleton.

One of paratypes (USNM 463560) shows oscular fringe at upper margin, fringe approximately 1 cm wide, composed of isolated small spicules, principally diactine-appearing, and mainly 0.01–0.02 mm in diameter, although some range to 0.10 mm across in dense hematite

FIGURE 14.—Taleolaspongia modesta *n. sp. and* Bulbospongia bullata *n. sp. from the Red Hill quarry.* Taleolaspongia modesta *n. sp.* 1, 2, 4, *Photomicrographs of paratype, USNM 463556, from bed 18, in which the dark, relatively fine-textured, finely spiculed, probably dermal part of the skeleton is perforated by light matrix-filled pores and, in part, overlies and underlies the coarse hexactines that appear light gray. They are the distinctive coarse spicules of the skeleton and are preserved either as silica or calcium carbonate. They apparently were replaced prior to the general pyritic replacement of most of the remainder of the skeleton, and the subsequent alteration of that part of the skeleton to hematite, proximal-distal marked by arrows, X5.* 3, 9, Bulbospongia bullata *n. sp., paratype, USNM 463561, from bed 19;* 3, *poorly preserved upper fringe of prostalia at the upper center margin of the sponge in figure 9; spicules relatively poorly defined as aligned dots of hematite, X5;* 9, *massively replaced fine-spiculed skeleton of* Bulbospongia bullata *in which skeletal detail is largely obscured in the massive hematite, but the fringe of prostalia shows moderately well around the nearly complete upper margin; other margins disrupted, in part, by breakage before burial, and in part, during collection, X1.* 5–8, Taleolaspongia modesta *n. sp.;* 5, *paratype, USNM 463555, from bed 12, shows the coarse hexactines as molds impressed into the surface composed of the relatively fine-textured, but regularly open porous, probably dermal part of the skeleton; the gently, upward-expanding, fanlike fragment suggests it is part of an open saucer-shaped or funnel-like sponge, X1.* 6, *Well-preserved fragment, with dark, presumed, dermal layer preserved as massive hematite interrupted by light matrix-filled circular, moderately uniform-sized pores or gaps in the skeletal net; light-colored coarse hexactines show through the net; paratype, USNM 463556, from bed 18, X1.* 7, *Massively replaced paratype shows two preservations of the dark, presumed, dermal layer; on the right more interrupted by pores and perhaps slightly more dermal than the moderately massive oval area on the left; both have impressions of coarse hexactines, like those characteristic of the species throughout the specimen; the slightly upward diverging nature of the coarse hexactines suggest, again, the fragment is part of a gently expanding, funnel-like or palmate sponge, X1.* 8, *Holotype, USNM 463554, from bed 7, shows the dense presumed dermal part of the skeletal net sculptured by the positive impression of the coarse hexactine spicules that are here moderately subparallel and uniformly spaced throughout; light matrix indicates positions of pores or gaps in the skeletal net, approximately X1.1.*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body wall. Individual spicules project at least 1 cm from more less clearly defined margin of sponge, and probably extend some distance into body of sponge, as well.

Discussion. In apparent overall growth form, the sponges described here may appear somewhat similar to flattened *Thamnodictya* Hall, 1884, or possibly even to *Phragmodictya* Hall, 1882. *Bulbaspongia bullata* contrasts sharply with those forms, however, and with all other dictyospongiids, in lacking an obvious reticulate skeletal structure, and with a skeleton made basically of unclustered, upward plumose, thatched monaxons.

Material. Holotype, USNM 463559, part and counterpart; paratypes, USNM 463560 part and counterpart, USNM 463561 part and counterpart, and USNM 463562, 463573, and 463574, are all from bed 19. In addition two unnumbered reference specimens were collected from bed 16 and one from bed 18. Figured "death assemblages" of fragments, USNM 463563 and 463564, part and counterparts, also show fragments of *Bullospongia.* Two reference specimens also occur from bed 21. Both the holotype and relatively complete paratype are present as part and counterpart, as are several other fragments.

Etymology. Bullatus, inflated, in reference to the hot-air-balloon-like inflated appearance of the sponges.

ROOT TUFTS

ROOT TUFT A

figs. 17.7 and 17.8

Description. Longest loglike fragments about 3 cm long, but originally much longer before fragmentation of possible diactines; spicules gently taper to point in one direction, at least, with maximum diameters approximately 0.4 mm; central canals to 0.04 mm in diameter well preserved as darker sediment-filled lines along axes of weathered spicules; no axial crosses nor distal anchors observed, latter would have confirmed assumed root tuft nature.

Discussion. These few isolated, but clustered, spicules have a preservation remarkably different from the general hematitic-replaced sponge skeletons common in the Red Hill collection. These spicules are very light gray silica. They occur on two isolated blocks, one as part and counterpart. Some spicules are in close parallel arrangement, as though part of spicular bundles, but this is uncertain. The spicules were certainly originally rather long, but are now broken into pieces. These apparent diactines are siliceous. Their recrystallization from opaline silica to a stable silica, perhaps chalcedony, must have happened prior to the pyritization of the associated smaller spicules and the subsequent overall hematite replacement and hydrothermal alteration of skeletal materials of these rocks. The spicules, thus, were not subject to the general pyrite-hematite transformation. These diactines are most like those that occur within fragments of *Taleolaspongia modesta* n. sp. as part of the moderately thick and densely spiculed wall. These may be isolated spicules eroded loose from that species. They are described separately here, however, to emphasize that such spicules also occur without any connection to those sponges.

Material. Figured specimens, USNM 463565 and 463566, include about 20 spicules from bed 5.

ROOT TUFT B

figs. 17.2, 17.3, 17.5, and 17.10–17.12

Description. Several isolated but compact and clearly identifiable root tufts principally from bed 6, with excellent specimens from bed 10 and isolated bits from beds 7 and 8. Most distinctive tufts are from bed 10; appear as goateelike or tresslike, wavy, tapering clusters of fine, long, hairlike spicules. Most complete specimen approximately 9 cm tall and expands upward from basal incomplete margin approximately 5 mm across, to open tuft margin at edge of fragment, 5 cm across. Individual

FIGURE 15.—Bulbospongia bullata *n. sp., type specimens from bed 19 of Red Hill quarry.* 1, *Paratype, USNM 463560, shows ragged, upper torn margin, but upward-expanding vaselike form with low ridges, particularly well expressed in the lower left; skeleton of apparently irregular diactine spicules that are relatively short and coarse; light-colored lens in the left center and lower left (arrows) is matrix-filling in spongocoel between the flattened upper and lower walls of the thin-walled sponge, X1.* 2, 3, *Part and counterpart of holotype, USNM 463559, showing balloonlike or light-bulb-like nature of the sponge with low, now-flattened gentle vertical ridges in the lower part and the moderately smooth upper part; base torn and upper oscular margin not preserved; plumose nature of the skeleton shows in the central part of each of the figures, X1.*

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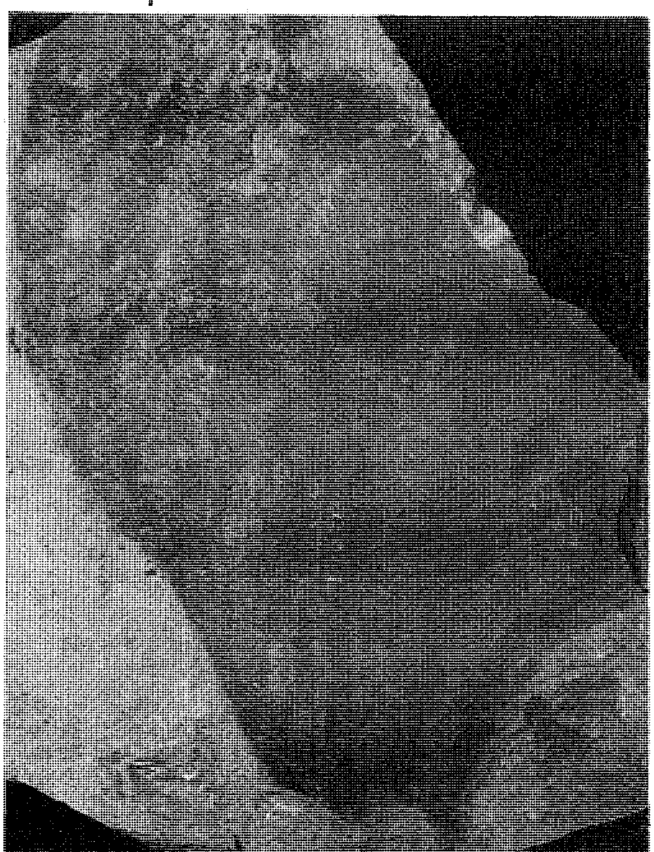

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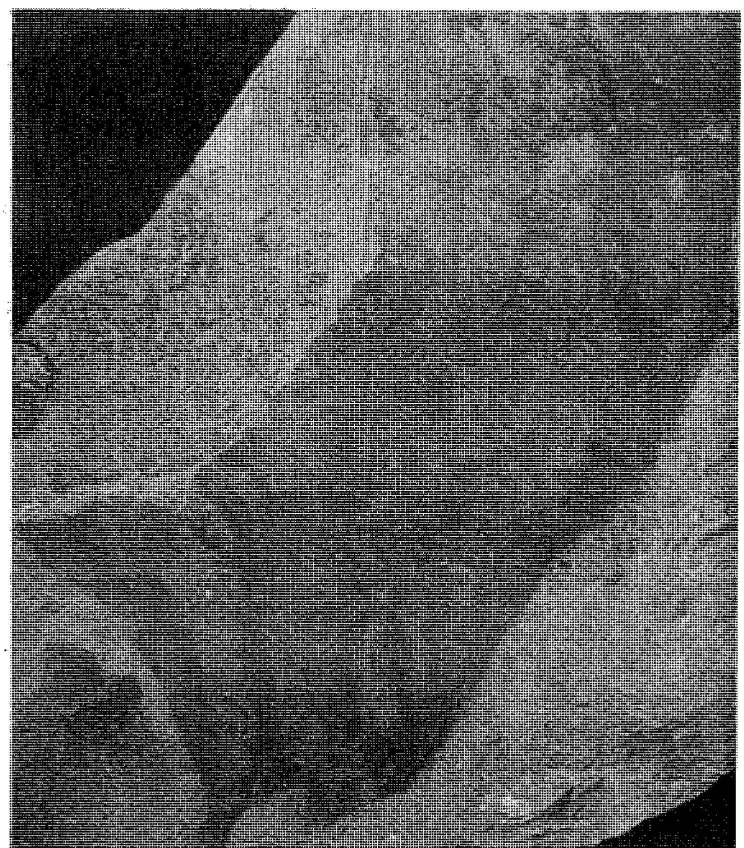

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spicules wispy and combine to produce moderately compact and well-defined tuft, with firm, clearly defined edges; principally unclustered but locally forming moderately dense spicule clusters, particularly near edge. Almost all spicules incomplete; only rarely traceable from tip to tip; most fragments represent spicules 30–40 mm long, but inconclusive, and show remarkable uniformity in diameter, approximately 0.01–0.02 mm; in only few instances can taper be demonstrated; most fragments as long, tiny cylinders in hematite replacement. No crossing central canals nor anchorlike terminations observed. Weak clusters bifurcate upward in few areas into small clusters reminiscent of skeletal structure of *Actinodictya nevadensis* n. sp., but relationship uncertain and no sure association with any particular species because of mutual isolation.

Samples in bed 6 show basically same spicule size but appear less well defined, less compact clusters, and with more irregular ray crossings to produce false appearance of stauracts. In some areas spicule spacing distant in apparent upper parts of tufts, but isolated and relationships to other species uncertain. Two or three wispy fragments may be separate tufts on some blocks or tufts branched distally or transported slightly; impossible to tell from material available.

Discussion. Relationships of the tufts to any of the species here described is uncertain, because tiny spicules of the dimensions noted here occur in several forms where only fragments of skeletal elements are preserved, and relationship to tufts are unknown. They do indicate, however, that some of the species were adapted to the moderately soft substrate represented by the lime mudstone matrix. They suggest, as well, that the sponges may have been transported only short distances and grew essentially in the environment where they are found.

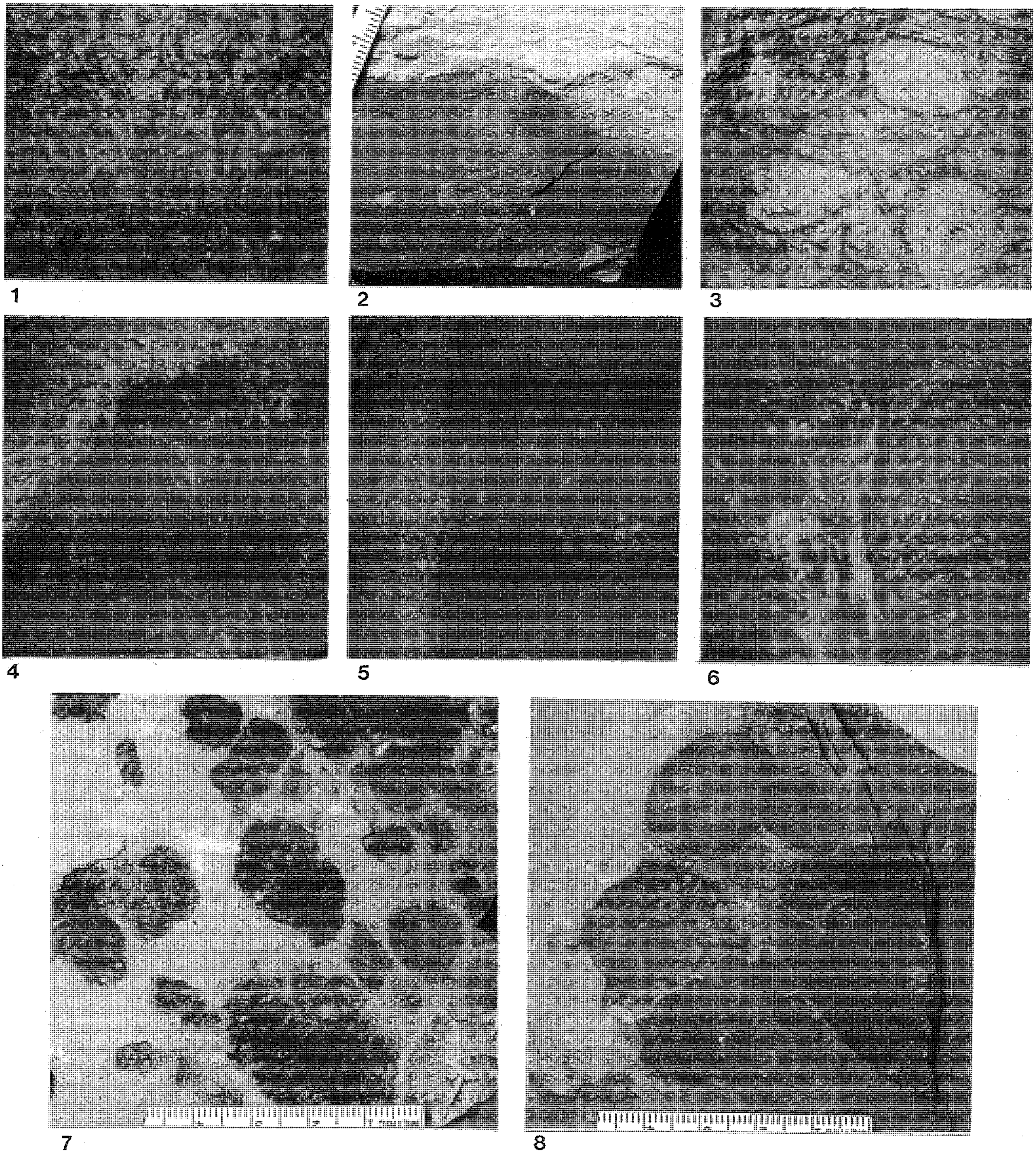
Material. Figured specimens, USNM 463567 and 463577 from bed 10, and USNM 463568, 463575, and 463576 from bed 6. In addition, two reference specimens occur in samples from bed 6, one each from beds 7 and 8 of the Red Hill quarry.

ROOT TUFT C
figs. 17.1, 17.4, 17.6, and 17.9

Description. Moderately coarse root tufts occur in several samples in collection; perhaps best characterized by sample 1 from bed 9. Tuft somewhat less organized than those with only fine spicules and include long hairlike spicules of essentially same dimensions as in fine tufts, approximately 0.02 mm in diameter, but associated with moderately regularly spaced, loglike segments of spicules 0.12–0.16 mm in diameter and latter scattered 0.2–0.5 apart. Small spicules between coarser ones locally form discrete clusters with approximately same diameter as coarse spicules; in some areas where hematite replacement relatively massive, differentiation of small clusters and coarse spicules difficult, but in other areas cluster and spicules distinctly different and separable.

Tufts form somewhat irregularly outlined masses of spicules 6 X 4 cm and appear flattened in diagonal direction and irregularly swirled, instead of forming long hairlike tuft, but with irregular ragged, torn edges, direction

FIGURE 16.—Bulbospongia bullata *n. sp. and fragments of new species of* Rufuspongia *and* Teganiella. 1, 6, Bulbospongia bullata *n. sp.;* 1, *paratype, USNM 463560, from bed 19, shows relatively coarse diactine spicules of the parallel or thatchlike skeletal structure, X5.* 2, *Paratype, USNM 463573, shows torn side or upper margin of the small fragment in which the thatchlike nature of the skeleton is preserved particularly well along the margin of the sponge, from bed 19, X1.* 3, Rufuspongia triporata *n. sp., paratype shows moderately large pores defined by tangential rays of gastral layer in skeleton, USNM 463549, from bed 11, X5.* 4, 5, Bulbospongia bullata *n. sp., photomicrographs of the holotype, USNM 463559, from bed 19;* 4, *torn base of the holotype shows the frayed thatch exposed near the margin of the sponge;* 5, *side of the holotype shows moderately well-defined edge of the sponge and upward-divergent thatch where two ridges diverge along the flattened lower left margin of the sponge as shown in figure 15.3, both X5.* 6, *Paratype, USNM 463574, from bed 19, shows a jet-of-water structure produced by the plumose diactine spicules that diverge upward and outward from one of the flattened ridges, X5.* 7, *Transported fragments of* Bulbospongia bullata *n. sp. and* Rufuspongia triporata *n. sp. show characteristic macerated debris of coin-sized fragments of skeletons, all preserved as relatively massive hematite; most of the dense skeletons are of* Bulbospongia *and the smaller, more open-textured specimens are of* Rufuspongia triporata; *a massively replaced hematite fragment of* Rufuspongia *sp. 1 occurs on the reverse side of the block; USNM 463564, from bed 19, X1.* 8, *Coarse* Teganiella ovata *n. sp. and associated fragments of* Bulbospongia *and* Rufuspongia triporata *from bed 16; the large* Teganiella *fragment in the lower right is the largest representative of that species in the collection; the two other small fragments in the upper center are of more typical size, USNM 463546, X1.*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of original orientation of tuft less certain; possible two partially overlapping tufts or as tuft fragments of upward, divergent system partially torn to produce ragged end.

Small incomplete tuft fragment from bed 8 shows essentially same pattern of spacing and sizes of spicules; grades in one direction to area where no coarse spicules occur. This suggests coarse spicules perhaps added by sponge in upper part of tuft, but no internal proof. Additional fragment from bed 18 shows almost same general pattern but with fewer fine spicules in tuft dominated by coarser spicules; some stauracts associated in matrix with sample from bed 18, but not within tuft itself; relationship remains only inferred, although stauractine spicules with rays of essentially same diameter as somewhat longer tuft spicules. Coarse spicules in tuft, however, shorter than associated smaller spicules in somewhat diagonally fractured surface.

Discussion. Like the small-spiculed tufts, relationship of these mixed tufts to particular genera or species is also uncertain, because all appear as isolated fragments, dissociated from intact skeletal nets of other sponges in the beds.

Material. Figured specimens, USNM 463569 from bed 9, USNM 463570 from bed 8, and USNM 463571 from bed 18 of the Red Hill quarry.

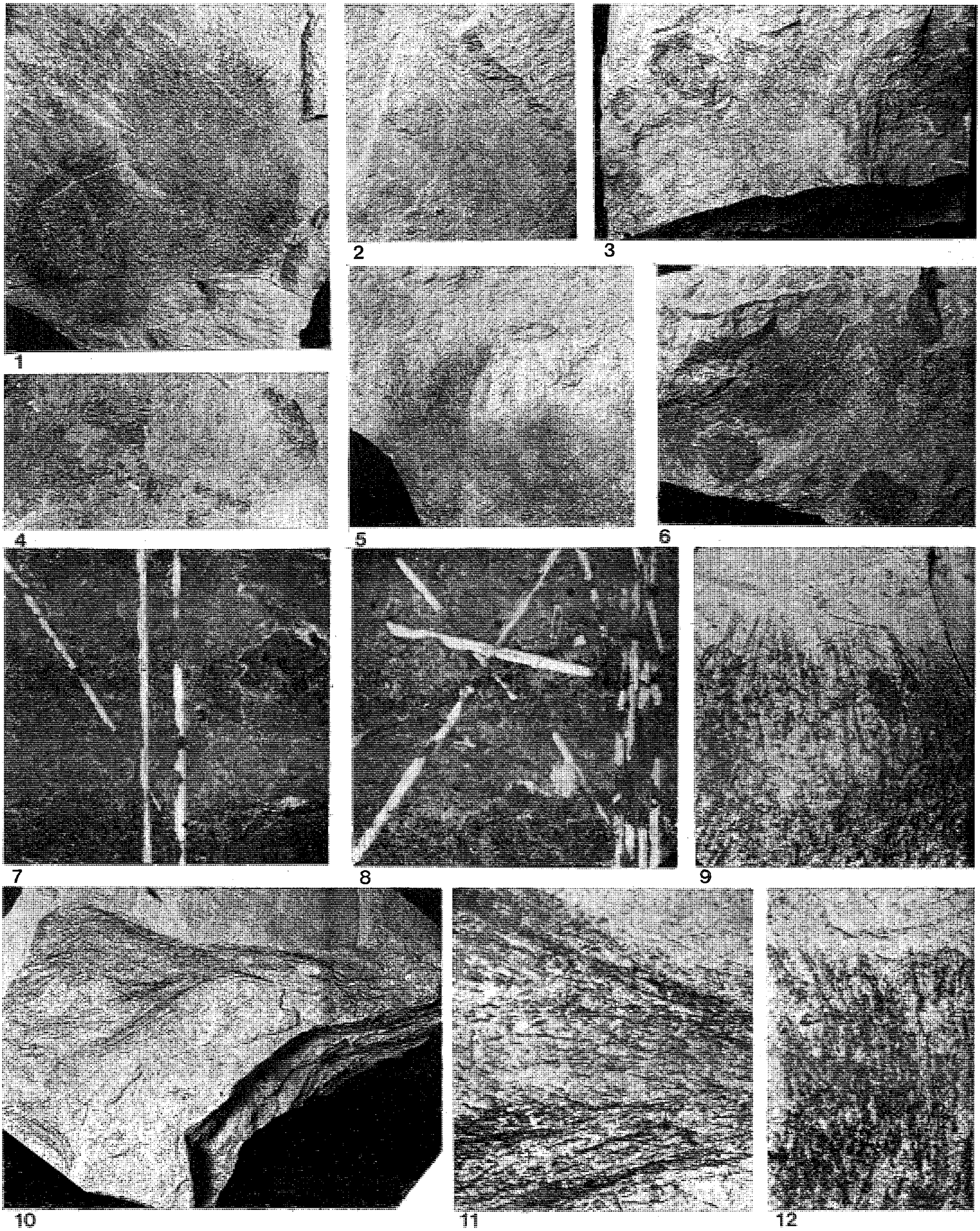
PHYLOGENETIC CONSIDERATIONS OF THE PROTOSPONGIID, HINTZESPONGIID AND DICTYOSPONGIID TRANSITION

Some of these Devonian sponges appear to have skeletons that are structurally transitional between protospongiid and dictyospongiid arrangements. Some of these apparent transitions may be due to variations in preservation, because the stauractine or hexactine natures of the spicules are often obscured by weathering, pyritic replacement and alteration of that pyrite to hematite. Some species do have the regular unbundled and quadruled skeletons of protospongiids.

A few specimens, preserved as limonite and included in *Cyathophycus,* clearly possess four-rayed spicules, some additional spicules with prominent, apparently swollen nodes, plus some hexactine spicules, along with rhabdodiactines, in a three-dimensional arrangement within the wall. Some *Cyathophycus* specimens with less dense hematitic replacement have up to 5 orders of four-rayed, or possibly six-rayed spicules, some of which show prominent nodal points. *Cyathophycus* was noted as a possible transitional form between protospongiids and dictyospongiids by Rigby (1986b), and the Ordovician species occur at a time when such a development might be expected between the early Paleozoic protosponge-dominated hexactinellid assemblages and the Middle Paleozoic dictyospongiid ones. The common ancestor of both groups may have been hexactine-bearing sponges with spicules in a regular horizontal-vertical arrangement.

Some sponges in the Red Hill fauna have dictyosponge-type skeletons and a skeleton composed largely of fine, regular, reticulate bundles of diactines. Skeletons of these sponges do include some stauractines or hexactines, however, and they have common hematitic spots at spicule centers or ray crossing points that suggest proximal-distal rays even when such are not clearly preserved. In addition, there are a number of sponges that have a regular meshwork of bundled spicules, apparently diactines, without prominent crossing points and, thus, are clearly of dictyospongiid grade. These latter sponges

FIGURE 17.—*Root tuft spicules from the Red Hill quarry.* 1, 4, 6, 9, *Root tuft C;* 1, *moderately coarse root tufts, less organized than ones with fine spicules, in irregularly outlined masses; crudely branched structure may indicate partially overlapping tufts, USNM 463569, from bed 9, X1;* 4, *less extensive and less well preserved fragment shows moderately coarse spicules particularly well in the middle part of the broken fragment, USNM 463570, from bed 8, X1;* 6, *moderately massive, coarse-spiculed root tuft associated with fragments of other sponges, spicules show best in right center, USNM 463571, from bed 18, X1;* 9, *photomicrograph of torn fragment end of coarse-spiculed tuft shows mix of coarse and fine spicules with coarse spiculed in the left and lower part, photograph enlarged of lower right part of tuft in* 1, *USNM 463569, from bed 9, X5.* 2, 3, 5, 10–12, *Root tuft B;* 2, *relatively fine-textured, openly porous tuft of moderately well aligned parallel small spicules, USNM 463575, from bed 6, X1;* 3, *fine spicules of moderately irregularly arranged tuft, USNM 463568, from bed 6, X1;* 5, *fibrous torn end of moderately broad, fine-textured root tuft replaced by hematite, as are other figured tuft spicules, USNM 463577, from bed 10, X1;* 10, 11, *well-defined, beardlike, fine tuft tapers from broad upper part on the left, to virtually single spicules on the right; spicules are not uniformly distributed, but occur in clusters or subtufts, USNM 463567, from bed 10;* 10, *X1;* 11, *X5.* 12, *Moderately open texture of fine-spiculed root tuft; root packing is characteristic of most specimens of fine tufts, USNM 463576, from bed 6; X5.* 7, 8, *Root tuft A; coarse, silicified spicules in lime mudstone are some of the coarsest spicules preserved in the Red Hill collection; loglike fragments are long, gently tapering, apparent diactines, but some may be rhabdodiactines with obscured central canals and proximal-distal rays in the moderately coarse silicification, from bed 5, USNM 463566, X5.*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appear to have a few stauractines, but these are normally observed only within quadrate openings between tracts of the principal skeleton, often in a diagonal orientation, although such spicules may occur in the skeletal tracts or straps, too.

Species of *Cyathophycus* and *Cyathophycella* of our collection apparently possess triaxon (hexactine and/or stauractine) principal spicules and lack the strongly bundled spicular rays characteristic of the Dictyospongiidae. *Cyathophycella*, however, does show a fine, latticelike microreticulation within each of the rectangularly arranged skeletal straps or tracts, which makes it similar to at least some Dictyospongiidae.

Actinodictya ranges in skeletal structure from the irregular type species, *A. placenta* Hall, 1890, through the somewhat less irregular *A. nevadensis* to the more regular *A. lamina*. All have irregularly oriented bands or tracts of long-rayed spicules, which give a somewhat stellate appearance to their skeletons. *A. lamina*, in addition, possesses variously defined horizontal and vertical tracts of long, thin-rayed apparent diactines, along with common hexactines and hexactine-based spicules, mainly stauractines. *A. lamina* also has a protosponge-like layer of separated and regularly oriented stauractines. *Actinodictya*, thus, can be interpreted as a morphologically transitional form between the Protospongiidae (with quadruled stauractine principal spicules), the Hintzespongiidae (with a protosponge-like layer and an irregularly spiculed and oriented layer), and the Dictyospongiidae *sensu stricto* (with bundled diactine principalia). Relationships of the hintzespongioids and dierospongioids to the protospongioids and the dictyospongioids, as these terms were used by Finks (1983), are uncertain, largely because of the discontinuous stratigraphic and geographic record.

SEDIMENTOLOGY AND TAPHONOMY

Individual beds of the Red Hill section range 2–10 cm thick. They consist largely of dolomite lime mudstones that contain fine terrigenous clastic sediments, mainly quartz grains with various degrees of roundness, and some clay, along with limited bioclastic debris. The beds show variable quantities of silt-size quartz grains, as well as variable amounts of fine to medium sand (up to 0.2 mm). Variations in sizes of sponge fragments and the relative amounts of terrigenous debris, along with variations in grain size of those clasts, likely reflect changes in depositional energy levels (fig. 18).

A method was devised for plotting three parameters, e.g., 1, species, 2, sizes of individuals, and 3, numbers of specimens, collected from each bed (fig. 18). Representative size classes of sponges and sponge fragments were chosen and given a numerical ranking for distribution evaluation. Those less than 2 cm across were given a size value ranking of 1; those 2–5 cm in maximum diameter, a ranking of 2; and those greater than 5 cm across, a ranking of 3. The size values or coefficients thus range 1–3. Numbers of specimens of each taxonomic group, within each size range, were counted. All size values, per bed and species, were summed and averaged. For example, in the *Rufuspongia* group from bed 6, we observed four specimens that are less than 2 cm across (4 X 1 = size values of 4), three are 2–5 cm across (3 X 2 = size values of 6), and four are greater than 5 cm across (4 X 3 = size values of 12). The sum of the values (4 + 6 + 12 = 22) divided by the number of specimens (11) yields an average size coefficient of 2.0 for the group from bed 6.

Distributions of some sponge groups, numbers of specimens of the group from each bed (shown on a logarithmic scale), and their size coefficients are plotted opposite beds of the quarried section in figure 18. The general small specimen size throughout the section is evident.

Fossil sponges and fish occur in close association throughout most of the quarry section; however, both are mostly concentrated in particular beds (e.g., beds 10–12, fig. 18). Samples from these beds, seen in thin section, also contain fragments of various other fossils, such as conulariids, inarticulate brachiopods, small gastropods, and cricoconarids. Locally, platelike fragments appear to be at high angles to bedding, which could indicate higher energy deposition than in some associated less disturbed beds.

Sponges in the collection are generally fragments, mainly pieces smaller than 5 cm across. They are normally moderately size-sorted, and some samples show some taxonomic sorting as well (e.g., *Rufuspongia* fragments, fig. 12.1). Sizes of skeletal meshes of some dictyospongids indicate that they must have been very large specimens, originally probably exceeding 50 cm high. Dictyospongiids and specimens of *Bulbospongia* are occasionally found as large, flattened, almost complete specimens up to 10–20 cm across. These larger specimens most probably were buried more or less in situ, because their fragile skeletal walls would otherwise have been torn apart. The extraordinary preservation of both sponges and fish indicate their rapid burial prior to decay.

Common specimens of *Teganiella ovata* n. sp. are the only sponges that occur as entire body fossils, probably because of their small size and firm skeletons. These sponges often occur in clusters that are closely packed and composed of sponges of similar size (figs. 11.4, 11.5). Because of compaction and their subspherical shapes, they now show poor orientation. Most of the *Teganiella* specimens now are preserved only as flattened outlines of the sponge bodies. These clusters of *Teganiella* specimens and associated small sponge fragments may indicate a preburial transport and size sorting, or, as noted earlier in discussion of the species, they may represent essentially in

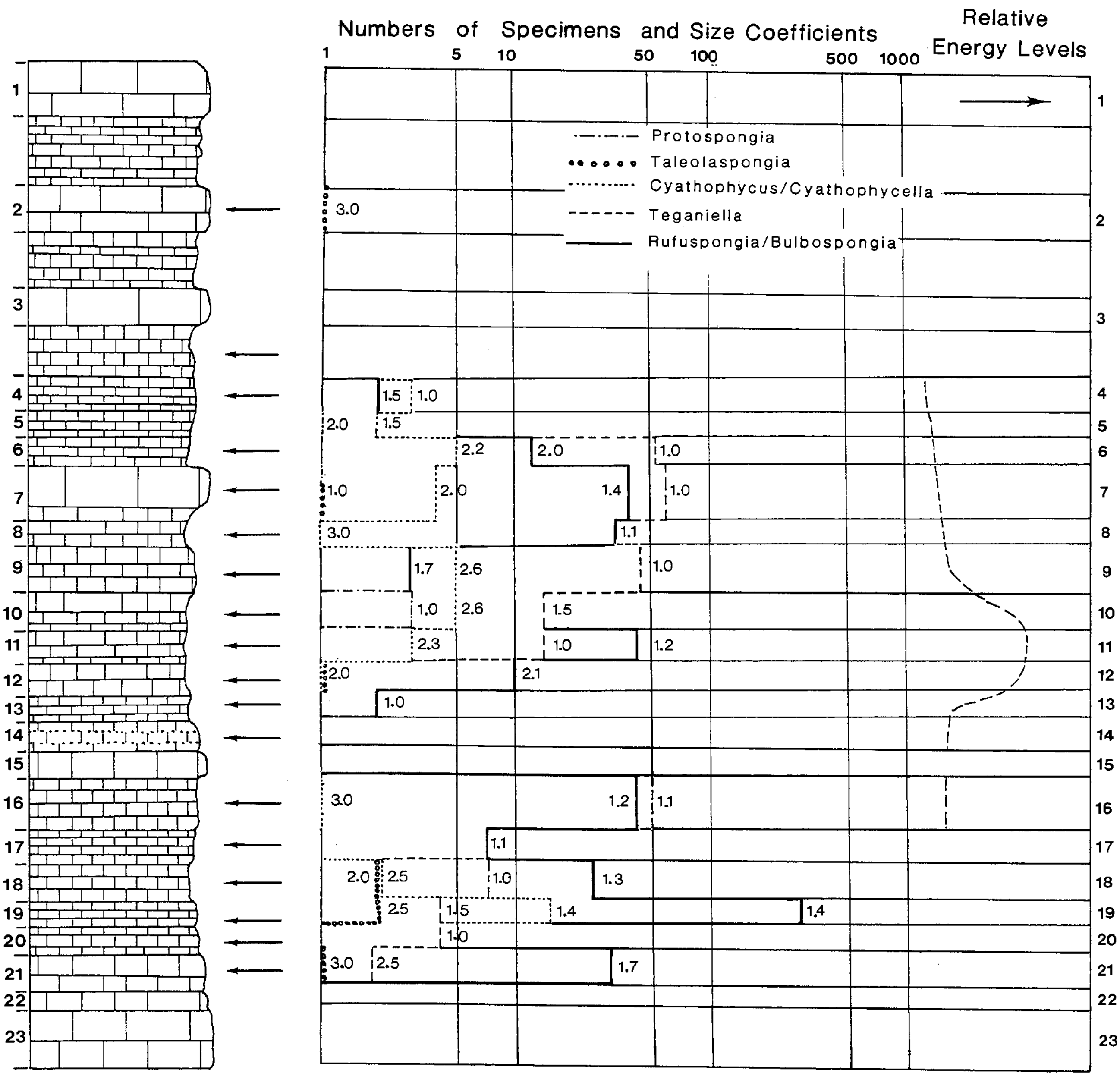

FIGURE 18.—*Distribution of several genera of sponges in the section of the Red Hill quarry; indicated by arrows at the right of the section, which is about one and one-half meters thick (see fig. 2). Numbers of specimens of these genera are shown for each bed by the bar graphs to the right. Average sizes of specimens of each genus are indicated by the size-coefficient numbers, to the right of the bars. The method of calculating the coefficients is discussed in the text. The coefficients show that most specimens are only about 2 cm across or smaller. A curve of relative energy levels is plotted to the right and shows a rise in energy levels during deposition of beds 9–12, as indicated by increase in terrigenous clastic content in these beds, as compared to other beds in the section. Energy levels, however, must have been low for accumulation of all of the lime-mudstone-dominated sequence.*

situ, mature, essentially monospecific communities. In either case, they do not show evidence of currents and transport like specimens of other taxa in the collection.

The general preservation of the sponges as hematite probably resulted from alteration of pyrite or limonite, which had replaced the originally opaline small siliceous spicules. The change to hematite probably occurred during a widespread later hydrothermal event within the region.

Only some very coarse hexactines and rhabdodiactines, which occur within fragments of *Taleolaspongia modesta* or as isolated root tuft spicules, are now silica and generally show no sign of hematite replacement. The general pyritic replacement of the original opaline silica of the small spicules most probably took place during early stages of diagenesis, perhaps as an early product of anoxic decay of soft tissues (and spicular axial filaments) within the sediment. These coarse spicules may have escaped pyritization because of their comparably smaller surface area to volume ratio.

Iron oxide spots, similar to those at nodal points of many spicules, are also quite common in the matrix outside the sponges, though they are more concentrated within the fossils. Some of the round spots seem to represent proximal or distal rays of spicules that extended out into the surrounding matrix. Such spots inside the skeletons may be simple secondary pyritic concentrations that preferentially occurred at ray junctions. These ray junctions could have been originally entangled with collagen fibers, like those common in Recent demosponges, such as in *Halichondria* Fleming, 1828. If Paleozòic hexactinellids actually contained more collagen than do Recent sponges, such organic accumulations may have kept the spicules in place and, on decaying, would have caused increased local H_2S production and, consequently, localized pyritization.

It is worthy of note that many Paleozoic hexactinellid sponges are preserved with pyrite- or limonite-replaced spicules, whereas most Mesozoic ones are preserved with spicules as siliceous- or calcite pseudomorphs.

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