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IV

No. 6.—MIDDLE CAMBRIAN SPONGIAE

(With Plates 60 to 90)

BY
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INTRODUCTION

The sponges of the Burgess shale member of the Stephen formation of the Middle Cambrian of British Columbia comprise nearly all of the siliceous sponges known to me from Cambrian strata of America. Dr. G. F. Matthew has described a number of minute forms from the Cambrian rocks of New Brunswick that he has referred to the Spongiae.[1] All the species described are represented by minute

[1] Trans. Royal Soc. Canada, Vol. VII, 1890, pp. 148-150. Trans. New York Acad. Sci., Vol. XIV, 1895, pp. 112, 113.

specimens in an unsatisfactory condition of preservation. With brief descriptions and diagrammatic illustrations, and only a hurried glance at the material fifteen years ago, I do not think I can comment upon the generic references of the several species named. Matthew deserves great credit for the results he secured from the fragmentary and poorly preserved Cambrian material of New Brunswick, but his work will require careful revision with the type specimens before many of the more obscure forms can be satisfactorily identified and classified.

Dr. J. G. Bornemann[1] has described cylindrical stems that are simple, branching and anastomosing, that occur in the Cambrian rocks of Sardinia, as a sponge analogous to the living Axinella.[2] He named it *Palaeospongia prisca,* gave a detailed description with many illustrations, and considered it probable that many so-called fossil algae such as *Palaeophycus* might be sponges somewhat similar to *Palaeospongia.*

The small spherical form from the Upper Cambrian described by Walcott as *Haguia sphaerica*[3] is probably a sponge, but in its present condition of preservation all traces of spicules have disappeared owing to the crystallization of the calcite; it must await the study of the American Archaeocyathinae and allied forms before a decision can be made.

There is also the Lower Cambrian Sponge *Leptomitus zitteli* Walcott,[4] which strongly resembles small specimens of *Tuponia lineata* Walcott described in this paper (see pls. 62, 63). The long longitudinal spicules are similar, and there appears to have been a compact dermal layer in which fine, short, simple spicules occur. It may be that better specimens of *Leptomitus* would show a structure similar to that of *Tuponia,* in which case the latter name would be a synonym of *Leptomitus,* which is now referred to the order Monactinellida.

There were probably many other forms of siliceous and calcareous sponges of which only a few traces have been found. My object in this paper is to call attention to the sponges from the Burgess shale and to leave to future investigation the collecting of material and study of the sponges of the Cambrian.

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[1] Die Versteinerungen des Camb. Schichtensystems der Insel Sardinien, Pt. 1, 1886, pp. 22-27, pl. 3, figs. 1-3, pl. 4, figs. 1-3.

[2] Rept. Voyage H. M. S. Challenger, Zool., Vol. 20, p. 178.

[3] Monogr. U. S. Geol. Surv., Vol. LXIII, Pt. II, 1899, p. 442, pl. LXIII, figs. 6, 6*a*.

[4] Bull. U. S. Geol. Survey, No. 30, 1886, p. 89, pl. 2, figs. 2, 2*a*. Tenth Ann. Rept. U. S. Geol. Survey, 1890, p. 597, pl. 49, figs. 1, 1*a*.

Habitat.—The sponges found in the Middle Cambrian Burgess shale, like the algae, were probably carried into the Wapta pool by currents, as they are widely scattered in the shale and are not forms that would flourish in muddy water. A description of the habitat and mode of deposition of the Burgess shale fauna is given on page 219 of this volume in connection with the description of the associated algal flora.

Manner of Preservation.—The sponge spicules and dermal layers are usually replaced by pyrite or coated with a thin black film.

The mode of occurrence of the sponges at Little Metis led Sir. J. W. Dawson to the following conclusions:[1]

> Originally rooted in the soft ooze of the sea bottom the specimens seem sometimes to have been buried *in situ,* so that when the shale is split they appear in transverse section or as round flattened discs; but in most cases they seem to have drifted from their anchorage, either with or without their anchoring-rods, and to have been flattened laterally. When entire, they sometimes present, when the shale is split open, a surface of dermal spines, masking the skeleton proper. In other cases the dermal spines come away with the matrix, leaving the skeleton spicules exposed. Thus the same species may present very different appearances under different circumstances. In most cases the body of the sponge has been more or less disintegrated or reduced to patches of loose spicules, and some large surfaces are covered with a confused coating of spicules and anchoring-rods belonging to several species. In some cases also the loose spicules, or fragments of them, seem to have been gathered in little oval or cylindrical piles and inclosed in pyrite. At first I was disposed to regard these as coprolitic; but Dr. Hinde doubts this, and regards them as merely loose spicules drifted together into hollows or wormburrows.

Genera and species.—The classification is mainly that of Zittel[2] with a few additions on account of forms unknown to him. The following genera and species are described in this paper:

SUB-CLASS SILICISPONGIAE

Order Monactinellida Zittel
Sub-Order Halichondrina Vosmaer
Genus Halichondrites Dawson
Halichondrites confusus Dawson
Halichondrites elissa Walcott
Genus Tuponia Walcott
Tuponia bellilineata Walcott
Tuponia flexilis Walcott
Tuponia flexilis var. intermedia Walcott
Tuponia lineata Walcott

[1] Trans. Royal Soc. Canada, 2d ser., Vol. 2, Sec. IV, 1896, p. 99.
[2] Text Book of Pal., Eastman, 2d ed., 1913.

Genus Takakkawia Walcott
Takakkawia lineata Walcott
Genus Wapkia Walcott
Wapkia grandis Walcott
Genus Hazelia Walcott
Hazelia conferta Walcott
Hazelia delicatula Walcott
Hazelia ? grandis Walcott
Hazelia mammillata Walcott
Hazelia nodulifera Walcott
Hazelia obscura Walcott
Hazelia palmata Walcott
Genus Corralia Walcott
Corralia undulata Walcott
Genus Sentinelia Walcott
Sentinelia draco Walcott
Family Suberitidae
Genus Choia Walcott
Choia carteri Walcott
Choia flabella (Hicks)
Choia hindei (Dawson) sp.
Choia ridleyi Walcott
Choia utahensis Walcott
Genus Hamptonia Walcott
Hamptonia bowerbanki Walcott
Genus Pirania Walcott
Pirania muricata Walcott
Order Hexactinellida O. Schmidt
Sub-Order Lyssacina Zittel
Family Protospongidae Hinde
Genus Protospongia
Protospongia erixo Walcott
Protospongia fenestrata Salter
Protospongia hicksi Hinde
Genus Diagoniella Rauff
Diagoniella hindei Walcott
Genus Kiwetinokia Walcott
Kiwetinokia metissica (Dawson)
Kiwetinokia spiralis Walcott
Kiwetinokia utahensis Walcott
Sub-Order Dictyonina Zittel
Family Vauxininae Walcott
Genus Vauxia Walcott
Vauxia bellula Walcott
Vauxia densa Walcott
Vauxia dignata Walcott
Vauxia gracilenta Walcott
Family Octactinellidae Hinde
Genus Eiffelia Walcott
Eiffelia globosa Walcott

Sub-Order Heteractinellida Hinde
Family Chancelloridae Walcott
Genus Chancelloria Walcott
Chancelloria drusilla Walcott
Chancelloria eros Walcott
Chancelloria libo Walcott
Chancelloria yorkensis Walcott

Comparison with recent sponges.—The Monactinellid sponges of the Burgess shale form a group that has little outward resemblance to many sponges of this Order. This is particularly true of the genera *Halichondrites, Tuponia* and *Takakkawia* as they more nearly resemble such Hexactinellid forms as *Euplectella* and *Holascus.* I have repeatedly examined the Cambrian specimens referred to the Monactinellida for traces of Hexactinellid spicules but without success.

In forms of growth and the arrangement of the dermal spicular layer *Hazelia* is suggestive of *Pachychalina* and *Rhaphidophlus,*[1] but the main skeletal strands are more like those of the Hexactinellida.

Choia (pl. 73) has the same general form and type of skeletal structure as *Trichostemma sarsii* Ridley and Dendy[2] from off the Azores, and the Australian seas.

There is considerable range of variation in the species of both fossil and living genera in size and form.

Among the Hexactinellids of the Cambrian there are none that have a close resemblance to living sponges. The branching form of *Vauxia* (*V. gracilenta*) may be compared in this character with the genus *Hexactinella,*[3] but the resemblance is only superficial.

None of the sponge remains clearly suggest the presence of the Horny Sponges (*Ceratospongia*), although if present they might have been preserved in the Burgess shale. The external appearance of species of *Hazelia* and *Vauxia* may be compared with that of the Ceratospongian genera *Thorecta* and *Stetospongia,* but there is nothing more known on which to base a comparison and possible identification.

Comparison with Metis shale sponge fauna.—We find in the Burgess shale five genera that occur in the Metis shale, *Halichondrites, Choia, Protospongia, Diagoniella,* and *Kiwetinokia,* and three

[1] Rept. Voyage H. M. S. Challenger, Zool., Vol. XX, 1887, pp. 19-25, 151-155, pls. 4, 5, 6, 28, 29, and 46.
[2] Idem, p. 218, pl. XLIII, figs. 1-4.
[3] Idem, Vol. XXI, 1887, pls. 93, 94.

that have not been seen in the Burgess shale. There are two elongate conical forms referred to *Cyathophycus* and *Acanthodictya,* a large *Protospongia*-like form referred to the genus *Palaeosarcus* Hinde, and some fragments placed under *Lasiothrix* Hinde.[1] Of the forms not common to the Burgess and Metis shale only two have special significance as indicating a different phase of development of the Hexactinellida. These are *Cyathophycus quebecense* Dawson[2] and *Acanthodictya hispida* Hinde.[2] Both of these forms suggest *Cyathophycus reticulatus* Walcott[3] of the Ordovician Utica shale, a form that apparently is not represented in the Burgess shale.

The stratigraphic position of the Metis shale is given by Dawson as probably in the lower member of the "Quebec group"[4] or "Lower Ordovician or later Cambrian age."[5] In addition to the sponges a brachiopod has been found in the Metis shale, which I have identified as *Acrotreta sagittalis* (Salter).[6] Dawson identified this species as *Obolella* (*L.*) *pretiosa* Billings,[7] but at the time he was apparently unacquainted with the type of that species which is an *Acrothele* or with *Acrotreta sagittalis* (Salter). (Compare figures of the latter species on plate 71, Mongr. 51, Pt. II, U. S. Geol. Survey, with those of *Acrothele pretiosa* on pl. 58 of the same memoir.) *A. sagittalis* occurs in both the Upper and Middle Cambrian and when discussing it in 1912 I said, "The *Acrotreta* (by error *Acrothele* in text) is a *Middle Cambrian* type, and nothing similar to it is known from the Upper Cambrian (should have been Chazy). As far as this shell (*A. sagittalis*) can locate the horizon, it is Cambrian, and probably low down in the Upper Cambrian, if not in the Middle Cambrian."[8] I have not obtained any further data since 1913 and must leave the question of the exact horizon of the Metis shale fauna for further investigation with the comment that both the sponges and the brachiopod point to the Cambrian age of the fauna.

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[1] See Dawson, Trans. Royal Soc. Canada, 2d ser., Vol. 2, Sec. IV, 1896, pp. 101-121.

[2] Idem, p. 109, figs. 18, 19, p. 110; figs. 20, 21.

[3] See Mem. Pal. Reticulate Sponges, Hall and Clarke, 1898, pl. 1.

[4] Idem, p. 97.

[5] Idem, p. 121.

[6] Monogr. U. S. Geol. Survey, No. 151, 1912, p. 705.

[7] Idem, p. 119.

[8] Idem, p. 705.

DESCRIPTION OF SPECIES

Sub-Class SILICISPONGIAE

"Skeleton composed either exclusively of siliceous elements, or of horny fibres enclosing siliceous spicules."

Order MONACTINELLIDA Zittel

(MONAXONIDAE Sollas)

Monactinellid spicules are abundant in thin sections of some portions of the Burgess shale and there are several species of which we have more or less of the skeletons that appear to belong in the Monactinellida. There are included in the genera *Halichondrites* Dawson and *Tuponia, Takakkawia, Wapkia, Hazelia, Corralia, Sentinelia, Choia, Hamptonia,* and *Pirania* described by Walcott in this paper.

The sponges of this order undoubtedly existed during Upper Cambrian and Ordovician time, as they occur in the Middle Cambrian and are met with in the Silurian as *Climacospongia* Hinde from Tennessee, and their skeletal spicules are abundant in Carboniferous and later rocks. As the largest group of recent marine sponges it is important and interesting to find their representatives so well developed in Middle Cambrian time.

The Monactinellida (Monaxonida) is defined by Ridley and Dendy in their great monograph on the Order as follows:

"Siliceous sponges with uniaxial megasclera."[1] (True skeletal spicules of the Sponge, microsclera=minute scattered spicules.)

Sub-Order HALICHONDRINA Vosmaer

"Typically noncorticate; skeleton usually reticulate; megasclera usually either oxea (straight spicules pointed at both ends) or styli (pointed at one end and rounded at the other).[2]

HALICHONDRITES Dawson

Halichondrites Dawson, 1889, Trans. Royal Soc. Canada, Vol. VII, Sec. IV, p. 52, text fig. 23. (Uses generic name and describes fragment of spicular dermal layer.) Idem, 1896, 2d ser., Vol. II, Sec. IV, p. 116. (Reprint of 1889 description and figure.)

Sir J. W. Dawson described fragments of the skeletal layer of a sponge in which simple, elongate, acerate spicules cross each other

[1] Rept. Voyage H. M. S. Challenger, Zool., Vol. 20, 1887, p. 1.
[2] Idem, p. 1.

obliquely to form an irregular elongate rhomboidal network. He thought that these patches of fine spicules might indicate the presence of a halichondroid sponge in the Little Metis sponge beds, and proposed the generic name without description and gave the fragments the name *H. confusus*. I found in the Burgess shale a large halichondroid sponge, the dermal layer of which corresponds so closely to the fragments described by Dawson that in the absence of further means of comparison I include it in the genus *Halichondrites* and use it as the type of the genus. The description of the species *H. elissa* includes all that is known of the genus.

Genotype.—Halichondrites elissa Walcott.

Stratigraphic range.—H. elissa is found in the lower 10 feet (3.05 m.) of the Burgess shale.

H. confusus occurs in a narrow band of the Metis shale which is of Cambrian and possibly Middle Cambrian age.

Geographic distribution.—H. elissa is found on the western slope of ridge connecting Wapta Peak and Mount Field, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

H. confusus occurs on the shore of the St. Lawrence River at Little Metis, Province of Quebec.

HALICHONDRITES ELISSA, new species

Plate 60, fig. 1; pl. 61, figs. 1, 1*a*.

Sponge elongate, tubular in form.

Reticulum.—Long, slender rods formed of hairlike spicules; the rods are in a right and left slightly oblique perpendicular arrangement so that they cross each other at a narrow, sharp angle; they are held together by a mass of fine acerate spicules that cross them obliquely and at all angles; buried in this confused mass there is a very fine, rectangular mesh with openings 0.5 mm. square, that presumably is formed of small acerate spicules; the long rods are formed of very fine threadlike spicules that are slightly interwoven in places but they may be parallel; they were presumably held together by fibrous connective tissue; flattened in the shale they average about 0.5 mm. in diameter.

The best preserved specimen of this sponge is broken off 12 cm. from what appears to have been the summit of the body, which as flattened has a diameter of 5.5 cm.; from the upper rim the long rods project directly upward from 3 to 5 cm.; at the upper border of the body the minute acerate spicules appear to be embedded in a membrane; most of them cross each other obliquely to form a dense mass

and they extend upward beyond the rim, while others are transverse or else more or less oblique to the vertical; over the surface of the body of the sponge there is the same fine spicular membrane which completely covers the large rods towards the top of the body and appears to have covered them everywhere before the membrane was removed by the splitting of the matrix from the surface of the sponge.

Observations.—The general form of the sponge is similar to that of the Ordovician *Cyathophycus reticulatus* Walcott,[1] but the spicular structure is quite different. The long slender vertical rods undoubtedly decreased in number towards the base and probably a number of them formed an anchoring rope or strand as in the Hexactinellid sponge *Holascus fibulatus* Schulze,[2] the semispiral arrangement of the rods and their crossing each other obliquely gave strength to the siliceous spicular outer wall which was bound together by a very fine outer spicular membrane. The long slender rods are scattered over the surface of the shale near the body of the sponge as well as a few fragments of the fine dermal membrane. A second sponge is represented near the type specimen by a large fragment a part of which rests on the latter (pl. 60); just what their relations were it is difficult to determine owing to the manner in which they are matted together. The body of the type specimen probably had a length of 15 or 20 cm., with a diameter at the upper end of about 4 cm. This general form is somewhat similar to that of *Cyathophycus quebecensis* Dawson.[3]

There is one fairly well preserved specimen in the collection and three fragments, one of which indicates a considerably larger body than the one described.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field on the Canadian Pacific Railway, British Columbia.

TUPONIA, new genus

Elongate, cylindric thin-walled sponge, with its skeleton formed of vertical, slender spicular rods, with very fine transverse, simple

[1] See Rauff, Palaeontographica, Vol. 40, 1894, pl. 2, fig. 1.

[2] Rept. Voyage H. M. S. Challenger, Zool., Vol. XXI, 1887, p. 87, pl. XVI, fig. 9.

[3] Trans. Royal Soc. Canada, Vol. VII, Sec. IV, 1889, p. 44, fig. 16.

spicules dividing the space between the vertical spicules into quadrilateral spaces of varying proportions.

Genotype.—*Tuponia lineata* Walcott.

Stratigraphic range.—*T. lineata* is found in the lower 10 feet (3.05 m.) of the Burgess shale, and *Tuponia bellilineata* occurs in the Mount Whyte formation, about 250 feet (75.75 m.) below the top of the Lower Cambrian and about 2,170 feet (661.85 m.) below the Burgess shale.

Geographic distribution.—Western slope of ridge connecting Wapta Peak and Mount Field, 1 mile (1.6 km.) northeast of Burgess Pass, above Field; also at the railroad tunnel 3 miles (4.8 km.) east of Field, British Columbia.

Observations.—*Tuponia* differs from *Halichondrites* Dawson in the manner of arrangement of the vertical and transverse spicules and in its form. Both the vertical and transverse spicules are embedded in a thin membranous dermal layer which has not shown other forms of spicules. There are no indications of a double wall such as occurs in the Dictyospongidæ[1] or in *Cyathophycus*.[2] The dermal layer or integument appears to have included the entire wall.

The identified species are:

Tuponia bellilineata Walcott
Tuponia flexilis Walcott
Tuponia lineata Walcott

TUPONIA LINEATA, new species

Plate 62, figs. 1, 1*a-b;* pl. 63, figs. 1, 1*a-c*

General form slender, elongate, cylindric and tapering gently towards the upper and lower ends; all specimens have been pressed flat in the shale, the evidence of their original cylindric form being the configuration of the upper end with its fringe of fine acerate spicules about the osculum(?) and the presence on some specimens of two distinct layers of the outer wall which represent the opposite sides of the tube; the tube-like form was somewhat flexible as it is found gently curved and partly contracted in places along its length but it was more rigid than *T. flexilis*.

Surface smooth and shiny except for the fine striation resulting from the presence of longitudinal spicules; the surface appears to be

[1] Mem. Pal. Reticulate Sponges, Family Dictyospongidae, 1898, Hall and Clarke, Albany, N. Y., p. 72.

[2] Idem, p. 23-25, pl. I.

that of a parchment-like more or less flexible film in which the spicules were embedded.

Reticulum.—The spicular skeleton is formed of a series of vertical rod-like spicules that when not crowded together are from 0.5 to 1 mm. apart; single spicules have been traced for a distance of 12 cm., and the larger are about 0.1 mm. in diameter; a central canal is indicated in the larger spicules by a narrow channel along the center of some of them; a number (3 to 5) of long, very fine, vertical spicules occur between the main ones on well-preserved specimens; the very delicate transverse spicules are long and cross beneath or inside of the main vertical spicules; they are usually so completely embedded in the dermal surface that their presence is indicated only by faintly defined lines; they outline a transversely quadrilateral space between the main vertical spicules that is crossed by the fine vertical secondary spicules. At the upper end both the primary and secondary vertical spicules extend above the edge of the tube to form a dense fringe and there are also some small irregular tufts of very slender, short acerate spicules. The vertical spicules may be parallel to the axis of the tube for a long distance or they may be slightly spiral and cross each other diagonally so as to form narrow rhombic spaces somewhat similar to those of *Halichondrites;* on one specimen the vertical spicules are parallel for 21 mm.; on another 36.5 cm. in length they are parallel the greater portion of the length and obliquely cross each other more or less toward each end (fig. 1, pl. 62); a few spicules appear to have escaped from the regular vertical series and cross obliquely without regard to the position of any of their associates. The lower end of the tube terminates in a short fringe of fine spicules.

The extreme thinness of the walls is shown by specimens where two sponges have been pressed down obliquely on each other; in such the main vertical spicules of the underlying sponge show clearly on the surface of the one above it as the result of having been impressed through its walls; fine examples of *Halichondrites*-like structure are thus formed.

Dimensions.—A specimen 36.4 cm. in length has a width as flattened on the surface of the shale of 6 mm. at the upper end, 14 mm. half way of its length, and 5 mm. near its base; it is contracted for a short distance to 6 mm. in width 14 cm. from its base. The probable diameter of this specimen when uncompressed was 4 mm. at the top, 9 mm. midway, and 3.5 mm. at the base. That this species grew to considerable size is proven by the presence of a portion of a large

sponge 18 cm. in length and 3 cm. in width as flattened on the shale, or about 2 cm. in diameter in a natural condition; it probably had a total length of from 70 to 80 cm. when entire.

Observations.—This remarkably slender, elongate tube-like sponge is a rather rare form in the Burgess shale; that one specimen should have been drifted into the deposit and found entire is most fortunate. It probably grew on a soft bottom with the base more or less buried in the sediment as there are no anchoring spicules of sufficient length to have supported so long a body. The closely allied species, *T. flexilis,* has a very slender base and may have had anchoring spicules. The differences between the two species are given under *T. flexilis.*

Sir William Dawson noted in the Little Metis sponge fauna "Groups of extremely simple straight spicules lying close together and parallel or more or less disturbed. They are narrow, and may have been cylindrical. One group has four long anchoring rods arranged in two pairs. They show no indications of cruciform spicules."[1] The above description applies quite closely to fragments of *Tuponia lineata* and suggests the presence of the genus *Tuponia* in the Metis shale.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

TUPONIA BELLILINEATA, new species

Plate 64, figs. 2, 2*a-b*

General form elongate, expanding very gradually upward.

Reticulum.—Fine vertical subparallel strands about 0.16 mm. across and usually 0.5 mm. distant from each other extend from where the frond is broken off below to the summit; they increase by branching at a very slight angle, and do not either undulate to any appreciable degree or inosculate; the interspaces between the main strands are crossed transversely by very narrow strands about 0.4 mm. in diameter and 0.8 mm. apart; the transverse strands may cross two or three of the vertical strands and interspaces and terminate, which causes a slight irregularity in the vertical position of the rectangular spaces between the main vertical strands and also to

[1] Trans. Royal Soc. Canada, Vol. VII, Sec. IV, 1889, p. 53, fig. 25. Dr. Dawson subsequently referred this fragment to the genus *Stephanella* Hinde with a question mark. Idem, 1896, 2d ser., Vol. 2, sec. IV, p. 117.

the ladderlike appearance of the spaces between each two vertical strands; owing to the condition of preservation the individual spicules have not been identified.

Fragments of the dermal layer remain on portions of the surface, showing it to have been dense and slightly roughened; spicular structure unknown.

Dimensions.—The only specimen in the collection has a length of 43 mm. with a width of 26 mm. at the top and 16 mm. where it is broken off; if it tapered to the base at the same angle its full length was about 105 mm.

Observations.—Of this species there is a single specimen, collected from a fine arenaceous shale of Lower Cambrian age. Its stratigraphic position is about 2,500 feet (762.5 m.) below the Burgess shale in which the other species of the genus *Tuponia* occur. It differs from *T. lineata* in the greater regularity of its vertical skeletal strands and transverse strands which divide the skeleton into ladderlike spaces; whether it had a long slender base similar to that of *T. flexilis* is unknown.

Formation and locality.—Lower Cambrian: (58q) Mount Whyte formation; about 250 feet (76.25 m.) below the top of the Lower Cambrian in gray siliceous shale (102 feet=36.6 m.) forming 5 of Mount Whyte formation, Mount Stephen section; just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, British Columbia, Canada.

TUPONIA FLEXILIS, new species

Plate 65, figs. 1, 1*a-d*

This species differs from *T. lineata* in having a flexible rope or strand-like form of growth.

Reticulum.—The main vertical spicules are more numerous and closer together and the secondary vertical spicules more clearly defined; the transverse spicules are exceedingly fine and obscure but present in the smallest cross sections of the strand where the structure can be determined; no cruciform spicules have been found in association with this species except those clearly belonging to the species referred to *Protospongia hicksi.*

Dimensions.—The largest specimen is a fragment 15 mm. across at right angles to the vertical spicules; all the rope-like specimens decrease very slightly in diameter; one 4 mm. in diameter decreases to 1.5 mm. in a distance of 14 cm., and another 35 mm. in length has an almost uniform width of 1.5 mm.: a rope-like strand curved in a

narrow U and with both ends broken off has a length of 21 cm. with a width of 6 mm. at the large end and 2.5 mm. at the smaller end; a number of the smaller specimens are shown by figures 1a, 1d, plate 65, which is a very good illustration of size and form.

Observations.—One specimen (fig. 1*b*, pl. 65) suggests that the sponge was a hollow tube or cylinder open at the top as in *T. lineata*. The oblique arrangement of the vertical spicules in portions of nearly all the specimens also indicates a cylindric form of growth.

At first I considered these strand-like sponges to be anchoring ropes of a large sponge, but on examining them closely and finding a double series of spicules crossing at right angles and the long vertical spicules running obliquely across so as to give strength to the assumed cylindric structure, this view was abandoned in favor of its being a sponge allied to *Tuponia lineata*.

Dr. Hinde[1] illustrates the anchoring rope of a sponge which he refers to *Hyalostelia fasciculatus* McCoy from the Cambrian, that resembles some specimens of this species, but the bundles of rod-like spicules are quite different in their arrangement.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

TUPONIA FLEXILIS var. INTERMEDIA, new variety

Plate 64, figs. 1, 1*a-b*

This form combines characters of both *T. flexilis* and *T. lineata*. The upper portion appears to have been a cylindric tube that gradually expanded from its base to the top without the contraction seen in *T. lineata* towards the summit. A specimen 15.5 cm. in length has a width of 14 mm. (as flattened) at the summit and 4 mm. where it is broken off at the base. The lower 8 cm. is flexuous with the vertical spicules crowded together as in *T. flexilis*, while the upper portion is similar to the spicular skeleton of *T. lineata* except that it is finer and tufts of minute simple spicules occur along its proportionally broader upper margin; obscure transverse spicules occur in the same manner as in *T. lineata* on the upper portion and as in *T. flexilis* on the lower part.

This form is placed as a variety of *T. flexilis* owing to its gradually tapering from top to base and its fine crowded vertical flexed spicules and less rigid form than that of *T. lineata*.

[1] British Fossil Sponges, Pt. 1, 1887, pl. 1, fig. 3.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

Genus TAKAKKAWIA, new genus

Slender, cylindric, thin-walled sponge with its skeleton formed of vertical strands of long spicules, with vertical bands of delicate simple spicules embedded in spongin; fine transverse spicules occur singly and in fine strands.

Genotype.—*Takakkawia lineata* Walcott.

Stratigraphic range.—Lower 10 feet (3.05 m.) of the Burgess shale.

Geographic distribution.—Western slope of ridge connecting Wapta Peak and Mount Field, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

Observations.—There is but one species of this genus. My impression, when collecting it was that the sponge would fall within the Hexactinellidae, but careful examination has thus far failed to show anything more than simple spicules that appear to have been monacts or diacts. It differs from *Tuponia* in form of growth and skeletal structure, but it has the strong vertical spicules and fine transverse spicules so characteristic of that genus.

TAKAKKAWIA LINEATA, new species

Plate 87, figs. 4, 4*a-c*

General form slender, elongate, cylindric and tapering gently to a slender base and slightly contracted towards the upper end; the tube was rigid and is rarely curved except in the upper half.

Reticulum.—The main skeletal elements are formed of long, simple, slender spicules that are gathered into vertical strands continuous from their inception to the upper rim of the body; these strands may be formed of two or three main spicules with several very fine ones that may continue as part of the main strand or curve out and terminate in the space between the strands; short spicules also start in the strand and project beyond it so as to give a frazzled appearance to parts of the strands; at the base there are several of the long spicules closely pressed together into a rounded point that is surrounded by a mat of extremely fine vertical spicules; the main spicules diverge and quickly gather as strands with spaces between

them; at about midway of the type specimen (fig. 4) there are eight strands; three of these merge into the adjoining strands as they near the top; in some specimens the strands appear as though they had been twisted so as to contract and expand several times in the course of their length; where the strands broaden out between the contracted zones the enclosed space between the spicules is filled with a shiny film similar to that of the narrow elongate bodies toward the summit of the sponge; towards the summit of the body the main spicules are merged into and obscured in a dense mat of fine vertical spicules forming the vertical bands.

The vertical bands are strong and resist breaking up in a remarkable degree; they have on each side one of the vertical strands described above and in the interspace between the strands there is a closely arranged series of vertical, very fine thread-like spicules, crossed by irregularly spaced, fine transverse slender spicules either singly or in strands so as to form quite regular quadrangular spaces in some parts, and in others, especially the lower half of the body, there are almost no traces of the transverse spicules; on several specimens the interspaces of the vertical bands are divided obliquely by imbricating, leaf-like, elongate oval-shaped masses of very fine spicules; these have a definite outline and appear to form a layer, distinct from the layer of straight, fine vertical spicules.

The vertical open spaces between the spicular bands appear in some examples to have resulted from the splitting open of the body of the sponge by compression, but in others there is no such indication and a few fine transverse spicules cross from strand to strand and sometimes across two or three spaces; we do not know the exact number of vertical strands and bands; eight strands with nine bands, one outside of the outer strand on each side, and one open space are shown on one specimen. Toward the summit of the sponge shiny, narrow elongate bodies pointed at the ends are arranged in a transverse band with their longer axis parallel to the vertical axis of the sponge; they appear to be in pairs in the vertical bands and to pertain to the inner wall as though they might have been arranged about the osculum some distance within the upper end of the body.

The vertical bands are well preserved on a number of specimens; they appear to have been formed of spongin with numerous vertical and oblique, very fine spicules, arranged at least in two layers.

Dimensions.—A sponge 42 mm. in length, flattened on the shale, has a width of 7 mm. at the center, 5.25 mm. at the summit, and 1 mm. near the sharply rounded base; the main spicules are about 0.16 mm. in diameter.

Observations.—What may be anchoring spicules occur in association with one specimen, but in the best preserved the lower end is slender as though the sponge stood up with its end embedded in the sediment. The presence of spongin is indicated by the very definite outline of the vertical bands and their evident character without the presence of a strong spicular structure. The spongin is preserved as a shiny smooth surface that under the microscope is resolved into a mass of minute crystals or points of pyrite. The large spicules are also often coated with pyrite.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass on the Canadian Pacific Railway, above Field, British Columbia.

WAPKIA, new genus

Elongate-oval, flattened fronds with distinct compact walls. Skeletal frame work formed of monactinal or diactinal spicules in a close, irregular net-work. Spongin indicated by firm surface and outlines of sponge.

Genotype.—Wapkia grandis Walcott.

Stratigraphic range.—Lower 10 feet (3.05 m.) of the Burgess shale.

Geographic distribution.—Western slope of ridge connecting Wapta Peak and Mount Field, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

Observations.—Wapkia is related to *Tuponia* and *Hazelia* by its mode of growth and spicular structure, but differs from *Tuponia* in having a more compact and stronger skeleton and from *Hazelia* by its transverse system of spicules. The description of the type species presents the character of the genus and species as far as determined.

WAPKIA GRANDIS, new species

Plate 66, figs. 1-3; pl. 67, fig. 1; pl. 68, figs. 1, 2, 2*a*

General form when flattened on the shale an elongate-oval, varying in width and outline. There does not appear to be any distinct base or point of attachment, although the fronds undoubtedly grew in an upright position as is indicated by the arrangement of the spicules (see pl. 66, fig. 1, and fig. 1, pl. 67). A double wall is indicated by fig. 1, pl. 66, but whether the frond was thin or tube-shaped is not readily determined; it is probable that it was thin on the edges with

an oval, hollow, transverse section. From the evidence afforded by seven well-preserved specimens both sides of the frond had the same wall structure.

Reticulum.—The skeletal elements include a well-developed, compact reticulation of simple strands and sometimes branching spiculofiber; in addition there are long, strong spicules embedded more or less in the walls, that are usually subparallel to the nearest outer margin of the frond. The main lines of the skeleton starting from what was evidently the lower portion of the frond branch upward and curve outward toward the margins (fig. 1, pl. 67), where they terminate in a fringe of fine, hair-like spicules; these main vertical lines are crossed by a system of transverse lines or strands that are often arranged in bands about 0.5 mm. apart extending outward from a central vertical strand that appears like a stripe with the transverse strands projecting at right angles from it (see fig. 2, pl. 68); the transverse strands with the intermediate thread-like spiculae terminate on the margins in an imbricating manner and appear like a fringe on the shale (fig. 1, pl. 68). The fibrous strands are formed of very delicate thread-like spiculae and styli that vary greatly in length; they appear to extend into the strand and to also mingle with the spicules of the interspaces between the main strands.

The spaces between the transverse and vertical strands are filled with a mat of spicules similar to those forming the strands, and they are arranged transversely and in general parallel to the adjoining strands but may be directly transverse to the axis of the frond even though the strands curve slightly (fig. 1, pl. 67); often the main strands are obscured by the mat of fine spicules; usually the transverse system of strands dominates to such a degree that the vertical strands are not to be seen except by close observation with a magnifying glass of low power (fig. 1, pl. 66). The long strong spicules appear to be buried in the wall or near the inner surface and are not often seen; when exposed they are more or less irregularly placed but in general parallel to the nearest margin of the frond; spicules 60 mm. in length have been measured where both ends were concealed by a covering of shale; on one specimen these strong spicules curve around subparallel to the rounded lower extremity of the sponge. No traces of anchoring spicules have been observed. The fine spicules forming the thick mat of the wall and the strands are very fine, 0.026 mm. in diameter; some of the spicules in the strands are a little coarser and have been traced 3 to 5 mm. in length before disappearing in the strand or the adjoining mat of fine spicules. The long vertical spicules average 0.15 to 0.20 mm. in diameter.

Dimensions.—A slender frond 170 mm. in length varies from 38 to 45 mm. in width except where it narrows near the rounded ends; one broken frond has a width of 80 mm. at the upper end and a length of 190 mm. to where it is broken off by fracture of the shale; a broad frond 140 mm. in length has a width of 85 mm.

Observations.—*Wapkia grandis* is the best example of a Cambrian halichondrite sponge known to me; its form and structure are finely preserved despite the rough treatment it had both before and after being embedded in the muddy sediment. I do not know of any closely related forms among either living or fossil species. The firm outlines and strong appearance of the fronds indicate a strong compact skeleton and sufficient spongin to give solidity and firmness to the walls.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

HAZELIA, new genus

Simple or branched, elongate cylindric or frondose thin-walled sponges with a thin dense dermal layer in which fine spicules and more or less of the skeletal spicules are embedded. The spicular skeleton (reticulum) is formed of elongate vertical undulating strands composed of exceedingly fine, elongate thread-like spicules; the strands bifurcate, and occasionally cross each other obliquely, and irregular clusters of acerate spicules serve to bind the strands together into a firm but loose skeleton; no transverse strands or long spicules observed.

Genotype.—*Hazelia palmata* Walcott.

Stratigraphic range.—Middle Cambrian: Stephen formation; *Ogygopsis* shale, on Mount Stephen; Burgess shale and superjacent bedded limestone, which give a vertical range of about 450 feet (137.25 m.).

Geographic distribution.—At Burgess Pass fossil quarry, in Burgess shale, on western slope of ridge connecting Wapta Peak and Mount Field, and on west slope of Mount Field 1 mile (1.6 km.) northeast of Burgess Pass above Field, also on northwest slope of Mount Stephen above Field, British Columbia.

Observations.—The strands of the skeleton of *Hazelia* are similar to those of *Halichondrites elissa* in being formed of very slender threadlike spicules that presumably depended upon a fibrous con-

nective tissue to bind them together, but here the resemblance ends as the strands of *Hazelia* are undulating, more or less inosculating where they come in contact with each other and they also radiate upward and outward from whatever may have been their basal point of growth.

Among living genera the arrangement of the dermal spicular layer of *Pachychalina*[1] and *Rhaphidophlus* is suggestive of that of *Hazelia,* but the main skeletal strands are more nearly like those of some of the Hexactinellida, but they differ radically in being formed of diact or monact spicules in *Hazelia.*

The species now referred to the genus are:

Hazelia conferta Walcott
Hazelia delicatula Walcott
Hazelia ? grandis Walcott
Hazelia mammillata Walcott
Hazelia nodulifera Walcott
Hazelia obscura Walcott
Hazelia palmata Walcott

HAZELIA PALMATA, new species

Plate 69, figs. 1, 1*a-c;* pl. 76, fig. 2

This species occurs as relatively thin fronds that grew in an upright position from a more or less narrow basal point of attachment; the fronds vary from a roughly circular outline to narrow elongate stemlike growths; the prevailing outline is that of a small bush expanding gradually to a broadly rounded summit.

Reticulum.—The skeleton is formed of several main lines of irregular or undulating fibrous strands that branch upward in a close, irregular dendroid manner, sometimes inosculating by sending out thread-like spicules that merge in among those of the adjoining strands; the spicules of the strands are very fine, often threadlike and of variable length; they are best seen at the upper margin of the frond where the strands project above the dermal layer or else on slightly worn surfaces of the frond; as far as can be determined, they are simple, diaxial spicules that were bound together by spongin when the sponge was living and the strands were embedded in a siliceous dermal membrane; the strand spicules apparently have their bases in the center of the strand and extend obliquely outward at angles dependent on their length, some extended for 5 mm. or more parallel to the axes of the strand. The dermal layer, when

[1] Rept. Voyage H. M. S. Challenger, Zool., Vol. 20, 1887, pl. 46, figs. 1, 4, 9.

unworn, is filled with minute simple spicules crossing at any angle and forming a matlike mesh; these spicules may or may not be interlaced with the spicules of the main strands; the strands vary from 0.5 mm. to 0.25 mm. and the spicules 0.08 mm. to 0.16 mm. in diameter. There is no evidence of any system of transverse spicules such as occur in *Tuponia*.

Dimensions.—The largest frond has a height of 60+ mm., with a width of 40+ mm., and fragments indicate somewhat larger fronds.

Observations.—Most of the fronds have a fairly regular growth of the skeletal strands, but some show irregular arrangement as though there had been a change in position of the frond and a new direction given to the increased growth. The thickness of the frond when living is unknown; it was probably thin as in the recent *Myxilla frondosa* Ridley and Dendy.[1]

This is one of the most abundant forms of *Hazelia*, and is often found matted down with fragments of crustaceans and algae in such manner as to suggest that it was considerably decomposed when embedded in the siliceous mud.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field on the Canadian Pacific Railway, British Columbia.

HAZELIA CONFERTA, new species

Plate 72, fig. 3

This is one of the cyathiform sponges that must have had a very delicate skeletal structure with a thick dermal membrane and abundant gelatinous tissue; the dermal membrane formed a strong protective covering that in the fossil state consists of very thin sheets pressed down on each other; the gelatinous tissue was pressed out from the edges of the specimen so as to form a line of irregular blotches; the whole aspect of the fossil gives the impression that the sponge was relatively soft and that it has been compressed until it is reduced to several filmlike layers.

Reticulum.—Very fine straight simple spicules occur in the dermal layer without any uniform arrangement. The skeletal framework is indicated by several patches of a minute rectangular mesh form of

[1] Rept. Voyage H. M. S. Challenger, Zool., Vol. 20, 1887, p. 144, pl. 26, figs. 1, 1*a*.

fine vertical strands crossed by still smaller transverse strands very much as in the more clearly defined skeleton of *Hazelia palmata*.

Dimensions.—The type specimen has a length of 100 mm. with a width as flattened of 50 mm. at the top; it terminates below in a rounded end 8 mm. in width. A second and larger but more irregular specimen has a length of 135 mm. with a width of about 60 mm., 40 mm. below the top; its lower end is rounded and there are traces of simple short spicules extending out from it that may have served to hold the rounded base in the mud.

Observations.—The type specimen indicates that the frond was hollow as there is a layer of shale about 3 mm. thick between what appears to have been the opposite walls of the sponge. The whole appearance of the specimens is such that there is little to base a comparison with other species referred to the genus; one broad specimen of *Hazelia delicatula* (pl. 70, fig. 1*e*) has a general resemblance in form and a very delicate skeletal structure, but it was a firm, well-defined frond unlike that of *H. conferta*.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on Canadian Pacific Railway, British Columbia.

HAZELIA DELICATULA, new species

Plate 70, figs.1, 1*a-g;* pl. 90, figs. 2, 2*a*, 4

This species occurs in a variety of forms: round, oval (figs. 2, 4, pl. 90), broad, elongate (fig. 1*d*, pl. 70), flattened stems (figs. 1*e*, 1*g*, pl. 70) and branching (fig. 1, pl. 70).

Reticulum.—The surface is slightly roughened by vertical, closely undulating strands of very slender elongate spicules and similar but small, short, transverse strands that cross the interspaces between the vertical strands in an irregular manner, their ends being fastened into the vertical strands, which gives a roughly irregular quadrangular mesh; on some portions of the surface the main strands have so divided as to inosculate with the adjoining strands to form oval or elongate oval spaces, the transverse strands not being present; both features, quadrangular and oval species, may be present on the same frond. Numerous delicate acerate spicules extend into the open space of the mesh from the strands or they may lie across it without any apparent relation to any other spicules or aggregated in minute tufts; these fine short spicules often form a spicular fringe about the irregular spaces of the mesh (fig. 1*c*, pl. 70). The strand spicules

vary from 0.08 to 0.16 mm. in diameter, and the strands are about 0.8 to 1 mm. across.

The dermal layer is a delicate membrane that is always present but often so thin that spicules show through it as though it was a tenuous film.

Dimensions.—The largest single specimen has a length of 90 mm. and a width of 25 mm. The one branching form has three strong branches, and is illustrated by figure 1, plate 70; a number of irregular circular or oval fronds are above 15 mm. in diameter.

Observations.—The dermal skeleton of this species recalls that of the recent *Pachychalina lobata* Ridley and *Rhaphidophlus filifer* Ridley and Dendy, and the skeletal framework of the latter is very suggestive of the manner in which the spicular skeleton of *Hazelia* may have been constructed.[1] In the fossil species we have only the flattened fronds and can obtain very little conception of how the skeleton was arranged transversely to the outer surface.

H. delicatula differs from *H. palmata* in details of the skeletal structure and in the delicacy of the surface markings and skeletal strands.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field on the Canadian Pacific Railway, British Columbia.

HAZELIA ? GRANDIS, new species

Plate 71, fig. 2

This species is represented by one weather-worn specimen that retains portions of the dermal and skeletal layers replaced by microscopic crystals of pyrite; the specimen indicates a thin-walled elongate, cyathiform sponge with a skeleton built up of narrow vertical spicular strands crossed transversely by rather delicate strands, the two forming a minute quadrangular mesh; there is also an indication of a dermal layer with fine, short, hairlike spicules; all spicules are obscured by the coating of pyrite crystals.

Dimensions.—The portion of the frond preserved has a length of 125 mm. with a width of 42 mm. at the top and 5 mm. where broken off at the lower end; the quadrangular spaces in the central portion are about 1.5 mm. across as they are indicated on the matrix where the sponge has flaked off.

[1] See Rept. Voyage of H. M. S. Challenger, Zool., Vol. 20, 1887, pl. 46, figs. 4, 9.

This form is nearer to that of *Hazelia obscura* than to the other species referred to the genus.

Formation and locality.—Middle Cambrian: (14s) *Ogygopsis* zone of the Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian and 3,540 feet (1,089 m.) below the Upper Cambrian in the *Ogygopsis* zone of the Stephen formation, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad, British Columbia.

HAZELIA MAMMILLATA, new species

Plate 90, figs. 3, 3*a*

This species is represented by a fragment of the dermal surface preserving four elevated mammæ with a round osculum at the summit of each; between the elevations about the oscula numerous small openings (pores?) occur that are surrounded by a meshwork of fine, delicate acerate spicules; the meshwork is much like that of *Hazelia delicatula* (pl. 70, fig. 1*c*).

Reticulum.—All that we know of the skeleton is the dermal mesh of irregularly arranged, short, acerate spicules; these occur about and between the small openings (pores) without any apparent regularity of structure.

Dimensions.—The fragment of the dermal surface preserved has a length of 15 mm. and a width of 9 mm.; the elevated ring about the oscula has a diameter of about 4 mm. and each osculum 1 mm.; the pore-like openings between the oscula are about 0.25 mm. in diameter.

Observations.—It is possible that this specimen belongs to a genus distinct from *Hazelia,* but with the dermal skeleton of the same type it appears reasonable to refer it to that genus pending the discovery of further material. Among recent sponges the osculum-bearing surface of *Pachychalina ? punctata*[1] is most suggestive of the surface of this species.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field on the Canadian Pacific Railway, British Columbia, Canada.

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[1] See Rept. Voyage H. M. S. Challenger, Zool., Vol. 20, 1887, pl. 6, fig. 2*b*.

HAZELIA NODULIFERA, new species

Plate 71, figs. 3, 3*a-b*

In this species the skeletal strands are closely undulated and they bear numerous nodes formed of tufts of fine short acerate spicules, the bases of which are more or less included with the main spicules of the strand; a dense dermal membrane, in whose strands tufts of spicules and fine dermal spicules are embedded, covers the surface and it is only on worn specimens that the skeletal structure and spicules are to be seen.

Dimensions.—A large broken frond covers a space 80 by 80 mm., and it was probably 120 mm. or more in height; a small frond attached to a brachiopod (*Nisusia alberta,* pl. 71, fig. 3) is 20 mm. in height and 10 mm. in width. The nodes vary in size on different fronds from 0.25 mm. to 1 mm., and they may be round or elongate in outline.

Observations.—This form is so well marked that I have separated it as a species although it might possibly be considered as a nodose variety of *H. palmata.*

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field on the Canadian Pacific Railway, British Columbia.

HAZELIA OBSCURA, new species

Plate 71, figs. 1, 1*a*

Of this species there are seven simple elongate specimens, none of which show indications of branching. The gradual enlargement in width and gentle curvature are present in five specimens, and all have a dense dermal layer that nearly obscures the skeletal structure; the few traces of the latter indicate it closely resembled that of *Hazelia delicatula,* but the spicules and the meshes of the skeleton are much smaller and the dermal layer is more dense. Transverse undulations suggest that the fronds were hollow and thin-walled, but there is no conclusive evidence of it, and all the specimens now appear to the eye to be simply smooth, flat membranous stems lying on the dark shale.

Dimensions.—The longest specimen has a length of 100 mm. and a width of 15 mm. at the upper end and 4 mm. where it is broken off at the base; another specimen has a width of 22 mm. near the upper end and 10 mm. where it is broken off 75 mm. below; one fragment has a uniform width of 17 mm. for a distance of 45 mm.

Observations.—All the specimens appear to have grown in an upright position and to have been broken off from their base before being drifted along to their final resting place where they were found widely distributed. They range through about 10 feet (3.05 m.) in thickness of the shale.

Formation and locality.—Middle Cambrian: (35k.) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field on the Canadian Pacific Railway, British Columbia.

CORRALIA, new genus

General form in the fossil state an erect, gradually expanding, undulating flattened cone with apex at the base. Spicular skeleton formed of closely arranged, strong vertical strands of simple elongate fine spicules. Dermal layer thin, dense and penetrated by slender spicules more or less connected with the vertical strands.

Genotype.—*Corralia undulata* Walcott.

Stratigraphic range.—Lower 10 feet (3.05 m.) of the Burgess shale.

Geographic distribution.—Western slope of ridge connecting Wapta Peak and Mount Field, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

Observations.—The species of this genus might be included under *Hazelia* except for the closely arranged vertical strands, strong undulation of growth, and probable tubular form. The spicules are obscured by the dermal layer, but can be seen fairly well with a strong lens. The type species is the only one thus far referred to the genus.

CORRALIA UNDULATA, new species

Plate 72, figs. 2, 2a

The specimens of this species occur as flattened elongate undulating slender cones with the sides gradually expanding from the base upward.

Reticulum.—The skeletal strands are about 1 mm. across near the upper end where the specimen is 20 mm. in width; they are separated by very narrow spaces or else touch each other; some of the strands look as though they were made of a bundle of smaller parallel strands; spicules obscure owing to covering by dermal layer, but where visible they are delicate, threadlike and appear to be parallel with the strand; by reflected light a series of minute transverse

strands may be seen crossing some of the spaces between the vertical strands in such manner as to divide the space into minute rectangles. The dermal layer has been so largely replaced by microscopic crystals of pyrite (FeS_2) that its spicules are rarely seen, a few minute monacts are visible towards the lower end of the specimen represented by figure 2.

Dimensions.—The largest specimen has a length of 75 mm. to where it is broken off above its base; as flattened its width is 25 mm. near the upper end and 15 mm. wide 40 mm. below.

Observations.—This species appears to have characters of both *Tuponia* and *Hazelia,* but it is hardly near enough to be included in either genus; with more and better preserved specimens it may prove to belong to one or the other, probably *Hazelia,* but with present information it is considered distinct and taken as the type of a genus.

At one place on the matrix there is a suggestion of the spicular structure of *Vauxia,* but whether the narrow vertical lines are casts of the spaces between the slightly convex ribs or ridges above or are true spicules cemented together as in *Vauxia* is not readily determinable.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on Canadian Pacific Railway, British Columbia.

SENTINELIA, new genus

Of this form there are only two species, represented by fragments that appear to have been broken from a sponge somewhat similar in form to the Hexactinellid, *Euryplegma auriculare* Schulze.[1] This superficial resemblance is unfortunately all there is for comparison with recent sponges as the skeletal structure of the fossil form is unknown, except that there are indications of simple monact spicules of varying length, some of which are gathered in radiating tufts which leads to the provisional reference of the genus to the Monactinellida. Both specimens are fragments of thin flat fronds with numerous round or oval flat tubercles scattered over the surface in which openings may have occurred.

Genotype.—*Sentinelia draco* Walcott.

Stratigraphic range.—*S. draco* occurs in the Stephen formation about 1,000 feet (305 m.) above the base of the Middle Cambrian

[1] Rept. Voyage H. M. S. Challenger, Zool., Vol. 21, 1887, p. 176, pl. CII.

in the Castle Mountain section of Alberta. A form doubtfully identified with it is from the Wheeler formation at about 1,580 feet (481.9 m.) above the base of the Middle Cambrian in Utah.

Geographic distribution.—*S. draco* is from Mount Stephen in British Columbia, Canada, and the Utah specimen from the House Range of central western Utah, United States.

Observations.—The chief value of this genus is in the indication that there was a group of sponges living in Middle Cambrian time of which we have only two fragmentary specimens.

SENTINELIA DRACO, new species

Plate 72, figs. 1, 1*a*

This species is represented by fragments of a frond having numerous round or oval, almost flat tubercles; some of the smaller tubercles have small openings in them, and this may have been the case with all the larger tubercles now open by erosion of the filmlike outer layer from off the top; how much of this was formed by original openings it is impossible to determine.

Reticulum.—Only faint traces of any skeletal structure are preserved; these indicate an irregular, minute reticulate mesh formed of slender straight spicules. The dermal layer is thin and the presence in it of minute simple straight spicules is indicated by raised lines on the surface.

The type fragment representing this sponge covers most of a space 50 by 60 mm. in size and shows no natural boundaries.

Observations.—The specimen referred to above and taken as the type of the species is from British Columbia; the second specimen, which is represented by figure 1*a*, is from Utah, and both occur in Middle Cambrian rocks. The Utah specimen is tentatively included under the species on account of its resemblance in form, as it is little more than a cast of the original fragment; it has one side with natural outline and it retains a slight convexity.

Formation and locality.—Middle Cambrian: (58 m) Stephen formation. About 1,000 feet (305 m.) above the top of the Lower Cambrian in bluish-black and gray limestone (138 feet = 42.09 m.) of the Stephen formation, Castle Mountain section; northeast slope of Castle Mountain, facing amphitheater, north of Canadian Pacific Railway, Alberta, Canada.

(3t) Wheeler formation: About 1,700 feet (518.2 m.) above the Lower Cambrian and 2,700 feet (823 m.) below the Upper Cambrian in the shaly limestones and calcareous shales of the Wheeler

formation, in the eastern part of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah, U. S. A.

Family SUBERITIDAE

CHOIA, new genus

Sponge, free, with a thin circular central disk, from the center of which spicules radiate to and beyond the margin of the disk; the central body or disk appears to have had one side slightly concave (upper) and the opposite rising to a central node or point (lower side).

Reticulum.—The central disk is formed on its lower side of a dense mass of fine spicules that radiate from a central point out to the not very sharply defined margin beyond which many of the small spicules extend as a fine fringe, and the long rodlike spicules which originate near or at the center continue on far beyond the disk; the bases of the long, relatively large spicules (probably monacts) are buried in a mass of spicules or lie outside of them on the upper side of the disk; the upper side of the disk has a more or less confused mass of fine spicules at the center, from which many of the larger, rod-like spicules radiate to and beyond the margin of the disk. There is no recognizable dermal layer, although in *Choia ridleyi* there is a dense layer on the lower side of the disk which I think is the flattened lower convex side, formed of matted layers of the fine radiating spicules.

Dimensions.—Most of the species are small with disks 10 to 15 mm. in diameter, but *Choia hindei* had a disk 60 mm. or more in diameter and that of *C. utahensis* was 40 mm. across.

Genotype.—*Choia carteri* Walcott.

Stratigraphic range.—*Choia carteri* and *C. ridleyi* occur in the Middle Cambrian Burgess shale 1,920 feet (585.6 m.) above the Lower Cambrian; *C. utahensis* is from the shaly portion of the Marjum formation 2,135 feet (656 m.) above the Lower Cambrian; *C. hindei* is from the Metis shale of probable Middle Cambrian age but its relations to the Lower Cambrian are unknown.

Geographic distribution.—*C. carteri* and *C. ridleyi* are from above Burgess Pass, British Columbia, Canada, *C. utahensis* from western central Utah, and *C. hindei* from the shore of the St. Lawrence River at Little Metis, below Quebec, Canada.

The genus is tentatively determined from the Middle Cambrian Menevian formation of St. Davids, Wales, by the species *Choia flabella* (Hicks).

The species now referred to *Choia* are:

Choia carteri Walcott
Choia flabella (Hicks)
Choia hindei (Dawson)
Choia ridleyi Walcott
Choia utahensis Walcott

Observations.—This most interesting genus may be compared with the living sponge *Trichostemma sarsii* Ridley and Dendy[1] a deep-water species from off the Azores and in the Australian seas. It has the same type of skeletal structure and general form. It is very easy to imagine specimens of this living sponge flattened by pressure assuming the appearance of *Choia carteri*.

Dr. George J. Hinde described a fossil sponge from the Utica shale of the Ordovician system which he named *Stephanella sancta*.[2] This sponge occurs in circular films or patches on the shale from 8 to 10 mm. in length and of an average thickness of 0.035 mm. Dr. Hinde stated, "It may be taken for granted that each of the numerous circular patches in this rock indicates the basal portion of a distinct sponge; but it is hardly likely that it represents the entire skeleton of the organism and it is insufficient to determine conclusively the nature of the sponge." He calls attention to a suggestion of Sir J. W. Dawson that they may be the root spicules of Hexactinellid sponges.

It is possible but not probable that the Middle Cambrian species described in this paper are congeneric with the Ordovician Utica shale species described by Dr. Hinde, but with our limited information in regard to the latter I prefer to place the Cambrian species in a genus which I consider was a free sponge with a central disk that in no way served as a part of a larger skeleton.

CHOIA CARTERI, new species

Plate 72, fig. 4; pl. 73, figs. 1, 1*a-b*; pl. 75, fig. 2

In the fossil state this species occurs as a flat circular disk with a fringe of fine straight spicules and a corona of long, slender strong spicules. Some of the specimens have a slight elevation or node at the center of the side that is formed of a dense mass of fine radiating spicules and on the opposite side which is flat or slightly depressed there are many straight irregularly arranged spicules of varying

[1] Rept. Voyage H. M. S. Challenger, Zool., Vol. 20, p. 218, pl. XLIII, figs. 1-4.
[2] Geol. Mag. London, N. Ser., Dec. III, Vol. VIII, 1891, pp. 22-24. Text fig. unnumbered.

length, from among which long straight spicules radiate to and far beyond the margin of the disk. As may now be determined the disk was slightly concave or flat above and more or less convex on the lower or opposite side. To what extent the long spicules radiated from more than the one horizontal plane they now occupy is unknown, but they probably extended outward in a broad belt so as to keep the sponge from sinking into the muddy bottom.

Spiculum.—There are no indications of a skeletal framework other than a mass of detached spicules that may have been held together by spongin fibers or by the interlacing of the spicules of the disk; the finer spicules are about 0.16 mm. in diameter and of undetermined length, owing to the manner in which they are matted down together to form thick, thatchlike layers on the under side from the center to the outer margin of the disk, and many of them extend from 1 to 3 mm. beyond the margin as a fine fringe; fragments 2 to 3 mm. in length may be measured; the long, rodlike spicules may be monacts but some of them appear to taper to a slender point at both ends; they vary from 0.32 to 0.64 mm. near disk and 0.4 to 0.8 mm. in diameter about 5 mm. from disk; some of those on the type specimen have a length of 18 mm., and on another specimen with a disk 10 mm. across a few are 25 mm. in length; several of these long spicules have spiral lines on the outside, and many are so broken in by compression as to indicate the presence of a central canal.

Dimensions.—The broadly oval disk of the type specimen, which is very much compressed and slightly distorted, is 12 by 15 mm. in diameter with long spicules on the average extending 10 mm. beyond the margin; on another specimen with a nearly circular disk the long spicules project about 15 mm. beyond the disk and a few 20 mm.; to these lengths we must add 4 to 5 mm. to obtain the entire length; the largest specimen has an oval disk 15 by 25 mm. in diameter, resulting probably from distortion of a circular disk.

Observations.—The confused mass of broken or short spicules is illustrated by figure 2, plate 75, the thatchlike mass of fine spicules by figure 1*b*, plate 73, and a fragment of the convex side of a disk by figure 1*a*, plate 73. *C. ridleyi* occurs in the Burgess shale but not in the same layer as *C. carteri;* it differs in its smaller average size and the long spicules are proportionally larger; *C. carteri* has only a general resemblance to *C. hindei* and *C. utahensis.*

C. carteri is represented in the collection by 10 specimens.

The specific name is given as a recognition of the work of Mr. H. J. Carter on the structure of the Hexactinellidae.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field; (14s) *Ogygopsis* zone of the Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian and 3,540 feet (1,089 m.) below the Upper Cambrian in the *Ogygopsis* zone of the Stephen formation, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field, on the Canadian Pacific Railway, British Columbia.

CHOIA RIDLEYI, new species

Plate 73, figs. 2, 2*a*; pl. 74, figs. 1, 1*a*

The general form and appearance of this species is the same as that of *C. carteri* except that it is smaller and more delicate and the long spicules are relatively stronger.

Reticulum.—The spicular structure is essentially the same as that of *C. carteri* except that the large spicules are much more prominent on the upper side and the fine spicules of the under side are finer and the thatchlike structure more dense. The smaller spicules average about 0.08 to 0.12 mm. in diameter and from 2 to 3 mm. in length; the large rodlike spicules average from 0.4 to 0.48 to 0.56 mm. in diameter a short distance beyond the disk, and some of them are 10 mm. in length from a disk 4 mm. across as flattened in the shale.

Dimensions.—The largest disks average 6 mm. in diameter, and the greater number less than 5 mm.; the longest spicules extend 8 mm. beyond the margin of the disk.

Observations.—This little species was found in considerable numbers on a limited surface of shale; one fragment 40 by 70 mm. has over 40 individual sponges flattened upon it. The differences between this and *C. carteri* are mentioned under the description of that species.

The specific name is in recognition of the work of Mr. Stuart O. Ridley, associate author with Mr. Arthur Dendy of the report on the Monaxonida (Monactinellida) of the Challenger expedition.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

CHOIA UTAHENSIS, new species

Plate 75, fig. 1

Of this species there is but one weathered specimen lying on the surface of a piece of shaly limestone. Most of the spicular structure has been eroded, but sufficient remains to outline the disk and the long radiating spicules.

Reticulum.—The disk was formed of a mass of fine elongate spicules radiating from the center to the edge of the disk, also long slender spicules interbedded in or resting on the fine spicules from the center outward and extending far beyond the margin; the spicules have all been replaced by calcite and a few retain their size and form; a small, fine spicule is about 0.1 mm. in diameter, and a long large one at 10 mm. from the margin is 0.5 mm. in diameter and its length 38 mm.

Dimensions.—Disk 38 mm. in diameter as flattened; the largest spicules extend out about 18 to 22 mm. beyond the margin.

Observations.—This large species is readily identified with the genus; its size seems to separate it from *C. carteri* and *C. ridleyi,* and its structure as far as known from *C. hindei,* and it probably occurs at a somewhat lower horizon than the latter species.

Formation and locality.—Middle Cambrian: (3y) About 2,150 feet (655.3 m.) above the Lower Cambrian and 2,250 feet (685.8 m.) below the Upper Cambrian, in the shaly limestones forming 1d of the Marjum limestone,[1] 2.5 miles (4 km.) east of Antelope Springs, in ridge east of Wheeler Amphitheater, House Range,[2] Millard County, Utah.

CHOIA HINDEI (Dawson)

Plate 76, figs. 1, 1*a*

Stephanella hindii DAWSON, 1896, Trans. Royal Soc. Canada, 2d ser., Vol. 2, Sec. IV, p. 117, fig. 28.

This is the largest species of the genus and fortunately there is sufficient of it preserved to indicate its size and character.

Reticulum.—The one large disk has a distinct round elevation at at the center about 15 mm. in diameter from the center of which a dense mass of slender spicules radiate towards the outer margin; these fine spicules are 10 mm. or more in length, and average 0.16 mm. in diameter; this lower side of the disk also has a mesh of

[1] Walcott, Smithsonian Misc. Coll., Vol. 53, Cambrian Geol. and Pal., No. 5, 1908, p. 180.

[2] Idem, pl. 13.

criscrossing short fine spicules over the central portions of the thick thatch of radiating spicules; a series of long, slender spicules are embedded in and radiate outward from the central part of the disk to the margin and from 40 to 50 mm. beyond; they are slender, 0.3 to 0.4 mm. in diameter, when their great length is considered.

Dimensions.—The one fairly well outlined disk is 60 mm. in diameter, and a fragment indicates a disk 80 mm, or more across with long spicules extending 40 to 50 mm. out beyond the disk.

Observations.—A fragment of a large disk has many of the delicate fine spicules radiating outward from the mass of the disk spicules, and there are also many broken or short spicules lying in and on the surface of the disk; nearly all of the long spicules penetrate into the mass of fine spicules on all of the specimens which indicates that none of them show the upper surface of the disk, which is usually in *C. carteri* and *C. ridleyi* formed largely of the long, stouter spicules.

This species is represented in the U. S. National Museum collections by about three-fourths of a large disk and large fragments of the marginal spicules of two other specimens. I did not realize, when collecting at Little Metis, that they represented a rare form, or I would have searched for all the fragments despite the incoming tide; it was a case of prying the shale loose, grabbing all possible, and running back from the onrushing water.

The specimens described by Sir W. J. Dawson are evidently the same in character as those I collected, but they are illustrated from a drawing made prior to his finding the best specimens. This drawing was published in 1889[1] as a spinose sponge.

Formation and locality.—Middle ? Cambrian: (339*s*) Little Metis black argillaceous shale, Little Metis, Province of Quebec, Canada.

HAMPTONIA, new genus

Globose, bladderlike shaped forms with thin loose walls. The spicules of the skeletal framework radiate in a more or less irregular manner; spiculae monactinal or diactinal. Traces of spongin present.

Genotype.—Hamptonia bowerbanki Walcott.

Stratigraphic range.—Lower 10 feet (3.05 m.) of the Burgess shale.

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[1] Trans. Royal Soc. Canada, Vol. VII, Sec. IV, 1889, p. 53, fig. 24.

Geographic distribution.—Western slope of ridge connecting Wapta Peak and Mount Field, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

Observations.—Among living forms the rotund forms of *Trichostemma*[1] might under great compression give a flat thin structure somewhat similar to that of *H. bowerbanki* but *Hamptonia* indicates a looseness of skeletal structure and irregularity of form not known in *Trichostemma.* By taking a confused mass of the diactinal spicules of *Bathydorus uncipe* F. E. Schulze and pressing them down between glass plates a mass of irregularly scattered slender spicules was obtained that resemble the scattered spicules on the surface of some portions of the body of *Hamptonia bowerbanki.*

HAMPTONIA BOWERBANKI, new species

Plate 76, fig. 3; pl. 77, fig. 1; pl. 78, figs. 1, 1*a*

The specimens representing this species are compressed until there is little more than a film of varying thickness on the shale; the surface has a brownish color and is more or less coated with microscopic crystals of pyrite.

Reticulum.—In the smaller specimens long, very slender spicules radiate in a matted mass from a spot that was probably the base of a more or less globular form of sponge; these spicules vary from 0.16 to 0.4 mm. in diameter and fragments 10 mm. in length are scattered about irregularly on the outer surface; in places on the margin the spicules extend a distance of 3 to 5 mm., forming a delicate fringe; on the surface of large specimens the spicules may radiate from two or more centers or from one or more lines following the longer axis of the sponge; in all specimens there is a space of varying width near the margin where the main body of the spicules extend outward at right angles to the margin.

Dimensions.—The largest specimen outlining the body of the sponge has a total length of 210 mm. and greatest width of 150 mm.; it probably represented an elongate globose mass with a major axis of 140 mm. and a minor axis of 100 mm.

Observations.—This is an unsatisfactory species to deal with on account of its condition and the absence of well-defined characters other than the irregularly radiating spicules and the general impression made that we have the remains of what was once a rather soft globular sponge.

[1] Rept. Voyage H. M. S. Challenger, Zool., Vol. 20, 1887, pl. XLIII.

Hamptonia differs from *Choia* in its looseness of structure and absence of strong radiating spicules; it probably grew in the same form and manner as *Choia* to the extent of not being attached to a fixed object. All of the specimens indicate that a thin-walled soft globular body was flattened in the shale, the spicular skeleton matting down in several thin parchment-like layers or forming only a thin film.

The presence in all specimens of a distinctly outlined form and the retention of the mass of spicules in a more or less regular arrangement indicates that there was sufficient spongin to serve as a base for holding both the general form and the loose spicular framework in position.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

PIRANIA, new genus

Tubular, simple stemmed or branched; growing from an obtusely pointed base; not known to have been attached.

The skeletal structure and comparisons are given in the description of the one known species.

Genotype.—Pirania muricata Walcott.

Stratigraphic range.—Middle Cambrian: Stephen formation; *Ogygopsis* shale, on Mount Stephen; Burgess shale and superjacent thin-bedded limestone, which give a vertical range of about 450 feet (137.25 m.).

Geographic distribution.—At Burgess Pass fossil quarry, in Burgess shale, on western slope of ridge connecting Wapta Peak and Mount Field, and on west slope of Mount Field 1 mile (1.6 km.) northeast of Burgess Pass above Field, also on northwest slope of Mount Stephen above Field, British Columbia, Canada.

Observations.—The details of form and structure are given under the description of the type species.

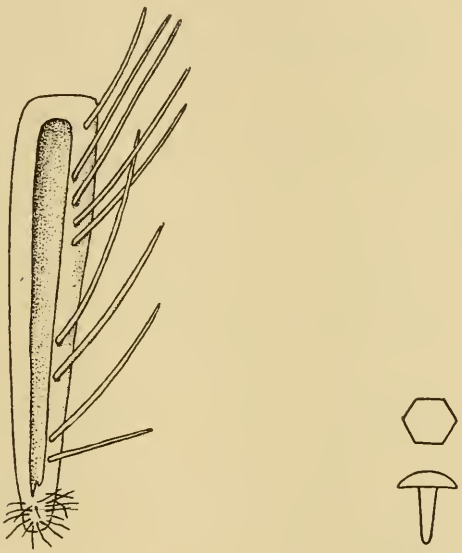
PIRANIA MURICATA, new species

Plate 79, figs. 1, 1*a-c*

Numerous specimens more or less crushed and flattened in the shale prove that the body of the sponge was in the form of a rather small, round, hollow stem, with one offshoot, as far as known, which

branched from the main stem at an acute angle. The body is formed of an outer plated wall, an interior wall (as yet of unknown structure), and an intervening space filled up with spicules and spongin that in the fossil condition is a mass of microscopic pyrite crystals which have replaced the organic matter, which is a common form of replacement among the fossils of the Burgess shale. The top of the tube is closed by a transverse layer of about the same depth as the thickness of the side walls.

Reticulum.—The outer surface of the sponge wall is covered with small hexagonal, slightly convex plates arranged in diagonal lines,



4. 4*a*.

Pirania muricata Walcott

FIG. 4.—Diagrammatic outline of section of the stem showing interior outer walls, large spicules and fine spicules at the base.
FIG. 4*a*.—Summit and side outline of plate spicule.

each plate is at the outer end of a stout spicule rounded off at the inner end; at the base of the body there is a cluster of minute slender spicules that radiate and cross each other in all directions: from the base to the summit long, more or less curved spicules with an expanded base (Tylostyli) and central canal radiate obliquely outward from the body.

The plates on a full-grown specimen are 0.4 to 0.6 mm. in diameter and the spicule (monact) attached from 0.5 to 0.6 mm. in length, and the large spicules average 0.6 mm. in diameter near the body of the sponge and extend out from it 6 to 8 mm.

Dimensions.—The body of an unbranched specimen has a length of 18 mm. exclusive of the long spicules, and a width flattened in the shale of 5 mm. The main stem of a specimen with one branch 20 mm. long is 25 mm. in length and 4 mm. wide at the top.

Observations.—I have examined 60 or more specimens of this species for spicules with three or more rays (triacts, tetracts, pentacts and hexacts), but without finding anything suggestive of their presence. The plate headed spicules of the outer body wall are very delicate and rarely preserved so as to show more than the outer portion of the plate, but on the broken-down edges of the wall in two specimens their inner extension is clearly shown; this has been flattened, but it evidently had a rounded blunt end and there are no traces of transverse rays.

None of the specimens show clearly how the large spicules pass through the outer wall; they originate in the interior, and their oblique course may be traced out to the margin of the body as the wall has been moulded over the spicules by pressure in the process of fossilization; one split-open specimen that is 3 mm. in diameter shows a hollow interior 1 mm. in diameter with walls 1 mm. thick; the bases of the oblique spicules enter the side walls but do not penetrate the interior. When the spicules are crowded together as in figures 1*d*, 1*e*, they suggest the presence of another species or variety, but I think this is owing to accidents of preservation and not to an original difference in form.

Pirania has been found in nearly all of the layers of shale at the Burgess Pass quarry, and fifty or more specimens were collected during the five seasons' work.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass; (61j) Stephen formation; yellow weathering band of calcareo-argillaceous shale, west slope of Mount Field, near Burgess Pass ridge about 3,000 feet (915 m.) above Field; also (14s) *Ogygopsis* zone of the Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian and 3,450 feet (1,089 m.) below the Upper Cambrian in the *Ogygopsis* zone of the Stephen formation, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field, on Canadian Pacific Railway, British Columbia.

Order HEXACTINELLIDA O. Schmidt

(*Triaxonia* F. E. Schulze)

"Siliceous sponges with six-rayed skeletal elements, the rays being normally disposed in three axes intersecting at right angles, and containing axial canals; elements either detached or fused together so as to form a lattice-like mesh. Dermal and flesh spicules exceedingly variable in form, but invariably six-rayed."

Sub-Order LYSSACINA Zittel

Skeletal elements either entirely detached, or only partially and in an irregular fashion cemented together. Root-tuft often present.

Family PROTOSPONGIDAE Hinde

Thin-walled, sack-, tube-like or spherical sponges, with walls composed of a single layer of cruciform tetraxial spicules (stauractins), arranged so as to form quadrate and subquadrate meshes. Elements non-fasciculate. The reticulation formed by the larger elements is divided into secondary squares by smaller spicules, so that the mesh-work is constituted of several series of squares.[1]

Genus PROTOSPONGIA Salter[2]

Dr. George J. Hinde described this genus as follows:[3]

Sponges probably cup- or vase-shaped, with walls consisting apparently of a single layer of spicular mesh. This is composed of cruciform spicules of varying dimensions; the larger are arranged so as to form a regular quadrate framework, which is divided into secondary squares by smaller spicules, and these are again subdivided in a similar manner, so that, when complete, there are four or five series of squares. The spicular rays appear to have been organically cemented together at their points of junction with each other, and there are traces of a delicate membrane in the interstitial areas between the rays, which may have united the entire meshwork together.

To the above there may be added as the result of the discovery of finely preserved Hexactinellid sponges by Dr. B. J. Harrington at Little Metis, Province of Quebec, and described by Sir J. W. Dawson assisted by Dr. Hinde, the following notes on the genus by Dr. Hinde.[4]

There are some differences of opinion as to the character of the spicular mesh-work and the systematic position of Protospongia, and fresh light on

[1] The above definitions are those given in Eastman's American edition of Zittel, Text-book of Pal., 1913, pp. 59, 60.

[2] Quart. Jour. Geol. Soc., Vol. XX, 1864, p. 238.

[3] British Fossil Sponges, Pt. II, 1888, p. 105.

[4] Trans. Royal Soc. Canada, Vol. VII, Sec. IV, 1889, pp. 39-44.

the points contested is afforded by these Quebec specimens. It has been doubted whether the body-wall of the sponge merely consisted of a single layer of spicules, or whether this layer corresponded to the dermal layer in other sponges of this group, and, as in these, was supplemented by an inner spicular skeleton. The evidence of the Quebec specimens favors the view that the body-wall of the sponge consisted only of a single layer of spicules. Various opinions have likewise been held as to whether the body-spicules were free, and merely held in their natural positions by the soft animal tissues, or whether they were cemented together by silica at the points where their rays are in contact. Prof. Sollas, in an able paper on the structure and affinities of the genus (Quart. Journ. Geol. Soc., Vol. XXX, p. 366), asserts "that they are separate, and not united either by envelopment in a common coating or, by ankylosis"; whereas it would seem that a certain degree of organic union must have existed to have allowed even the partial preservation of the mesh-work of the body-wall in the fossil state, and I have regarded the delicate film of pyrites, which extends over the mesh-work in many specimens, as indicating a connected spicular membrane which served to hold the larger spicules in position. From the study of the Quebec specimens I still think a certain degree of organic attachment existed where the spicular rays were in contact, but I am quite prepared to admit that it was not of the same complete character as in typical Dictyonine hexactinellids. Prof. F. E. Schulze has clearly shown that a certain degree of irregular coalescence takes place in the body-spicules of undoubted Lyssakine sponges, and now that we know that *Protospongia* was furnished, like most of the sponges of this group, with anchoring spicules, there is good reason to regard this and the allied Palaeozoic genera as belonging rather to the Lyssakine than to Dictyonine hexactinellids. This is the position assigned to them by Carter and Sollas.

From the study of collections obtained after the above was written Dawson added to the description the species *P. tetranema, P. mononema, P. polynema,* and *P. delicatula.*[1] From these the following description of the genus is derived.

Sponge body globular, rounded or broadly oval with an osculum at the summit and slender anchoring spicules.

Reticulum.—Wall of the sponge formed of a single layer of cruciform spicules of various dimensions so arranged as to form a framework with quadrate or oblong interspaces. The rays of the large spicules form the boundaries of the larger spaces and the smaller spicules the secondary and tertiary interspaces. The rays of the individual spicules appear to have been united by sarcode or held in a fine spicular film and not cemented together by a siliceous cement. The osculum has short spines about it and there may be a great development of protective dermal spines. The rays of the large body spicules taper gradually from the central body to their pointed extremities; the rays of the smaller spicules and the slender dermal

[1] Trans. Royal Soc. Canada, 2d ser., Vol. 2, Sec. IV, 1896, pp. 101-106.

and protective spicules appear to be nearly cylindrical. The anchoring rods or spicules vary from the single rod of *P. mononema* to the four rods of *P. tetranema*. The latter are slender, filiform, cylindrical rods, pointed at both ends, with their proximal ends inserted apparently in the basal part of the body of the sponge; the anchoring rod of *P. mononema* is described as having from two to four short spreading branches at the base or a single elongated anchor-shaped spicule with fine rays.

FIG. 5.—*Protospongia mononema*. Restored.

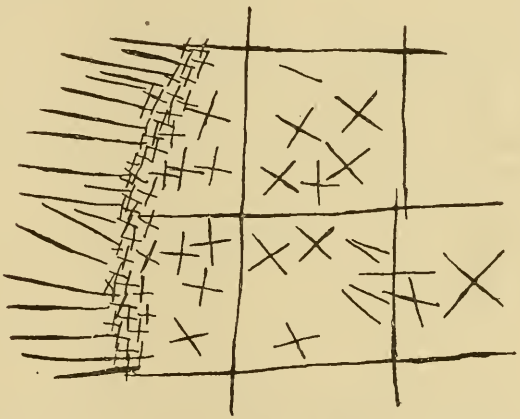


FIG. 6.—*Protospongia mononema*. Cruciform and protective spicules, × 5.

The presence of a dermal membrane is indicated in many specimens by a rusty brown covering of minute pyrite crystals.

The studies of Dawson and Hinde indicate that *Protospongia* is the simplest known form of the Hexactinellida and its occurrence in the Lower Cambrian proves it to be one of the earliest sponges yet known from Cambrian strata. The spicules from the Lower Cambrian [1] are apparently identical with those from the Middle Cambrian of Wales.

Dawson gives diagrammatic figures of two species of the genus, one of which is reproduced here for comparison with the Burgess shale species and as illustrating the genus.[2]

[1] Tenth Annual Rept. U. S. Geol. Survey, 1890, p. 597, pl. XLIX, fig. 2.

[2] Trans. Royal Soc. Canada, Vol. VII, Sec. IV, 1889, p. 40, figs. 5 and 6.

The spicules referred to *Protospongia* from the Middle Cambrian of eastern Asia indicate two species, one of which I gave a definite name, *P. chloris,*[1] and which is quite distinct from *P. fenestrata*, but may be compared with the stronger spicules of *P. hicksi*. The spicules of the second species, *Protospongia* sp. undt.[2] are similar to the more slender spicules of those from western America that I have tentatively referred to *Protospongia hicksi* Hinde. The Chinese specimens occur in limestone and have round smooth rays; the figure illustrating the spicule (fig. 4, pl. 1 of Chinese report) incorrectly represents a median depression on the ray.

The species from the Little Metis shales now referred to *Protospongia* are:

Protospongia delicatula Dawson
Protospongia mononema Dawson
Protospongia polynema Dawson
Protospongia tetranema Dawson

The species now recognized from undoubted Cambrian strata are:

Protospongia fenestrata Salter, Lower and Middle Cambrian
Protospongia hicksi Hinde, Middle Cambrian
Protospongia crixo Walcott, Middle Cambrian
Protospongia chloris Walcott, Middle Cambrian

PROTOSPONGIA FENESTRATA Salter

Plate 80, figs. 1, 1*a-b*, 2

Protospongia fenestrata SALTER, 1864, Quart. Jour. Geol. Soc., Vol. XX, 1864, p. 238, pl. XIII, figs. 12*a-b*. (Original description and illustrations.)

Hinde in his monograph of British Fossil Sponges, 1888, p. 106, gives the Synonymy of this species up to that date and describes what he knew of the species as follows:

The fragments of the wall of this species which have been preserved are insufficient to indicate the probable form of the Sponge. The cruciform spicules forming the skeletal mesh are of a delicate character, the rays are circular in section and nearly of an even thickness throughout their length. It is probable that the spicules were originally rectangular, but in the type specimen the rays are now oblique, owing to the distortion produced by the compression of the rock matrix. There are five different series of squares in the Sponge-wall, the rays bounding the largest squares are 8 mm. in length by 0.2 mm. in thickness, whilst the rays forming the secondary and smaller squares are 4 mm., 2, 1, and 0.5 mm. in length, respectively. The junction of

[1] Research in China, Carnegie Institution of Washington, Vol. 3, 1913, Pub. No. 54, p. 59, pl. 1, figs. 2, 2*a*.

[2] Idem, p. 60, pl. 1, fig. 4.

the rays with each other is, in no case, distinctly shown; they can be traced nearly to the point of contact, and do not apparently overlap the squares in which they are situated.

The typical example of this species, now in the British Museum, exhibits a fragment of the Sponge-wall on the surface of a slab of hard, black shale. The original silica of the spicules has been replaced by iron-pyrites, and a delicate film of this mineral extends over the surface of the Sponge, and is probably a replacement of a siliceous dermal membrane, which served in part to hold the spicular mesh together. Not only is the spicular framework distorted, but in all the specimens I have seen it is partially broken up and many of the spicules absent or displaced.

I collected a few fragments of the wall at St. Davids in 1888 and among them have found a group of rectangular spicules (fig. 1*a*, pl. 80) with two very long and two shorter rays. The rays are round and ornamented with a very fine irregular fretwork which is probably caused by a slight erosion of the surface; on another specimen there are a number of long, simple delicate anchoring spicules (pl. 80, fig. 1).

Dr. Hinde thought the oblique rays were distorted by compression of the matrix, but I find in our St. Davids specimens rectangular and oblique spicules associated on the same surface of shale.

Dr. George F. Matthew has described and illustrated[1] under the names of *Protospongia ? minor* and var. *distans* some fine, slender spicules that appear similar to those of *P. fenestrata* from St. Davids, and they occur at about the same horizon of the Middle Cambrian in Wales and New Brunswick. I am inclined to consider that they should be referred to *P. fenestrata* Salter.

Delicate cruciform spicules that I refer to this species occur in the black shales of the *Paradoxides hicksi* zone in Newfoundland.

Spicules agreeing in details with those from St. Davids occur in the shaly Lower Cambrian limestones of eastern New York[2] in association with a large Lower Cambrian fauna. It is to be recalled, however, that while individual spicules from widely separated localities and stratigraphic position may be apparently similar the sponges might have been quite different, hence specific determinations based only on the spicules must be considered as tentative and more or less doubtful.

To the south in Alabama similar single spicules occur abundantly in the siliceous nodules of the Middle Cambrian Coosa formation (89x), but none were found in the shales.

[1] Trans. Royal Soc. Canada, Vol. 3, Sec. IV, 1885, Pub. 1886, p. 30, pl. V, figs. 2, 3.

[2] Tenth Ann. Rept. U. S. Geol. Survey, 1890, p. 597, pl. XLIX, fig. 2.

On the western side of North America rectangular spicules with slender rays occur in the Bloomington formation and also Spence shale of Idaho in association with a large Middle Cambrian fauna. The associated but scattered spicules vary in size from 30 mm. with rays 15 mm. in length to rays 4 mm., 2.5 mm. and 0.5 mm. in length, which correspond somewhat to the variations of the spicules in typical specimens from Wales.

Cruciform spicules that may have belonged to this or an allied species of *Protospongia* occur on the surface of shaly limestones of the Middle Cambrian Marjum and Wheeler formations of the House Range in central-western Utah.

Another Middle Cambrian locality[1] (57n) occurs in the Eldon limestone of British Columbia, where somewhat distorted, scattered spicules of this type were found on the surface of a thin-bedded layer of limestone, which closely resemble the oblique spicules from Wales.

P. fenestrata is represented in the Middle Cambrian fauna of China by cruciform spicules embedded in limestone, that have four slender, round rays meeting at the center of the spicule,[2] but no specimens were found with indications of the skeleton of the sponge.

The presence of spicules resembling those of *P. fenestrata* in the *Ceratopyge* limestone of Sweden is discussed by Moberg and Segerberg[3] and an illustration given (pl. 1, fig. 5), but with the data available it is difficult to determine if the spicules belong to this species or to *P. hicksi* or an undetermined species. The same is true of all the spicules from Swedish Cambrian strata referred to *P. fenestrata* and *P. hicksi*.[4]

Rauff (1894)[5] notes occurrence of species at localities in Norway and Sweden, but with only scattered spicules on which to base identification the determination of authors is necessarily tentative unless there is a considerable amount of material and actual comparison made of typical specimens with those from other localities.

Formation and locality.—Middle Cambrian: (318h) Shales of the Menevian at St. Davids, South Wales.

North America, Middle Cambrian. (1) (Manuel formation) Shales of zone A of No. 7 of the Manuels Brook section,[6] Manuels

[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 209.

[2] Research in China, Vol. 3, p. 60, pl. 1, fig. 4. *Protospongia* sp. undt.

[3] Med. Lunds Geol. Fältk., Ser. B, No. 2 (Aftr. Kongl. Fys. Sälls. Handl., N. F., Bd. 17), 1906, p. 59, pl. 1, fig. 5.

[4] See Rauff, 1894, Palaeontographica, Vol. 40, pp. 236, 237.

[5] Idem, p. 236.

[6] Walcott, Correlation Papers—Cambrian, Bull. U. S. Geol. Survey, No. 81, 1891, p. 261.

Brook, a small stream which flows into Conception Bay from the east, near Topsail Head, Newfoundland.

The representative of the species also occurs in the Middle Cambrian, St. John formation, at Porters Brook, St. Martins, New Brunswick. It is described as *Protospongia ? minor* by Matthew (Trans. Royal Soc. Canada, Vol. 3, Sec. IV, 1885, pub. 1886, p. 30, pl. V, figs. 2, 3).

(89x) Conasauga formation; siliceous nodules embedded in argillaceous shale, Livingston, Coosa Valley, Floyd County, Georgia.

(5g) Spence shale; 100 feet above Brigham formation; dark argillaceous shales and blue-black calcareous shales, Two-Mile Canyon, 3 miles (4.8 km.) southeast of Malad, Oneida County, Idaho.

(57n) Eldon formation; about 3,000 feet (914.4 m.) above the Lower Cambrian and about 700 feet (213.4 m.) above the base of a limestone correlated with No. 4 of the Eldon limestone on Mount Bosworth,[1] on the northwest slope of Mount Stephen, above Field, on the Canadian Pacific Railway; also (61b) Stephen formation; summit of southeast spur of Mount Odaray, 7.5 miles (12 km.) south of Hector on the Canadian Pacific Railway, British Columbia, Canada.

(30g) Marjum limestone about 2,350 feet (716.3 m.) above the Lower Cambrian 2.5 miles (4 km.) east of Antelope Springs, Millard County; also (15h) Wheeler formation; south wall of Rainbow Valley, both in House Range, Utah.

Lower Cambrian: (38a) Limestone 2 miles (3.2 km.) south of North Granville, on the road which turns south from the road running between that village and Truthville, 4 miles (6.4 km.) west-northwest of Granville, Fort Ann quadrangle (U. S. G. S.), Washington County, New York.

PROTOSPONGIA HICKSI Hinde

Plate 80, figs. 3, 3*a-b*

Protospongia fenestrata Hicks, 1871, Quart. Jour. Geol. Soc., Vol. XXVII, p. 401, pl. XVI, fig. 20. (Identifies spicules as belonging to *P. fenestrata.*)

Protospongia fenestrata F. Roemer (in part), 1880, Lethaea palaeozoica, Th. 1, p. 316, fig. 59*b*. (Describes and illustrates spicules from Wales. Also a large doubtful form from Sweden.)

Protospongia fenestrata Sollas, 1880, Quart. Jour. Geol. Soc., Vol. XXXVI, p. 362, fig. 1. (Identifies spicules as *P. fenestrata.*)

[1] Idem, Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, p. 209.

Protospongia hicksi HINDE, 1888, British Fossil Sponges, Pt. II, p. 107, pl. 1, figs. 2, 2*a*. (Describes and illustrates species.)

Protospongia hicksi RAUFF, 1894, Palaeontographica, Vol. 40, p. 237. (Brief description and distribution as far as known.)

Dr. Hinde describes this well-marked species as follows:[1]

Sponge probably vasiform; the portions preserved indicate that the type specimen was at least 100 mm. in height by 75 mm. in width at the summit. The spicular mesh is composed of robust cruciform spicules, the rays are approximately rectangular, and nearly of a uniform thickness throughout their length. The centers of the spicules are slightly elevated, so that they are not strictly horizontal. The rays of the smaller spicules in the majority of cases dip beneath those of the larger forms. Five series of squares are present in the complete mesh, the largest are 8 mm. in diameter and the smallest 0.5 mm.; the axes of the largest spicules are 11 mm. in length and 0.52 mm. in thickness, whilst the smallest are 1 mm. in length and 0.2 mm. in thickness.

. . . . A comparison of this form with the type of *P. fenestrata* shows, however, a very considerable difference in the thickness of the spicular rays, sufficient to indicate it as a distinct species, which I have named in honor of its discoverer.

In no case in this species are the points of contact of the spicules with each other clearly shown, but the structure of the mesh appears to me to justify the view that the spicules are cemented together where they join each other; Prof. Sollas states, however, that they are separated and not united either by envelopment in a common coating or by ankylosis.

Fragments of mesh and detached cruciform spicules, apparently belonging to this species, have been discovered in Norway, Sweden, and also in Nevada, at approximately the same geological horizon.

The specimens from the Burgess shale correspond so closely to the description and illustrations given by Dr. Hinde that I cannot find any reasonable grounds for considering the specimens from the widely separated localities as representing distinct species; the size and appearance of the spicules and meshes are similar and both are from the Middle Cambrian. In two fragments of the outer wall of *P. hicksi* there are both strong and very delicate cruciform spicules, but both are more nearly similar to the characteristic spicule of *P. hicksi* than to the spicules of *P. fenestrata*.

Dr. Hinde identifies this species from Nevada, but I find that the Nevada spicules are smaller and the rays proportionally more slender.

The spicules and surface of the shale are coated with a black carbonaceous-appearing film abounding in minute crystals of pyrite. The largest fragment of the wall is 6 by 4 cm. and gives no indication of the form of the sponge.

[1] British Fossil Sponges, 1888. Pt. II, pp. 107, 108.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass above Field, British Columbia.

Also (61f) in the thin-bedded limestones about 350 feet (106.75 m.) higher in the same section.

DIAGONIELLA Rauff

Diagoniella RAUFF, 1894, Palaeospongiologie Palaeontographica, Vol. XL, 1894, p. 248, pl. 1, fig. 21.

Dr. Hermann Rauff proposed name as subgenus of *Protospongia*

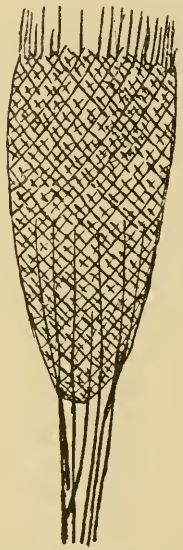


FIG. 7.—*Diagoniella cyathiformis* (after Dawson, fig. 13).

but without description, and gives *Protospongia coronata* Dawson as example, also mentions *P. cyathiformis* Dawson.

Dawson in reviewing the Little Metis fossil sponges considers that the diagonal arrangement of the spicules is hardly sufficient variation from *Protospongia* to warrant establishing the genus *Diagoniella* but he found "other peculiarities of these species (*P. coronata, P. cyathiformis*), which might fairly entitle them to constitute distinct sections of the genus." [1]

I am in agreement with Rauff in placing the species with the diagonally arranged spicules in a genus distinct from *Protospongia.*

[1] Trans. Roy. Soc. Canada, 2d ser., Vol. 2, Sec. IV, 1896, p. 106.

Diagoniella is distinguished by the diagonal arrangement of the rhombic openings formed by large cruciform spicules; the obliquely arranged spicules serve to separate the genus from *Protospongia* and they give the body of the sponge a very characteristic appearance.

In addition to the two species *D. coronata* and *D. cyathiformis*[1] we now have *D. hindei* from the Middle Cambrian.

In the material I collected at Little Metis in 1888 there is a large broken fragment of *Diagoniella cyathiformis* Dawson that is 15 cm. in length and 7 cm. in width; large cruciform spicules with rays 11 mm. in length form the foundation for meshes 7 to 8 mm. across, which are subdivided by smaller rectangular spicules down to openings 1 mm. across. This sponge is probably nearly as large as *Palaeosaccus dawsoni* Hinde.[2]

Genotype.—Protospongia coronata Dawson.

Stratigraphic range.—D. coronata and *D. cyathiformis* occur in a narrow band of the Metis shale which is of Cambrian and probably of Middle Cambrian age. *D. hindei* is found in the lower 10 feet (3.05) of the Burgess shale.

Geographic distribution.—Shore of the St. Lawrence River at Little Metis, Province of Quebec.

Western slope of ridge connecting Wapta Peak and Mount Field, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

DIAGONIELLA HINDEI, new species

Plate 81, figs. 1, 1*a-c*

General form that of a straight cornucopia flattened on the surface of the shale; truncated at the top with probably a relatively large osculum the margins of which appear to have had a number of short, fine, thread-like spicules; the body wall is built up of cruciform spicules arranged in oblique encircling lines with many minute secondary spicules; traces occur near the base of fine straight anchoring spicules.

A large specimen has a length of 11 mm. with a width of 6 mm. at the top; it was a third narrower before being flattened out. This species must have occurred in large numbers, as a piece of shale 10 cm. by 18 cm. has 52 specimens flattened on its surface.

Observations.—A brown incrustation of minute spicules of pyrite forms a thin film on all the specimens of this species in the collection;

[1] Trans. Royal Soc. Canada, Vol. VII, Sec. 4, 1889, pp. 41 and 43.

[2] Geol. Mag., Dec. III, Vol. X, 1893, p. 56, pl. IV.

it presumably represents a delicate spicular membrane formed of minute spiculae which are so incrusted with pyrite that only traces of them are occasionally seen; one specimen has a number of short, minute thread-like spiculae extending from it at its base and one definite cruciform spicule; another has the spiculae so well preserved along the sides near the base that the diagonal arrangement of the spicular meshes is clearly discernible (fig. 1*b*), and it may be traced over the entire body.

D. hindei differs from *D. coronata* Dawson[1] by the form of the body and relative size of its cruciform spicules and from *D. cyathiformis* Dawson by its smaller size and minute root spicules.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

Genus KIWETINOKIA, new genus

This genus includes three species represented by large or small groups of displaced spicules in a more or less confused and scattered condition on the surface of shaly or thin-bedded limestone. It is assumed that the long, slender spicular rods belong with the cruciform and triradiate spicules as they are intimately associated with them in the three species.

Reticulum.—The evidence afforded by specimens of *K. utahensis* indicates that the skeletal elements were detached and arranged so as to form quadrate and irregular meshes from the cruciform spicules, the wall of the sponge being further strengthened by triradiate (prodiaenes ?) spicules and long slender spicular rods that probably served as anchoring spicules. The rods of *K. utahensis* are solid and papillose, while those of *K. metisensis* and *K. spiralis* are formed of very slender spicules closely twisted together in a rope-like strand; both types of rod are nearly the same size; another rod includes a long stem (35 mm.) composed of 2 spicules twisted around each other and what may be a base formed of two prongs each of which is short and enlarged at the end (fig. 1a, pl. 89); this rod appears to be a form intermediate between the straight simple rod associated with *K. utahensis* and the spiral rod of *K. spiralis*. This sponge probably grew in the form of a sack or elongate sphere that was anchored in the mud by long spicules; a mass of spicules

[1] Trans. Royal Soc. Canada, Vol. VII, Sec. 4, 1889, pp. 41 and 43.

70 mm. in length and 45 mm. in width and the occurrence of large triradiate spicules show that it grew to a considerable size.

Genotype.—*Kiwetinokia utahensis* Walcott.

Stratigraphic range.—*K. utahensis* has a range of 100 feet (30.5 m.) or more in the Marjum formation and occurs in thin-bedded limestones of the Ophir formation of the Oquirrh range section and the Spence shale of the Ute formation. *K. spiralis* is from the Marjum formation about 600 feet (183 m.) above *K. utahensis*. All of the preceding are in the central portion of the Middle Cambrian of the Cordilleran Province. *K. metisensis* occurs in Little Metis shales, the stratigraphic horizon of which has not been fully determined but is presumably Cambrian.

Geographic distribution.—*K. utahensis* occurs in the House and Oquirrh ranges of Utah and southeast of Malad, Idaho. *K. spiralis* is from the House range of Utah, and *K. metisensis* from Little Metis on the St. Lawrence River, Province of Quebec, Canada.

Observations.—The family relations of *Kiwetinokia* are rendered very uncertain as we do not know positively that the triradiate spicules belong with the cruciform spicules and long anchoring spicules; they all occur together but whether one or the other may have been drifted in among the others is not easily determined. It is highly probable that the cruciform spicules and rods belong together and very probable that the triradial spicules belong with them as they occur in direct association both in the Utah and Little Metis specimens. Assuming that all three types of spicule belong with *Kiwetinokia*, the genus may be placed tentatively under the Hexactinellida, family undetermined.

The rods referred to *Hyalostelia* from Silurian and Carboniferous formations[1] have a spiral twist but they are so unlike those from the Cambrian that I do not think it at all probable they belong to the same genus.

Dawson describes "peculiarly ornamented spiral rods" associated with fragments of a large sponge (*Palaeosaccus dawsoni* Hinde) in the Little Metis sponge beds. He says:

> They appear as if they consisted of several very minute filaments spirally twisted together like the strands of a rope. Each filament has a row of projecting tubercles which in the rod are definitely arranged in quincunx, so that the general arrangement is very striking. At the distal end the rods are slightly curved and the raised lines are more straight and assume more the aspect of distinct fibers.

[1] See Hinde, British Fossil Sponges, Pt. 1, 1887, pl. 1, figs. 3, 4, 5; Pt. 2, 1888, pp. 110, 118, 129, 161.

The rods are found almost exclusively on the same surface with this sponge. They do not appear to belong to any other form in these beds. Fragments of the base of the sponge show that the strands of the framework have there an imperfect spiral arrangement, though slender, and if several of them coalesced at the base they would assume the form of the spiral rods.[1]

The rods are evidently of the same general character as those associated with species of *Kiwetinokia,* but are quite different in details of structure.

KIWETINOKIA UTAHENSIS, new species

Plate 89, figs. 1, 1*a-c*

An entire specimen of this species has not been found, but fragments are sufficient to give some idea of its size and character. One specimen (fig. 1) has a length of 70 mm. and width of 45 mm. with evident loss both in length and width.

Reticulum.—The skeletal elements are all detached and lie in a confused mass on the shale. Large and small cruciform spicules (tetraxine) similar in form to those of *Protospongia* predominate, but unlike the latter the surface is finely papillose; associated with the largest mass of cruciform spicules there are slender spicular rods with a papillose surface; one rod broken off at each end is 20 mm. in length with a diameter of 0.5 mm.; a rod on a separate fragment of shaly limestone but in association with scattered cruciform spicules is 30 mm. in length; on the same surface there is one mesh intact formed of four cruciform spicules, also several Y-shaped triradial spicules formed of one extended branch (rhabdus?) and two short branches (actines ?); some of these spicules may be compared with protriaene spicules of the Tetractinellida[2] in which the cladi are directed forward; only two cladi (branches of the ecactine) having been developed. A similarly shaped spicule occurs in the recent *Chrotella macellata.*[3]

The rays of the largest cruciform spicules are from 7 to 8 mm. in length and 0.5 mm. in diameter at their base; smaller spicules with rays 2 to 3 mm. in length and still smaller are associated with the larger spicules. The triradial spicules (prodiaenes) of the type specimen are small and obscure, but on another surface of shaly limestone the branches (actines) are from 12 to 15 mm. in length; another sur-

[1] Trans. Royal Soc. Canada, 2d ser., Vol. 2, Sec. IV, 1896, p. 113.

[2] See Rept. H. M. S. Challenger, Zool., Vol. XXV, 1888, pp. lv-lviii.

[3] Idem, pl. IV, fig. 5. Dr. W. J. Sollas said (p. 20) when describing the skeleton of this species, "the protriaenes with widely diverging cladi project their cladi into the cortex, thus contributing essentially to its support."

face has numerous small cruciform spicules on it and sixteen small triradial spicules.

Observations.—This species lived in the Cordilleran sea of Middle Cambrian time, ranging as now known from central western Utah to southern Idaho. It may be that the spicules from the type locality in the House range of western Utah and the Oquirrh range of northern Utah and those from southeast of Malad, Idaho, are not from this species, but in all three localities both the triradial and cruciform spicules are similar, all occur on the surface of shaly limestone, and the stratigraphic horizon of all is sufficiently near the Middle Cambrian *Micromitra* (*Iphidella*) *pannula* zone to permit of considering that this sponge might occur in the formations and localities listed below.

K. utahensis differs from *K. spiralis* in having the associated rods spiral and formed apparently of a number of closely combined spicules twisted so as to resemble a rope.

Formation and locality.—Middle Cambrian: (11q) Marjum formation; about 2,300 feet (701 m.) above the Lower Cambrian, and 660 feet (203 m.) below the Upper Cambrian, in the limestone forming 1c of the Marjum formation, and (3x) about 2,200 feet (670.6 m.) above the Lower Cambrian and 810 feet (249 m.) below the Upper Cambrian in the limestones forming 1d of the Marjum formation, both 2.5 miles (4 km.) east of Antelope Springs, in ridge east of Wheeler Amphitheater, House Range, Millard County; also (3e) Ophir formation; thin-bedded limestone less than 400 feet (121.9 m.) above the quartzitic sandstones of the Cambrian, at Ophir City, Oquirrh Range, Tooele County, all three in Utah.

(5g) Spence shale; 100 feet (30.5 m.) above Brigham formation; dark argillaceous shales and blue-black calcareous shales, 155 feet (47.2 m.) forming 4a of [typewritten] Malad section; Two Mile Canyon, 3 miles (4.8 km.) southeast of Malad, Oneida County, Idaho.

KIWETINOKIA SPIRALIS, new species

Plate 89, figs. 2, 2*a-b*

This species is represented by a few scattered cruciform spicules associated with a number of fragments of long, slender rope-like rods formed of closely twisted strands that appear to have been very slender spicules etched by transverse raised bands dividing them into sections slightly longer than wide; whether these bands formed the base of minute spines as in the rods associated with *Hyalostelia*

gracilis Hinde[1] is not determinable from the specimens. No triradiate spicules have been found in association with the rods or cruciform spicules.

The largest cruciform spicule has rays about 1.25 mm. in length; their surface is unknown as it has been removed by the solution of about one-half the thickness of the body and rays; the long spiral rods average from 0.4 to 0.5 mm. in diameter, one broken rod has a length of 40 mm.

This species is closely allied to *Hyalostelia metissica* Dawson[2] by the character of the spiral rods and quadrangular spicules; owing to our having but one specimen of *K. spiralis* and that very incomplete no further comparisons can be made. It must be understood that there is no connection between the rods and spicules further than that they are associated on the surface of the thin-bedded limestone.

K. spiralis occurs about 600 feet (183 m.) higher in the House Range section than *K. utahensis*. It differs from the latter in the character of the associated slender rods (anchoring spicules).

Formation and locality.—Middle Cambrian: (10z) Marjum formation; about 2,900 feet (884 m.) above the Lower Cambrian and 1500 feet (457.2 m.) below the Upper Cambrian in the central part of the limestone forming 1a of the Marjum limestone, in the long cliff about 2 miles (3.2 km.) southeast of Marjum Pass, House Range, Millard County, Utah.

KIWETINOKIA METISSICA (Dawson)

Hyalostelia Metissica Dawson, 1889, Trans. Royal Soc. Canada, Vol. VII, Sec. IV, p. 49, fig. 20. (Describes and illustrates species.)

Sir William Dawson described the species as follows:

This species has not yet been seen in a perfect state or showing its general form. It seems to have been of a specially friable or decomposable character. The body appears as irregular patches of broken up skeleton, which, under the lens show a confused mass of cruciform spicules large and small, slender rods and some peculiar triradiate spicules, apparently in some cases with oblique angles, though this may perhaps be a result of distortion, cruciform spicules with one ray curved, and minute stellate spicules. The whole somewhat resembles, though with difference in detail, the debris of the body of the modern Hyalonema, when crumbled and examined under the microscope. Associated with these patches, and also found separate, are many large anchoring rods of peculiar structure. They consist of several slender spicules twisted together spirally so as to resemble a rope. Each strand has little

[1] British Fossil Sponges, Pal. Soc., 1887, p. 129, pl. 1, figs. 5, 5*a-f*.

[2] Trans. Royal Soc. Canada, Vol. VII, Sec. IV, 1889, p. 49, fig. 20.

tubercles externally to give greater holding power, and the whole, when well preserved, constitutes one of the most beautiful of sponge structures. In one or two cases the spiral threads were seen to be unwound at their proximal ends, as if passing into the slender rods of the body of the sponge.

Observations.—This species has the same type of spiral rod as *K. spiralis,* also cruciform and triradiate spicules found with *K. utahensis.* The stellate spicules suggest the 5 to 9 radiate spicules of *K. utahensis.* The two forms appear to belong to the same genus.

Formation and locality.—Middle? Cambrian: Little Metis black argillaceous shale, Little Metis, Province of Quebec, Canada.

8. 8*a*.

FIG. 8.—*Kiwetinokia metissica* (Dawson). Spicules × 5, and (8*a*) large spiral anchoring rod magnified. (After Dawson.)

Sub-Order DICTYONINA Zittel

Family VAUXININAE, new family

Simple or branched, elongate cylindric, crateriform or frondose thin-walled sponges with a thin, dense dermal layer; skeletal spicules cemented to form a continuous framework in such a manner that the vertical rays of each spicule (tetract) are applied to the corresponding rays of opposing spicules; each transverse ray is cemented to the opposite vertical line of rays so as to form irregular quadranuglar meshes with more or less irregularly disposed spicules scattered over the quadrules thus produced; axial ray extends inward. Root tuft absent or unknown.

Observations.—The Vauxininae are probably the Cambrian ancestors of the Dictyonina of the Trias, Jurassic and Cretaceous periods, although they differ in their thin walls and the four-rayed spicules of the skeletal framework, three of which are on one plane and one axial ray penetrating inward at right angles to the surface

of the sponge. These sponges have in common with the Dictyonina a continuous spicular skeletal framework formed by cementing together the points of the rays, and their growth results in cylindric, branching or flattened sponges.

The Vauxininae is represented in the Middle Cambrian by the genus *Vauxia*.

VAUXIA, new genus

Elongate, cylindric single or branching, crateriform and frondose thin-walled sponges; skeleton formed of spicules (tetracts) bearing two main rays that combine to form the strong vertical sides of irregular roughly outlined quadrangles with the interspaces more or less filled in with minute spicules of various outlines; the third ray is slender and extends across between the vertical lines to form a straight or slightly curved transverse boundary of the meshes; the axial ray extends inward.

Genotype.—Vauxia gracilenta Walcott.

Stratigraphic range.—Lower 10 feet (3.05 m.) of the Burgess shale.

Geographic distribution.—Western slope of ridge connecting Wapta Peak and Mount Field, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

Observations.—In form the single tubed or unbranched species resemble the Ordovician *Cyathophycus reticulatus* Walcott,[1] but their spicular structure is quite dissimilar. The vertical lines seen so plainly on *Vauxia gracilenta* at first sight recall those of *Tuponia lineata,* but on close examination they are found to be formed of the strong short rays of spicules arranged so as to be cemented together at the ends of the rays; both the vertical and transverse rays may be regularly or irregularly curved and they are slightly enlarged towards their distal end where they unite with the rays of adjoining spicules; in the skeleton of *V. bellula* the points of the rays have been so cemented and embedded that they appear to be continuous and to have a common central canal; in this condition the skeleton is similar in appearance to the frond of the graptolite *Dictyonema* when it is flattened in the shale; there are some ray-like spicules that appear to be slender thorny processes from the rays of the skeletal spicules. The minute spicules of the quadrangular spaces are irregular in form but appear to indicate triacts and tetracts with curved and

[1] See Mem. Pal. Reticulate Sponges, Family Dictyospongidae, 1898, Hall and Clarke, Albany, pl. 1.

undulating rays, the effect of which is to give a very irregular network in the interspaces. As far as known, the walls were thin and only one layer of spicules has been discovered, although in *V. densa* the outer dermal membrane may have had a layer of minute spicules embedded in it and the gastral membrane may have been similarly provided, but there is no evidence of it.

The presence of both simple and branching forms of *V. gracilenta* and *V. densa* is most interesting and unusual among Cambrian sponges. It recalls species of the recent genus Hexactinella.[1]

In all specimens the original siliceous matter of the spicules has been removed and replaced either by pyrite or a black carbonaceous-appearing material or a combination of the two.

The species referred to the genus are:

Vauxia gracilenta Walcott. Genotype
Vauxia bellula Walcott
Vauxia densa Walcott
Vauxia dignata Walcott

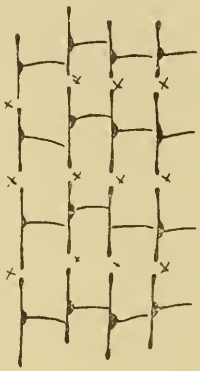
VAUXIA GRACILENTA, new species

Plate 82, figs. 2, 2*a-d;* pl. 83, figs. 1, 1*a-c*

This species occurs both in the form of simple cylindric tubes flattened on the surface of the shale or with a main tube and one or more branches (pl. 82, figs. 2, 2*a*), and rarely a secondary branch springing from a primary branch. A few examples of a thickly branched form were collected that resemble a closely branched plant (fig. 2*c*, pl. 82). Specimens preserving more or less of the thin outer dermal layer have a dull black surface that in a reflected light is slightly roughened by vertical and transverse lines of the spicular skeleton beneath. When the dermal layer is not present the spicules are finely exposed (figs. 1*a-c*, pl. 83); individual spicules are rarely seen as they are so strongly cemented into the skeleton that even in fragments of the sponge they do not separate on their broken and often macerated surfaces. As far as I am able to determine the skeleton is formed of spicules having three rays on one plane and an axial ray that presumably extended inward; the three surface rays are usually more or less curved with their ends fused or cemented to the ends of the opposing rays, or to the side of one of them; this gives a ladder-like structure to each pair of vertical rows of spicules and the entire skeleton is formed of irregularly quadrangular meshes; within the meshes thus formed there is a very delicate secondary

[1] See Rept. H. M. S. Challenger, Zool., Vol. XXI, 1887, pls. 93, 94.

irregular structure formed of minute spicules (monacts, triacts or pentracts) with bent rays that are cemented to similar adjoining rays or to the rays of the principal spicules; this forms irregularly oval, round or angular openings that are only seen on well-preserved specimens; when the walls of the opposite sides of a tube are pressed together by the flattening of the tube so that the spicules appear to belong to a single thickness of the wall the structure is still more complicated (pl. 83, fig. 1*b*). The ladder-like structure is illustrated by fig. 1*c*.



Vauxia gracilenta Walcott.

FIG. 9.—Diagrammatic figure of the arrangement of the principal spicules, the rays of which are cemented together at the points indicated by X.

The principal spicules are about 0.5 mm. across from end to end of the rays.

Dimensions.—Single compressed tubes have a length of 80 mm. and a width flattened on the shale of 10 mm. at the upper end or about 7 mm. as a cylinder; one branch of a branched specimen with slender tubes has a length of 110 mm. and a width flattened of 7 mm. (fig. 1, pl. 83); in another branching specimen 100 mm. in length the branches average 2.5 mm. in width, flattened (fig. 2*c*, pl. 82); many intermediate sized tubes occur in the collection that indicate that the size of the tube was quite variable.

Observations.—The occurrence of hundreds of almost unbroken specimens results from the strong spicular skeleton as a direct fracture was necessary to break even a slender tube, but many of the branches were more readily broken from the main branch; many surfaces of shale are almost covered with the flattened branches and single tubes especially in the layers 20 feet (6.1 m.) to 50 feet (15. 25 m.) above the lower portion of the Burgess shale.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

VAUXIA BELLULA, new species

Plate 82, figs. 1, 1*a-b*

This species occurs as simple, elongate flattened slender tubes that taper very gradually from the summit to the base; a few specimens have a rather dense dermal layer resembling that of *Vauxia densa,* but the larger number show the skeletal structure characteristic of the genus, and a few exhibit it very distinctly.

Reticulum.—The spicules forming the skeleton appear to be similar in form to those of *V. gracilenta* and cemented to their opposites in the same manner; the rays, however, are more regular and form a more regular elongate quadrangle, and the rays have been so uniformly cemented together that the sides of the lattice-work are uniform and the spicules appear to have a central communicating canal extending throughout the skeleton (fig. 1*a,* pl. 82). At the summit of the body a fringe of fine, short spicules is indicated on a few specimens.

Dimensions.—The largest specimen as flattened has a length of 115 mm. with a width of 13 mm. at the top.

Observations.—This species may be compared in form with single tubes of *V. gracilenta,* but it is not as slender, the dermal layer is different, and the spicular skeleton more regular. When the spicular skeleton is well exposed it has the appearance of the mesh-like structure of the graptolite *Dictyonema,* and if a fragment of it was found similar to that represented by figure 1*b,* plate 82, it would in all probability be referred to the Graptolitoidea.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

VAUXIA DENSA, new species

Plate 84, figs. 1, 1*a-c*

Sponges either simple or branched; tubes transversely corrugated by slight undulations or nearly smooth; dermal layer dense and usually preserved as a dull black film that suggests a carbonaceous

mineral, but as that is the general appearance of nearly all the fossils in the Burgess shale it has little significance; where the dermal surface is slightly oxidized and of a brownish color it is covered with very minute crystals of pyrite and they are also very abundant on the black specimens.

Reticulum.—The skeletal structure is usually concealed by the dermal layer, but when that has been partially removed vertical lines connected by slightly curved transverse lines appear and when the dermal layer is still further removed a skeletal structure similar to that of *Vauxia gracilenta* is plainly indicated, but the individual spicules are not readily determined; on frayed edges the broken spicules (fig. 1b, pl. 84) appear to have the same irregular curved rays as in *V. gracilenta;* there is a fine transversely reticulate structure at the upper end of the specimen represented by fig. 1, which appears to have been along the margin of the osculum.

Observations.—This species differs from *V. gracilenta* by its larger body, thick dermal layer, and obscure skeletal structure: from *V. bellula* by its undulating surface and more irregular skeletal structure, and *V. bellula* is not known to have had a branching form of growth.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

VAUXIA DIGNATA, new species

Plate 81, figs. 2, 2a-c

This is a branching sponge closely allied to *V. gracilenta* in form and size. The main skeletal structure is of the same type but much more irregular; the dermal layer is thick and made up largely of minute irregular spicules obscured by a film-like covering; it is roughened by irregular inosculating and branching more or less vertical ridges that give the surface much the appearance of that of *Ventriculites* of the Cretaceous; some of the minute spicules recall those of the surface of *Callopegma*, but this is a superficial resemblance although the general form of the skeletal frame-work is not unlike that of *Rhagadinia* also of the Cretaceous.[1]

Specimens of this species are rare, only two having been collected.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge

[1] Zittel. Text-book of Pal., Eastman Ed., 1913, pp. 53, 54, 66.

between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

VAUXIA (?) VENATA, new species

Plate 85, figs. 1, 1*a-b*

Broad turbinate or bowl-shaped, thin-walled sponge, expanding above into a broadly undulated margin. Skeletal spicules cemented to form a very fine continuous framework by the union of the ends of the rays of the opposing spicules; the openings in the framework are very irregular, although the vertical lines formed by the union of the rays are fairly direct; this arises from the irregular disposition of the transverse rays and the interpolation of additional lines of spicules with the expansion from the base upward; minute irregular spicules or curved spine-like extensions from the skeletal spicules form a fine irregular mesh in the lattice work spaces, especially when the thin outer siliceous dermal layer is well preserved.

Dimensions.—On the largest specimen the distance from the base to the margin is 60 mm. and the indentations on the margin about 30 mm. apart; the vertical lines of the skeleton average about five to the millimeter.

Observations.—This is the largest expanded form of the *Vauxia* group of sponges. Its form and minute skeletal mesh serve to distinguish it from all other species. The raised vertical lines of the skeleton are very distinct on some portions of the surface, standing out clearly, although covered with a delicate dermal film.

The form of the full-grown sponge is somewhat doubtful, as the fossil specimens are almost completely flattened on the shale, but the basal portion of the specimen illustrated indicates that it was bowl-shaped with an undulating margin.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, one mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

Family OCTACTINELLIDAE Hinde

Dr. Hinde[1] in discussing the genus *Astraeospongia* Roemer said:

> The spicules of this genus are so distinctly marked off from those of any other group of Sponges that in my opinion they characterize a separate sub-order. The constancy and the regular disposition of the six horizontal rays,

[1] British Fossil Sponges, Pt. II, 1888, p. 134.

and the additional rays of the vertical axis, clearly show that the genus cannot be ranked with the Hexactinellidae. The same features likewise distinguish it from any of the genera included in the Heteractinellidae, though some of the spicules of *Tholiasterella,* consisting of six horizontal rays and a vertical ray, bear a certain resemblance to those of *Astraeospongia* (pl. VII, figs. 1*c,* 1*d*). But in *Tholiasterella* the horizontal rays are very inconstant, varying from five to nine in number, and further, their mode of union with each other also indicates the absence of any real affinity betwen these groups.

Rauff[1] regards the establishment of this sub-order as doubtful, but with the presence of the type in Cambrian time with the same form of spicule I think we are justified in recognizing it as a long established group of sponges characterized by a fixed form of spicule unknown in other sponges except as one of several forms found in some genera of undetermined ordinal relations.

The genus *Astraeospongia* first appears in the Silurian (Niagara) and extends up into the Devonian. The discovery of the new genus *Eiffelia* extends the range of the sub-order Octactinellidae to the Middle Cambrian and affords another proof of the primitive character of the sponges of this group.

Genus EIFFELIA, new genus

Spheroidal or irregularly globular form with six-rayed skeleton elements forming a close irregular mesh; stellate hexatins with the rays on one plane and a vertical ray.

Genotype.—Eiffelia globosa Walcott.

Stratigraphic range.—Lower 10 feet (3.05 m.) of the Burgess shale.

Geographic distribution.—Western slope of ridge connecting Wapta Peak and Mount Field, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

Observations.—Eiffelia differs from *Astraeospongia* Roemer[2] in being formed of a relatively thin layer of spicules, more or less regularly arranged in an outer layer, while the spicules of *Astraeospongia* form an almost solid inner skeleton. Among living genera of the Hexactinellidae species of *Pheronema*[3] have the general form of *Eiffelia,* but the latter is a very simple form and has as far as known only one type of spicule.

I agree with Dr. George J. Hinde that Astraeospongia should be classed under a distinct sub-order for which he proposed Octacti-

[1] Palaeontographica, Vol. 40, 1893, p. 171.

[2] Sil. Fauna des West. Tennessee, 1860, pp. 13, 14.

[3] Rept. H. M. S. Challenger, Zool., Vol. XXI, 1887, pl. 54, fig. 1.

nellidae.[1] Dr. Karl Zittel[2] suggests that the supernumerary rays may result from branching, but from my study of the spicules of *Astraeospongia* and *Eiffelia* this does not seem probable.

EIFFELIA GLOBOSA, new species

Plate 86, figs. 1, 1*a-b*

General form globular with truncated apex in which there is a shallow concavity about one-third the transverse diameter of the body. This outline of the form is taken from a number of compressed and flattened specimens, but it is fairly correct. The surface of the body is formed by the interlacing of large and small six-rayed spicules, which forms a lattice-work; some of the larger stellate spicules have a spread of 12 mm. from point to point of the rays in flattened specimen 30 mm. in transverse diameter; the cup of one

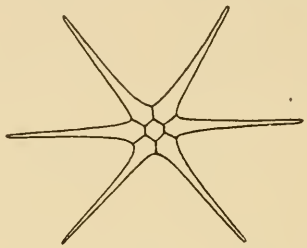


FIG. 10 (×6).—A spicule with central node and six rays.

specimen is lined with what appears to have been an integument in which small spicules similar to those of the exterior surface are imbedded. The spicules are usually flattened in the shale to such an extent as to be little more than a film without relief and show six rays, but in one specimen in which the spicules are preserved in pyrite (FeS_2) there is a central hexagonal disk and a convex base to each ray which forms the body of the spicule; the six long rays are apparently nearly round and marked by two or more longitudinal striae; a few rays indicate that they had a central canal and were not solid; the central disk has a clearly indicated protuberance at the center and in some examples it appears as though a vertical ray had been broken off and in others there is a hollow suggesting the breaking off of a portion of the disk; these appearances clearly point to the presence of one and perhaps two additional vertical rays, one on each side, projecting at right angles to the six long rays.

[1] British Fossil Sponges, Pt. II, 1888, p. 133.
[2] Text-Book Pal., Eastman Ed., 1913, p. 63.

I have not seen traces of anchoring or thread-like spicules or anchoring filaments on the 13 specimens in the collection; several specimens have a suggestion of a compact tissue or epidermis which when examined with a lens is found to be formed of minute crystals of pyrite (FeS_2) which were probably formed when the sarcode of the sponge was present.

Observations.—The spiculae of this species are apparently similar to those of the Silurian species *Astraeospongia meniscus* Roemer[1] in having six rays in one plane radiating from a central raised button-shaped disk, and indications of one or two additional vertical rays, one on each side of the central disk extending outward at right angles to the plane of the six main rays. I find a specimen of *A. meniscus* Roemer in the collections of the U. S. National Museum (Catalogue No. 36955) in which a spicule 6 mm. in diameter has a central vertical ray 1.5 mm. in length rising from the disk. The spicules of *A. meniscus* Roemer have been entirely replaced by calcite if they were originally siliceous as probably was the case.

Six-rayed microscopic spicules probably of *E. globosa* have been noted and photographed in thin sections of the Burgess shale; also four rayed, cruciform spicules of undetermined relations.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field on the Canadian Pacific Railway, British Columbia.

Sub-Order HETERACTINELLIDA Hinde

Heteractinellida Hinde, 1888, British Fossil Sponges, Pt. II, 1888, pp. 96 and 168. (Proposes name as designating a new Sub-Order equivalent to Hexactinellida Zittel.)

Dr. Hinde based this suborder on large spicules occurring in the Carboniferous limestones, which have a variable number of rays, ranging from 6 to 30, and disposed so as to form either stellate or umbrella-shaped spicules that appear to have been free or partially fused together into a skeleton.

The first genus assigned to the Heteractinellida is *Tholiasterella* Hinde, which is described as follows:[2]

Form of Sponge unknown; the skeleton consists of spicules, which bear a general resemblance to the handle and ribs of an umbrella. The handle or

[1] Sil. Fauna des West. Tennessee, 1860, p. 14, pl. I, figs. 6, 6*a-d*.

[2] British Fossil Sponges, Pt. II, 1888, p. 168.

vertical ray of the spicule supports on its summit a variable number of rays which radiate from it in a generally horizontal direction. A central disc of variable proportions is formed by the union of the bases of the horizontal rays and the upper surface of this, and the rays may be either smooth or covered with tubercles or blunted vertical spines. In some cases spicules of an irregular form are present, in addition to the normal umbrella-spicules.

The spicules of the body of the Sponge appear to have been aggregated together without definite arrangement; they seem to have been mostly free from each other, and merely held in position by the interlacing of their rays; but in some cases the rays appear to have been partially cemented together. The outer surface or dermal layer of the Sponge consisted of a framework with irregular interspaces, formed by the intervening and partial fusion of the horizontal rays of larger and smaller "umbrella" spicules, whilst the shafts of these spicules penetrated into the interior of the Sponge.

Zittel[1] places *Tholiasterella* among the genera of undetermined relations, but I think it is desirable to at least bring it with *Asteractinella* Hinde[2] and the Middle Cambrian genus *Chancelloria* under Heteractinellida as a subordinal term. The spicules of *Chancelloria* are not quite so abnormal as those of *Asteractinella*, but they apparently have the characteristics of those of *Tholiasterella* in the 6 to 9 rays on one plane with an axial ray at right angles to them.

Zittel, commenting upon Hinde's Heteractinellida, concluded that as the suborder was based on isolated spicules of undetermined relationships to the body of the sponge and hence to other known orders of the Spongiae its systematic position was in doubt; he therefore treated Heteractinellida as *incertae sedis* and said that it may perhaps best be regarded as an aberrant Hexactinellid.[3] By the discovery of practically entire specimens of *Chancelloria* showing the Tetractinellid arrangement of the spicules in the cortex Zittel's suggestion is no longer tenable. The form of the spicules distinguishes *Chancelloria* from the Tetractinellida and the structure of the spicular skeleton from the Hexactinellida. With these points taken into consideration, I think that Hinde's conclusion that a distinct subordinal group is represented by the spicules from the Carboniferous is sustained, also that *Chancelloria* exhibits characters that justify including it under a family distinct from that which would include *Tholiasterella* Hinde and *Asteractinella* Hinde.

[1] Text-book Pal. Eastman Ed., 1913, p. 62.
[2] British Fossil Sponges, Pt. II, 1888, p. 172.
[3] Text-Book Pal. Eastman Ed., 1913, p. 63.

Family CHANCELLORIDAE new family

With tough ectosome and dense choanosome. Spicules not united to form a coherent skeleton. Spicules (megascleres) typically with a central disk, six rays essentially in one plane and an axial ray; various modifications of this form occur that result in from 4 to 9 rays in one plane, and the disappearance of the axial ray in many spicules.

Genus *Chancelloria* Walcott.

CHANCELLORIA, new genus

General form elongate, tubular or finger-shaped, or broad and frondose. All of the specimens are flattened in the shale and most of them appear to have been more or less broken. Spicules distributed irregularly in the outer dermal layer (ectosome), also in an intermediate layer and an inner layer (choanosome). No microscleres have been observed. Large spicules (megascleres) umbrella-shaped, with 4 to 9 principal horizontal rays and a central disk or vertical axis with an inner axial ray and possibly in some species an outer ray; there are also marginal spicules with 2 or 3 long, slender, straight or curved rays.

Genotype.—*Chancelloria eros* Walcott.

Stratigraphic range.—*C. eros* occurs in the lower 10 feet (3. 05 m.) of the Burgess shale and central portion of the *Ogygopsis* shale of the Stephen formation, both Middle Cambrian; *C. yorkensis* is found in a bed of Middle Cambrian argillaceous shale of the York formation; *C. drusilla* in the Middle Cambrian Conasauga shales, and *C. libo* in Middle Cambrian Conasauga formation.

Geographic distribution.—*C. eros* was found at the Burgess Pass fossil quarry, in Burgess shale, on western slope of ridge connecting Wapta Peak and Mount Field, and on west slope of Mount Field 1 mile (1.6 km.) northeast of Burgess Pass above Field, also on northwest slope of Mount Stephen above Field, British Columbia; *C. yorkensis* occurs in shales in a railroad cut alongside the city gas house, York, York County, Pennsylvania; *C. drusilla* is from Livingston, Coosa Valley, Floyd County, Georgia, and *C. libo* from limestone in Murphrees Valley, Blount County, Alabama.

Observations.—The presence of a well-preserved sponge of this type is most unusual, as in the absence of a strong spicular skeleton little more than scattered spicules were to be expected. The Burgess shale specimens show the outline of the soft parts either as a dark

smooth surface with the spicules embedded in it or with a brownish or rust-colored surface resulting from the oxidation of the pyrite which has replaced the soft parts. The second species, *C. yorkensis,* is preserved only as masses of spicules on the surface of the shale that retain a little of the original outline of the sponge but the individual spicules have been largely displaced from their natural position in the wall of the sponge. The sponge wall was undoubtedly a rather firm mass of soft tissue and a strong dermal layer with the spicules arranged as in figures 1, 1*e,* 1*c,* plate 88. Completely flattened on the shale, the former tubular and frond shape of *C. eros* is indicated by the presence of a very thin layer of shale between the two walls that represent the opposite walls of the sponge when in a natural state.

The occurrence of this genus in Middle Cambrian time on both the western and eastern sides of the continent is of interest as it indicates that the genus came from the Arctic regions or else extended all around the southern shore-line of the continent.

The general form of the spicules suggests those of the Carboniferous genus *Tholiasterella* Hinde[1] in having from 5 to 9 rays with a vertical ray, but beyond this resemblance there is little in common between them.

The spicules of the genotype, *C. eros,* have from 4 to 7 simple horizontal rays and a vertical axial ray; *C. drusilla* has six or seven horizontal rays (usually seven) and a vertical axial ray, while *C. libo* has eight horizontal rays, two of which appear to rise as a bifurcation of a principal ray, the presence of an axial ray is not determinable as the concave side of the central disk is uppermost in the few specimens of the spicules in the collection. The presence of bifurcating rays is very important as it is a feature very strongly developed in the Carboniferous genus *Tholiasterella.*[2]

Of all the sponges occurring in the Burgess shale those of this genus have been the most difficult to classify. At first only fragments of the dermal layer were studied, and these showed spicules that appeared to be triaenes and referable to the Tetractinellida; later a specimen was collected that had the triaene-appearing spicules and on a worn margin 6-and 7-rayed spicules with a central disk and clearly defined structure comparable to the spicules of *Tholiasterella*[3] Hinde of the Carboniferous system of Europe in general

[1] British Fossil Sponges, Pt. II, 1888, p. 168, pls. VII and VIII.
[2] Idem, pl. VII, figs. 1 and 2.
[3] Idem, p. 168.

form but not in detail of structure. It may be that *Chancelloria* is the Cambrian representative of *Tholiasterella* and *Asteractinella*[1] Hinde, the latter being degenerate forms of the suborder.

The species referred to the genus are:

Chancelloria drusilla Walcott, Middle Cambrian (pl. 87. figs. 2, 2*a-e*)
Chancelloria eros Walcott, Middle Cambrian (pl. 86, figs. 2, 2*a-c;* pl. 88, figs. 1, 1*a-f*)
Chancelloria libo Walcott, Middle Cambrian (pl. 87, figs. 1, 1*a*)
Chancelloria yorkensis Walcott, Middle Cambrian (pl. 87, fig. 3)

CHANCELLORIA EROS, new species

Plate 86, figs. 2, 2*a-c;* pl. 88, figs. 1, 1*a-f*

General form tubular, finger-shaped or in fronds of varying outline; there are twelve of the elongate and four frond-like specimens in the collection, all of which are flattened in the shale; that they were hollow or filled with very soft tissue is indicated by a specimen in which the greatly reduced space between the walls is filled with a thin layer of shale between the dermal spicular layers of the former opposite walls.

Reticulum.—The skeletal spicules are not united to form a connected framework but occur more or less irregularly in the walls of the sponge. In specimens preserving the dermal layer intact only the outlines of the spicular rays are to be seen, the spicules being embedded in the compact skin-like layer; when the dermal layer has been partially removed, either before or after being embedded in the sediment, two of the rays of each spicule are exposed with their points extending upward (see fig. 1*e,* pl. 88), and it is only when the spicules have been displaced in relation to the dermal layer that their structure is revealed; the two exposed rays diverge at an angle of from 80 to 90 degrees, and the first impression is that they represent two actines of a triaene spicule, but displaced spicules in the outer layer (ectosome) and flat-lying spicules in the inner layer (endosome) prove that the spicules have a definite body formed of a small disk hollowed out on one side and slightly convex on the other; some show a tubercle that in one spicule appears as though it might have been the base of a vertical ray with a central canal; there are from 4 to 9 rays, each of which is truncated at its inner end where it joins the central disk, it is then expanded and fitted closely to the adjacent rays for a short distance; a clearly defined line delimits

[1] British Fossil Sponges, Pt. II, 1888, p. 172.

the inner end and sides of each ray within the disk; the base of each ray is swollen and has a shallow round pit on the upper side corresponding in appearance to the hollow on the central disk; the rays taper rapidly from where they join the body of the spicule and each one forms a slender, straight or curved acicular ray; the rays may be nearly on a plane or may curve downward into an umbrella-like form; apparently there are some two or three rayed spicules with a swollen central body, but these may be portions broken off from many-rayed spicules. The presence of a vertical or axial ray on the larger stellate spicules is not readily proven for, if present, they have been crushed down into the mud and concealed or broken off; it is the presence of an apparently broken off base in the center of the body that leads to the conclusion that a vertical ray existed; there is also a strong probability of its presence as it occurs on similar spicules in *Chancelloria drusilla*.

The central body of the spicule appears to have been embedded in the outer wall (ectosome) with its convex side towards the base and the transverse axis horizontal or nearly at right angles to the vertical axis of the sponge, two of its rays turned upward just beneath this dermal outer covering and the others were embedded in the cortex within; an inner wall of flat-lying spicules is indicated by one specimen illustrated by figure 1*f*, plate 88. Tufts of fine slender spicules occur along the upper margin that appear to be pressed down with the rays of the longer spicules.

Dimensions.—The largest specimen has a length of 95 mm., with a width as flattened on the shale of 20 mm. at its upper end and 5 mm. where broken off at the basal end. A frondlike specimen is 38 by 41 mm., and is broadly rounded at the top and almost transverse at the base. The two exposed rays of the spicules in the elongate specimen (fig. 1*c*, pl. 88) average from 2.5 to 3 mm. in length in the upper half and from 1.5 to 2 mm. in the lower part; a small-sized, six-rayed spicule, 3 mm. in diameter from the tips of the rays, has the following proportions; body of spicule 0.5 mm., central disk or node 0.25 mm., length of ray from where it joins the body to its tip 1.25 mm.; some large detached spicules have rays 10 mm. in length, but these may belong to a separate and as yet unrecognized species.

Observations.—This species differs from *C. yorkensis* in its larger and stronger spicules, and from *C. drusilla* and *C. libo* in the form of the spicules. It is the one species of the suborder Heteractinellida Hinde that has its form and structure fairly well preserved.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass; and (14s) Ogygopsis zone of the Stephen formation, about 2,300 feet (701 m.) above the Lower Cambrian and 3,540 feet (1,089 m.) below the Upper Cambrian, at the great "fossil bed" on the northwest slope of Mount Stephen, both above Field on the Canadian Pacific Railroad, British Columbia.

Seven-rayed spicules indistinguishable from those of *C. eros* occur above the Burgess shale in association with cruciform spicules referred to *Protospongia* cf. *hicksi* on the surface of a fragment of shaly limestone of the Middle Cambrian (61f) Stephen formation on Mount Field, British Columbia, Canada.

CHANCELLORIA DRUSILLA, new species

Plate 87, figs. 2, 2*a-c*

Of this species we have the casts of scattered spicules that occur in compact siliceous nodules; some show only the hollow left after the removal by solution of the siliceous spicules, and in others there is a cast of the spicule; owing to the manner of preservation some interesting details of structure are retained.

Spicules with a central disk from which six or seven rays radiate on one plane and a vertical axial ray at right angles to the other rays; the central disk is hollowed out on the upper or outer side and the inner side rises as a bulbous base for a tapering ray that may be straight or slightly curved; this ray is the handle of the umbrella-shaped spicules formed by the disk and horizontal rays. The horizontal rays taper rather rapidly from their base to a more or less extended aciculate distal end; in some spicules the transverse rays appear to be on a plane but in others they tend gently downward or inward toward the axial ray which gives the spicule an umbrella shape; casts of the central disk and bases of the rays indicate that the opposite side of the central disk was concave or hollowed out and that a spherical cavity was present on the inner end of each of the horizontal rays. (See fig. 2*a*.)

The larger spicules average 7 mm. in diameter from the tips of their rays, and smaller ones occur down to 2 mm. across.

There are many rectangular spicules of varying size with four slender rays associated with the spicules of this species which I have referred to *Protospongia fenestrata* Salter ? as it is not probable

that they belonged to the same type of sponge as *Chancelloria drusilla.*

Observations.—This species differs from *C. eros* and *C. libo* in the form and structure of the spicules, and I do not know of other species with which to compare it.

Formation and locality.—Middle Cambrian: (89x) Conasauga shales; argillaceous shale with embedded siliceous nodules, Livingston, Coosa Valley, Floyd County, Georgia.

CHANCELLORIA LIBO, new species

Plate 87, figs. 1, 1*a*

Of this species only a few spicules are known; they are on the surface of a weathered fragment of limestone and the siliceous spicule has been entirely replaced by calcite. The outer side of the central disk is concave and closely resembles that of *C. drusilla,* the inner side has not been seen; there are four strong horizontal rays radiating from the disk and two pairs of smaller rays on opposite sides of the disk that appear to be the representatives of two large rays that have bifurcated close to the central disk, the branches of which extend outward nearly parallel to each other. These spicules appear to be congeneric with those of *Chancelloria eros* and *C. libo,* and to differ from both in the arrangement of the rays.

Formation and locality.—Middle Cambrian: (89) Conasauga formation; limestone in Murphrees Valley, Blount County, Alabama.

CHANCELLORIA YORKENSIS, new species

Plate 87, fig. 3

Of this species there are two specimens indicating a similarity in outline to the elongate slender forms of *C. eros* (pl. 88, figs. 1, 1*d*) and several fragments of what were evidently pieces of the dermal layer. In all specimens the material that replaced the original cortex has been removed by solution, including the spicules (megascleres) which are now represented by their molds; these indicate that the general character and form of the spicules was essentially the same as those of *C. eros* except that most of the rays are more slender except for an occasional spicule that has rather thick, rounded curved rays. The spicules were all displaced, more or less broken and pressed down in the calcareous mud to such an extent that only the information gained by the study of the fine material representing *C. eros* enables me to recognize their form; the greater number are

represented by two rays curving from a base so as to resemble the tines of a two-tined pitchfork; these appear to be fragments of six, or more, rayed spicules that have been broken away in pairs from the central disk.

This species is not satisfactorily preserved, but as it proves the wide distribution of the genus it is given a specific name that indicates the locality where it was found.

Formation and locality.—Middle Cambrian: York formation; (48) cellar diggings, corner of Penn and North Streets, city of York, and (48d) argillaceous shales in railroad cut alongside of the Gas House, city of York, York County, Pennsylvania.

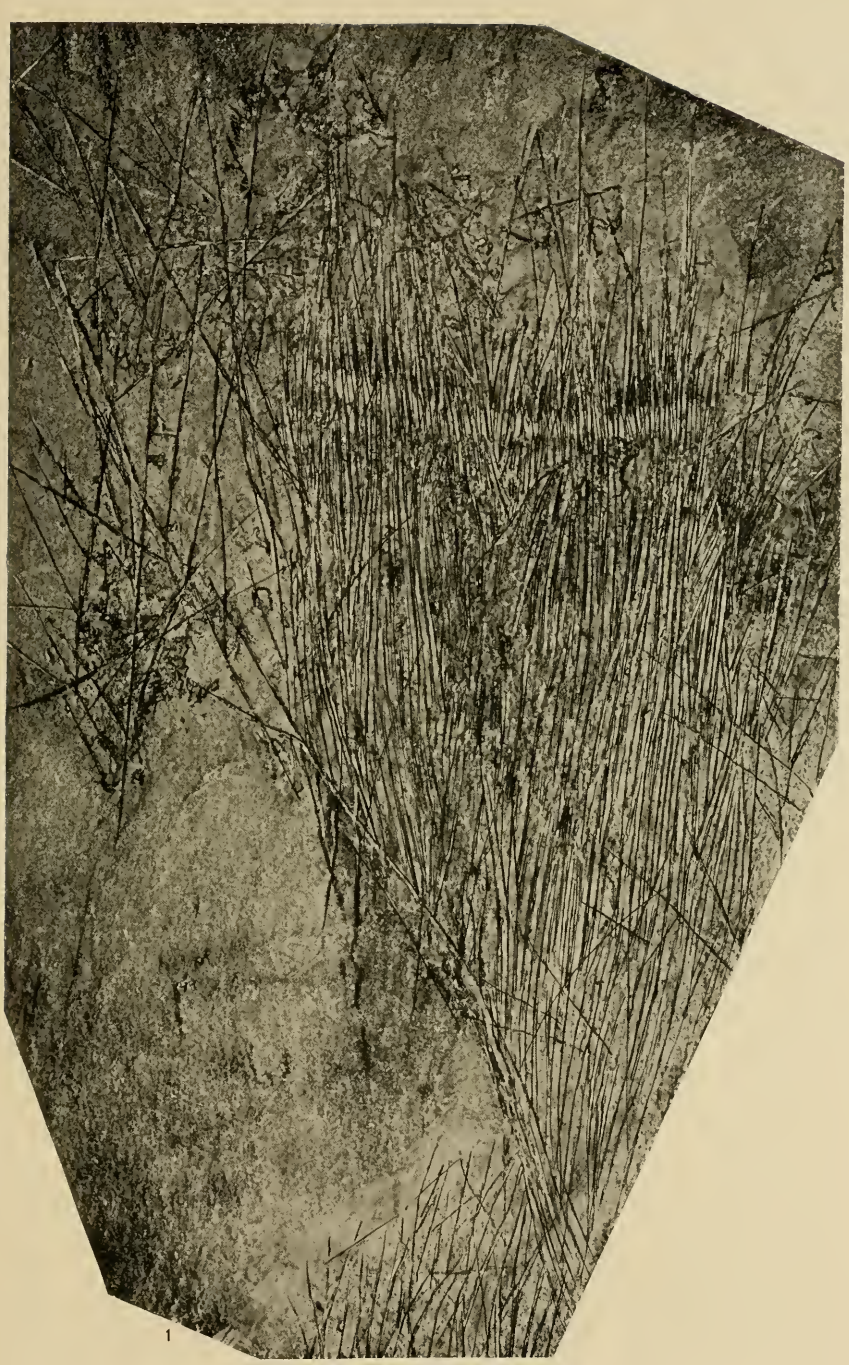
DESCRIPTION OF PLATE 60

PAGE

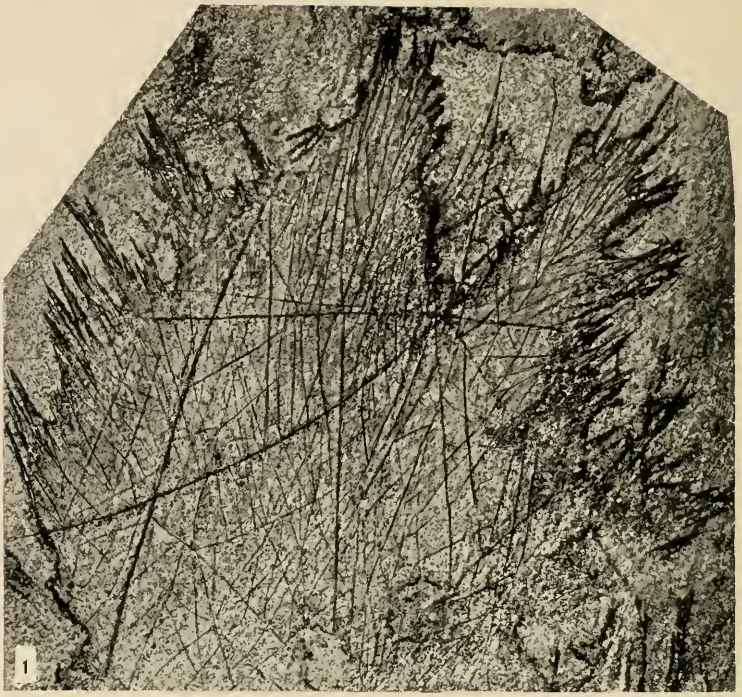
Halichondrites elissa Walcott (see pl. 61) 270

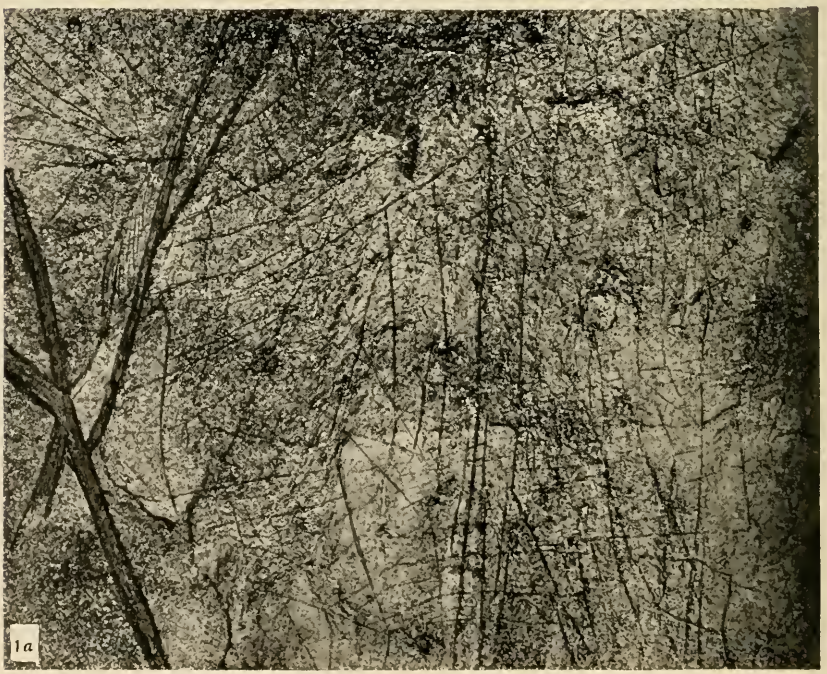
FIG. 1. (Natural size.) A sponge flattened with its skeleton more or less distorted and broken up on the surface of the shale. U. S. National Museum, Catalogue No. 66447.

The specimen represented on this plate is from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.



HALICHONDRITES ELISSA Walcott





HALICHONDRITES ELISSA Walcott

DESCRIPTION OF PLATE 61

PAGE

Halichondrites elissa Walcott (see pl. 60) 270

FIG. 1. (×6.) A mat of minute spicules of the dermal layer that were crowded out above the left upper end of the cup represented by fig. 1, pl. 60. U. S. National Museum, Catalogue No. 66447.

1*a*. (×6.) A portion of the dermal layer of the lower left side of the preceding figure enlarged to show the finer spicules.

The specimen represented by figs. 1, 1*a* is from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

DESCRIPTION OF PLATE 62

PAGE

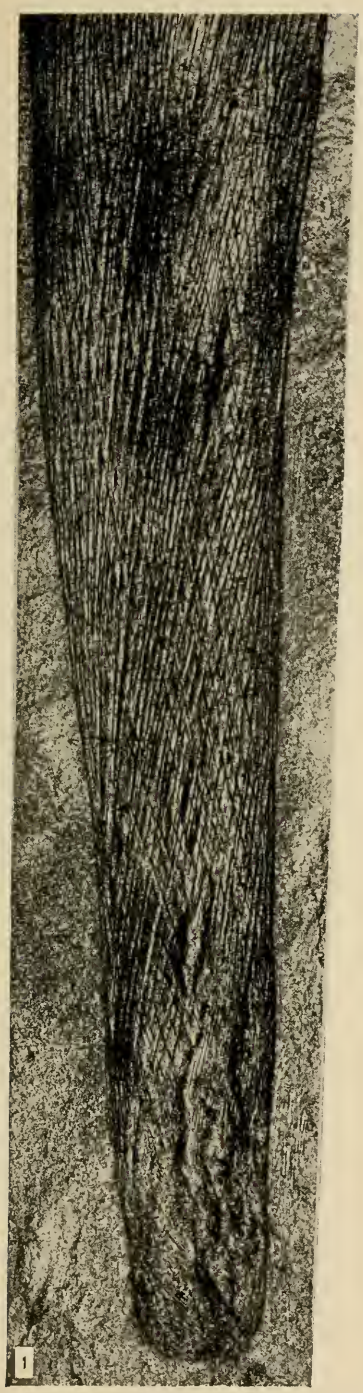
Tuponia lineata Walcott (see pls. 63 and 90) 272

FIG. 1. (×4.) Lower portion of fig. 1*b*, pl. 63, to illustrate oblique crossing of vertical spicules and base of sponge. U. S. National Museum, Catalogue No. 66448.

1*a*. (×4.) Upper end of fig. 1*b*, pl. 63, enlarged to illustrate the fine waving spicules about the margin. U. S. National Museum, Catalogue No. 66448.

1*b*. (×4.) Upper end of a specimen illustrating spicules around the margin of the osculum. U. S. National Museum, Catalogue No. 66449.

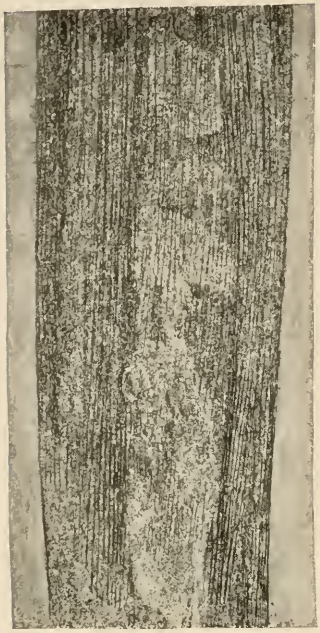
The specimens represented on this plate are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




1*a*


1*b*

TUPONIA LINEATA Walcott



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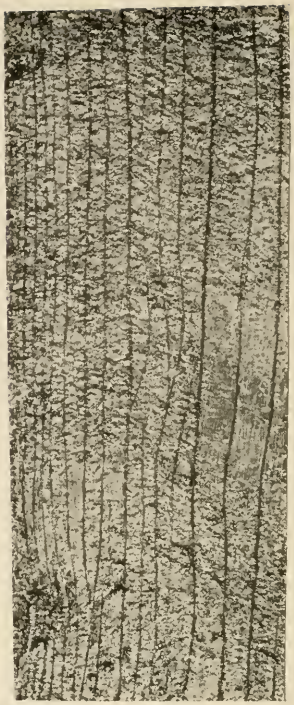

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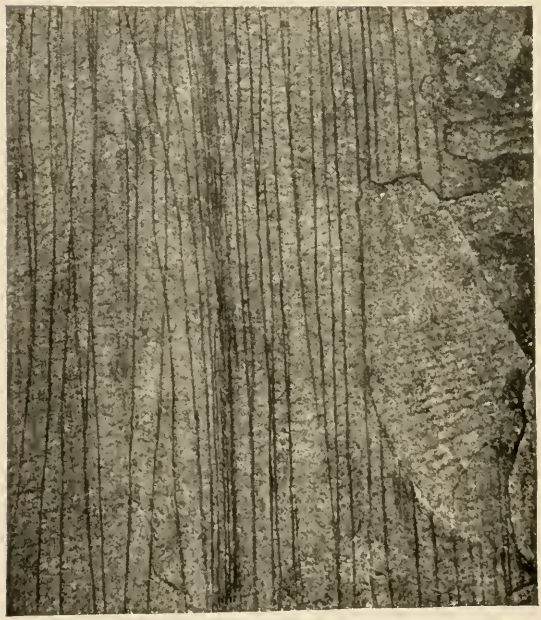


1a

1b

TUPONIA LINEATA Walcott

DESCRIPTION OF PLATE 63

PAGE

Tuponia lineata Walcott (see pls. 62 and 90) 272

FIG. 1. (× 3.) Portion of a flattened tube that appears to have had fragments of other organisms drifted into it before it was flattened in the shale. U. S. National Museum, Catalogue No. 66450.

1*a*. (× 4.) Section illustrating vertical and transverse spicules. U. S. National Museum, Catalogue No. 66451.

1*b*. (½ of natural size.) A long slender specimen flattened in the shale, showing general form and appearance of the sponge. U. S. National Museum, Catalogue No. 66448.

1*c*. (× 2.) Enlargement of a section of specimen represented by fig. 1*b* to illustrate strong and fine vertical spicules. U. S. National Museum, Catalogue No. 66452.

The specimens represented on this plate are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

DESCRIPTION OF PLATE 64

PAGE

Tuponia flexilis intermedia Walcott 276

FIG. 1. (Natural size.) Type specimen, showing flexible portion with section above resembling that of *T. lineata*. U. S. National Museum, Catalogue No. 66453.

1*a*. (× 4.) Upper portion of specimen represented by fig. 1, enlarged to illustrate tufts of spicules at upper margin of the sponge.

1*b*. (× 5.) Enlargement of the surface of the central portion of fig. 1, to illustrate the vertical strands and traces of transverse strands.

Tuponia bellilineata Walcott 274

FIG. 2. (Natural size.) View of type specimen. U. S. National Museum, Catalogue No. 66454.

2*a*. (× 6.) Vertical strands.

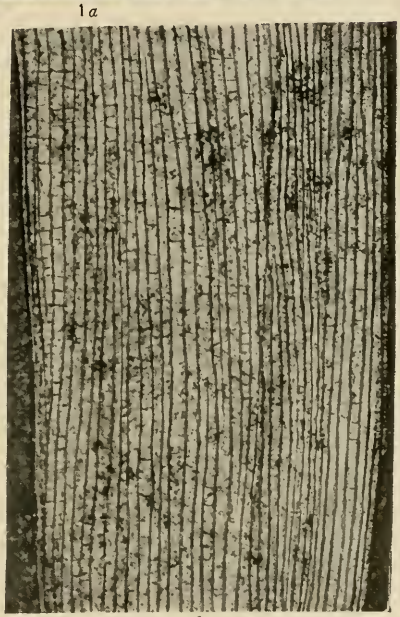
2*b*. (× 8.) Transverse and vertical strands.

The specimens represented on this plate are all from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

1

1a

2a



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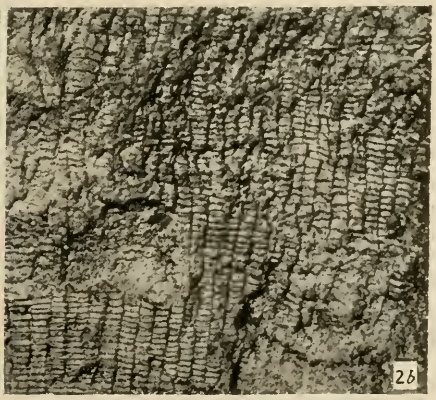
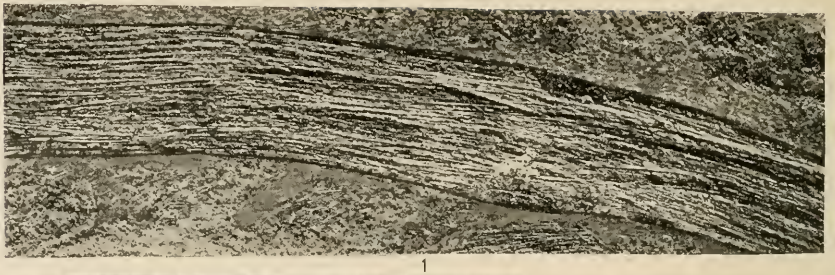
2



2b

1. Tuponia flexilis intermedia Walcott
2. Tuponia bellilineata Walcott



1

1a

1b

1d

1c

TUPCNIA FLEXILIS Walcott

DESCRIPTION OF PLATE 65

PAGE

Tuponia flexilis Walcott 275

FIG. 1. (×4.) Portion of a narrow specimen, enlarged to illustrate the long spicules. U. S. National Museum, Catalogue No. 66781.

The specimen is on a slab with *Edithella gracilens* Walcott.

1*a*. (Natural size.) Fragment of an undulating rope-like specimen associated with specimens represented by fig. 1*d*. U. S. National Museum, Catalogue No. 66455.

1*b*. (Natural size.) The upper portion of a long specimen showing indications at the summit that it was originally a cylinder. U. S. National Museum, Catalogue No. 66457.

1*c*. (Natural size.) The lower portion of the specimen represented by fig. 1*b*.

1*d*. (Natural size.) Surface of shale on which this species is matted down along with fragments of *Protospongia,* etc., and associated with specimen represented by fig. 1*a*. U. S. National Museum, Catalogue No. 66456.

The specimens represented on this plate are all from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

DESCRIPTION OF PLATE 66

PAGE

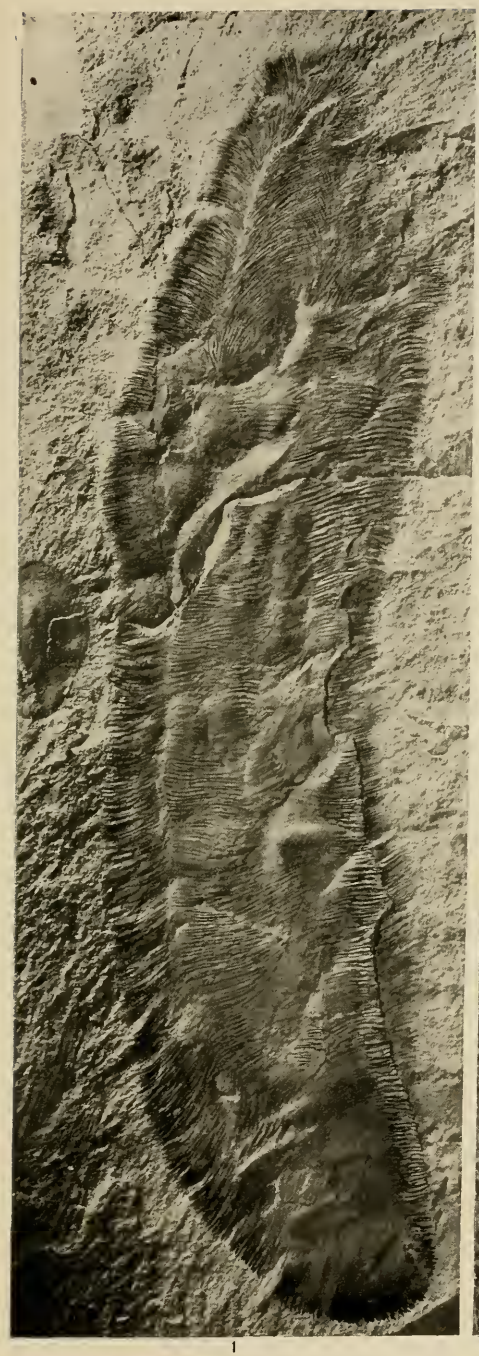
Wapkia grandis Walcott (see pls. 67 and 68) 279

FIG. 1. (Natural size.) A slender specimen, flattened on the shale. On the right side the upper wall is exfoliated so as to disclose portions of the opposite wall. For detailed structure see enlargement of the upper portion of this specimen on pl. 67. U. S. National Museum, Catalogue No. 66458.

2. (×4.) Enlargement of the surface of a specimen to illustrate the strong vertical spicules, transverse spicular strands and mat of fine transverse spicules. U. S. National Museum, Catalogue No. 66459.

3. (×6.) Enlargement of the surface to illustrate the diagonal spaces formed by the crossing of the spicular strands. U. S. National Museum, Catalogue No. 66460.

The specimens represented on this plate are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.



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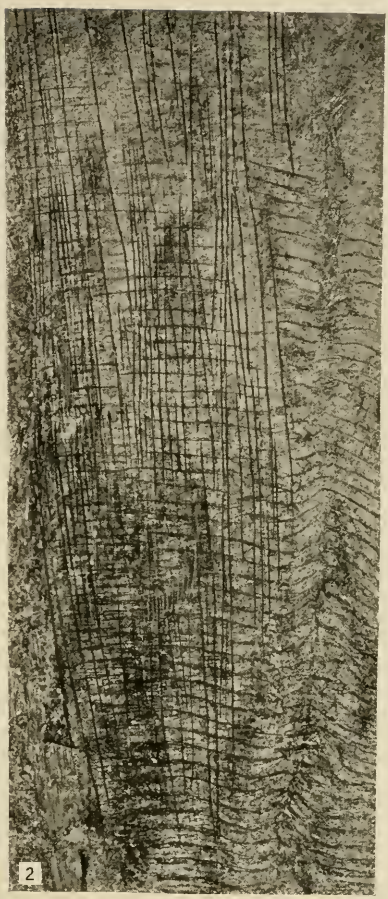

3

WAPKIA GRANDIS Walcott

WAPKIA GRANDIS Walcott

DESCRIPTION OF PLATE 67

PAGE

Wapkia grandis Walcott (see pls. 66, 68) 279

FIG. 1. (×4.) Enlargement of upper portion of fig. 1, pl. 66, to illustrate the vertical strands that curve outward, the transverse slightly arched strands and the mat of fine transverse spicules. U. S. National Museum, Catalogue No. 66458.

From locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

DESCRIPTION OF PLATE 68

PAGE

Wapkia grandis Walcott (see pls. 66, 67) 279

FIG. 1. (×4.) A portion of the lower end of fig. 1, pl. 66, enlarged to show the imbricating lamellæ near the right outer margin of the specimen. U. S. National Museum, Catalogue No. 66458.

2. (Natural size.) Specimen showing transverse strands arranged along several vertical axes. U. S. National Museum, Catalogue No. 66461.

2*a*. (×2.) Enlargement of the upper right-hand section of the specimen illustrated by fig. 2, to exhibit the transverse strands and mat of fine transverse spicules.

The specimens represented on this plate are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

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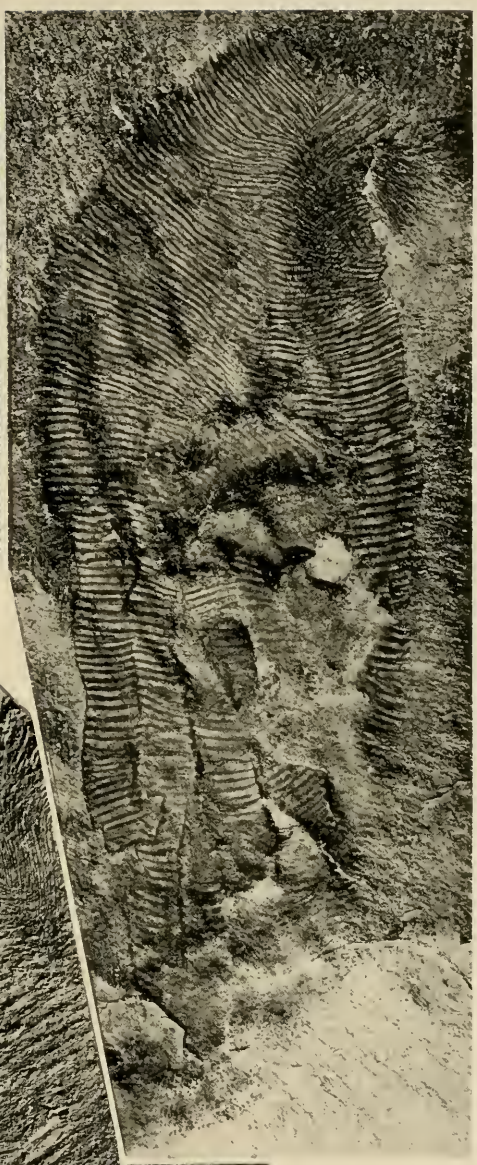

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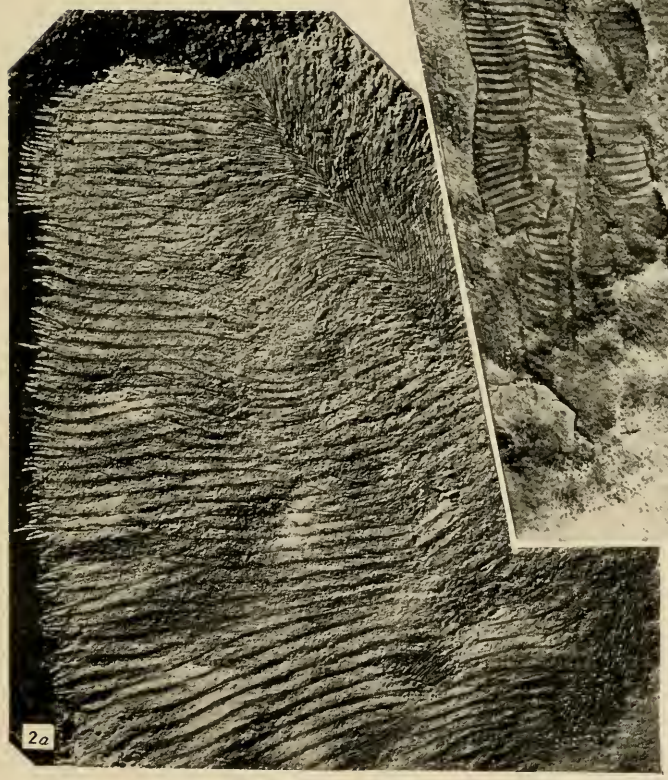
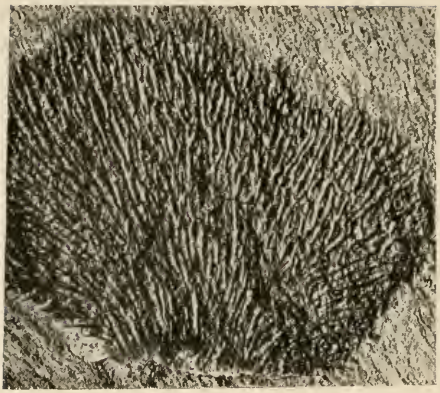


2a

WAPKIA GRANDIS Walcott



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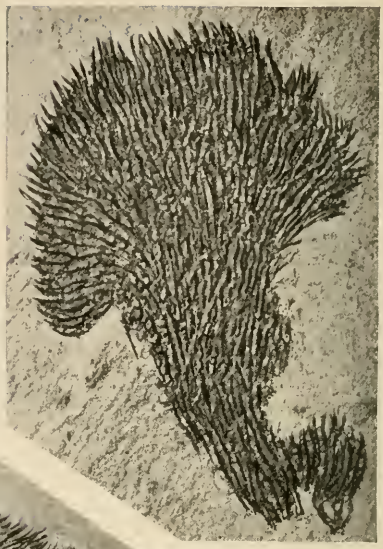
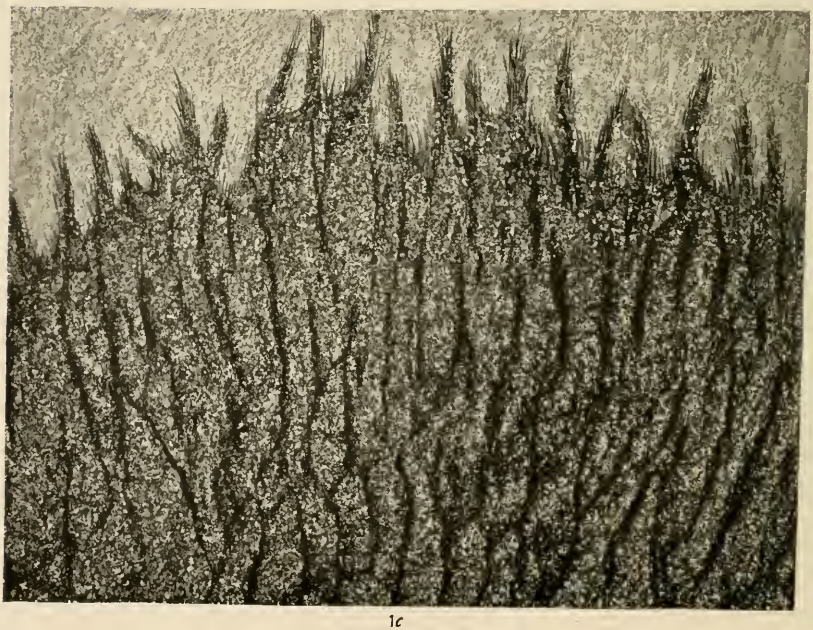


1*a*

1*b*



1*c*

HAZELIA PALMATA Walcott

DESCRIPTION OF PLATE 69

PAGE

Hazelia palmata Walcott (see pl. 76, fig. 2) 282

FIG. 1. (×2.) A transversely oval frond. U. S. National Museum, Catalogue No. 66462.

1*a*. (×2.) Frond showing arrangement of strands. U. S. National Museum, Catalogue No. 66463.

1*b*. (Natural size.) A flattened frond with irregular growth of skeletal strands of spicules. U. S. National Museum, Catalogue No. 66464.

1*c*. (×8.) Margin of frond represented by fig. 1*a* with ends of spicular skeletal strands.

The specimens represented on this plate are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

DESCRIPTION OF PLATE 70

PAGE

Hazelia delicatula Walcott (see pl. 90) 284

FIG. 1. (Natural size.) A small branched specimen. U. S. National Museum, Catalogue No. 66465.

1*a*. (×4.) Delicate vertical undulating skeletal strands. U. S. National Museum, Catalogue No. 66466.

1*b*. (×4.) Surface with obscure skeletal strands and fine dermal spicules. U. S. National Museum, Catalogue No. 66467.

1*c*. (×6.) Surface of dermal layer with spicules and only a slight trace of skeletal strands. From specimen represented by fig. 1*d*. U. S. National Museum, Catalogue No. 66468.

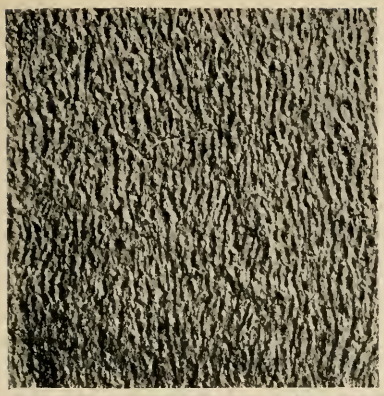
1*d*. (Natural size.) An upright elongate rounded frond broken off at the base. U. S. National Museum, Catalogue No. 66468.

1*e*. (Natural size.) An unusually large frond. U. S. National Museum, Catalogue No. 66469.

1*f*. (×6.) Enlargement of the surface of specimen represented by fig. 1*e*.

1*g*. (Natural size.) Portion of a frond with thickened margins. U. S. National Museum, Catalogue No. 66470.

All of the specimens represented on this plate are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.



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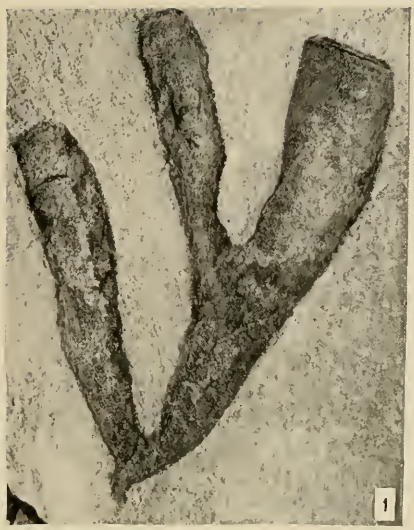

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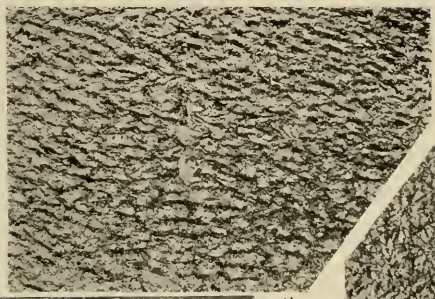
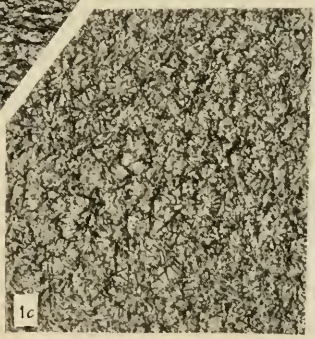


1b



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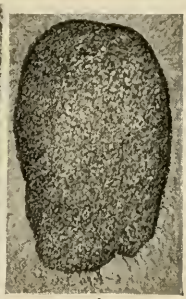

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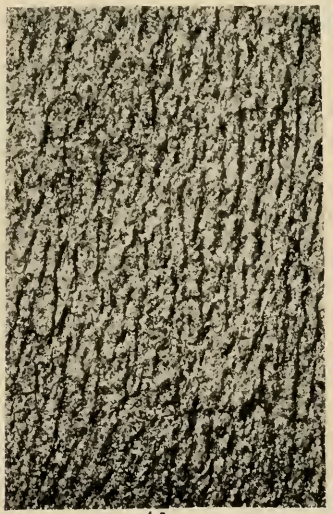

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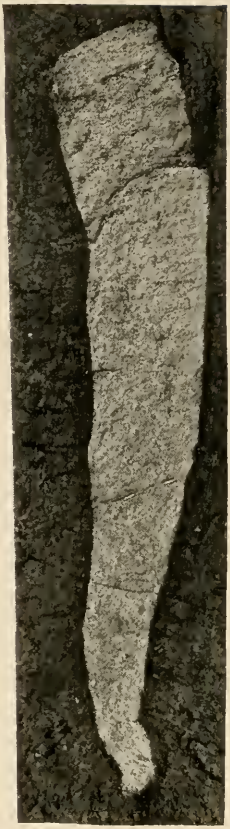
HAZELIA DELICATULA Walcott

1



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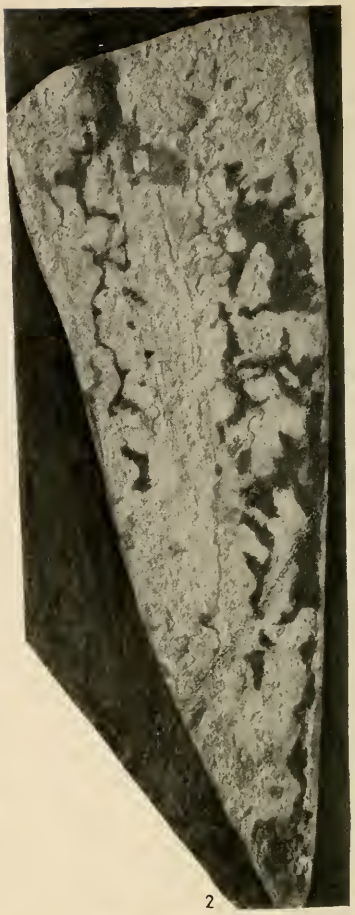

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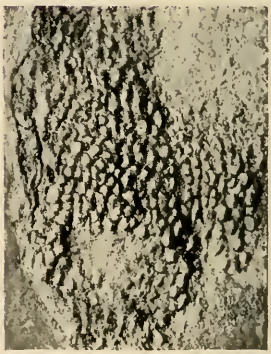


3b

1. Hazelia obscura Walcott
2. Hazelia grandis Walcott
3. Hazelia nodulifera Walcott

DESCRIPTION OF PLATE 71

PAGE

Hazelia obscura Walcott 287

FIG. 1. (Natural size.) A slender elongate simple form. U. S. National Museum, Catalogue No. 66471.

1*a*. (Natural size.) A slender simple form with very dense epidermal layer. U. S. National Museum, Catalogue No. 66472.

Hazelia ? grandis Walcott..... 285

FIG. 2. (7 mm. shorter than natural size.) The dark places on the specimen represent the mineralized wall of the sponge; traces of the reticulate skeletal structure are to be seen in the impression left by the wall of the sponge where it is flecked off in the central portion. U. S. National Museum, Catalogue No. 66473.

The specimen represented by fig. 2 is from locality 14s, Middle Cambrian: *Ogygopsis* zone of the Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian and 3,540 feet (1,089 m.) below the Upper Cambrian in the *Ogygopsis* zone of the Stephen formation, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad, British Columbia.

Hazelia nodulifera Walcott..... 287

FIG. 3. (Natural size.) A small upright frond attached to the valve of a brachiopod, *Nisusia alberta* Walcott. U. S. National Museum, Catalogue No. 66474.

3*a*. (× 4.) Enlargement of the specimen represented by fig. 3 to illustrate nodose surface.

3*b*. (× 3.) Fragment of a frond with strong nodose surface. U. S. National Museum, Catalogue No. 66475.

All of the specimens represented on this plate except fig. 2 are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

DESCRIPTION OF PLATE 72

PAGE

Sentinelia draco Walcott 290

FIG. 1. (Natural size.) Type specimen which has suffered much from compression and weathering on surface of a shaly limestone. U. S. National Museum, Catalogue No. 66477.

From locality 58m, Middle Cambrian: Stephen formation; about 1,000 feet (305 m.) above the top of the Lower Cambrian in bluish black and gray limestone (138 feet, 42.6 m.) of the Stephen formation, Castle Mountain section; northeast slope of Castle Mountain, facing amphitheater, north of Canadian Pacific Railway, Alberta, Canada.

1*a*. (Natural size.) Specimen tentatively referred to this species. U. S. National Museum, Catalogue No. 66478.

From locality 3t, Middle Cambrian: Wheeler formation; about 1,700 feet (518.2 m.) above the Lower Cambrian and 2,700 feet (823 m.) below the Upper Cambrian in the shaly limestones and calcareous shales of the Wheeler formation, in the eastern part of Wheeler Amphitheater, east of Antelope Springs, House Range, Millard County, Utah.

Corralio undulata Walcott 288

FIG. 2. (Natural size.) A flattened specimen preserving undulations of growth, vertical strands of the skeletal structure, and faint indications of the fine transverse strands; the fine slender acerate spicules of the strands and interspaces are not sufficiently clear to photograph. U. S. National Museum, Catalogue No. 66479. (35k.)

2*a*. (Natural size.) A frond illustrating the spicular strands more clearly than fig. 2. U. S. National Museum, Catalogue No. 66480. (35k.)

Hazelia conferta Walcott 283

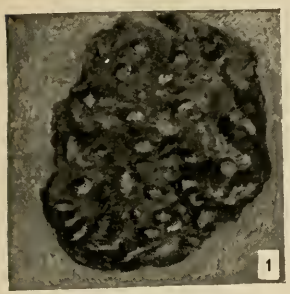
FIG. 3. (Natural size.) View of type specimen illustrating compression of a relatively soft sponge. The pressing out of the gelatinous tissue from beneath the dermal membrane is well shown at the left side and towards the lower end. U. S. National Museum, Catalogue No. 66476.

The specimens represented by figs. 2, 2*a*, and 3 are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

Choia carteri Walcott (see pls. 73 and 75) 292

FIG. 4. (×6.) Fragment of specimen preserving the thatch of fine spicules with some of the long, larger spicules. U. S. National Museum, Catalogue No. 66481.

From locality 61j, Middle Cambrian: Stephen formation; yellow weathering band of calcareo-argillaceous shale; west slope of Mt. Field, near Burgess Pass ridge, about 3,000 feet (914.9 m.) above Field on Canadian Pacific Railway, British Columbia.



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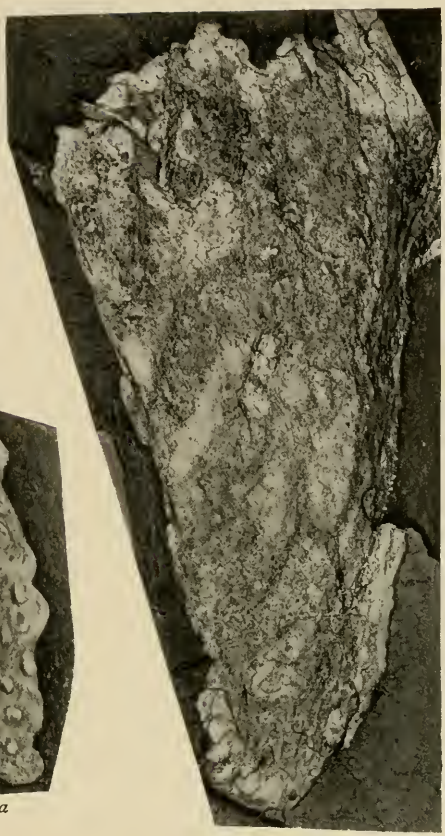

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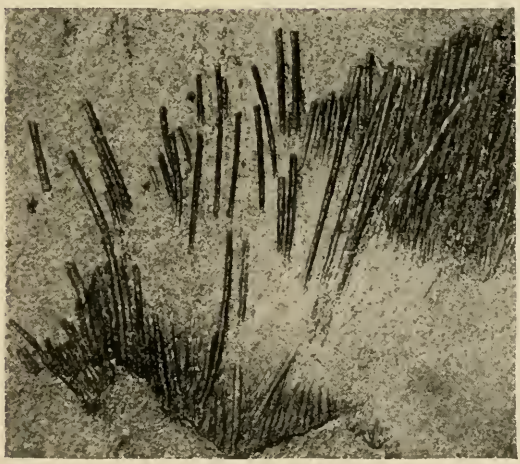
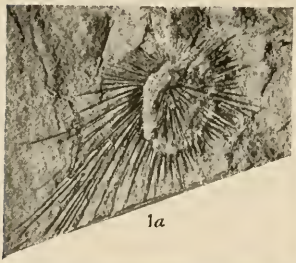


4

1. Sentinelia draco Walcott
2. Corralia undulata Walcott
3. Hazelia conferta Walcott
4. Choia carteri Walcott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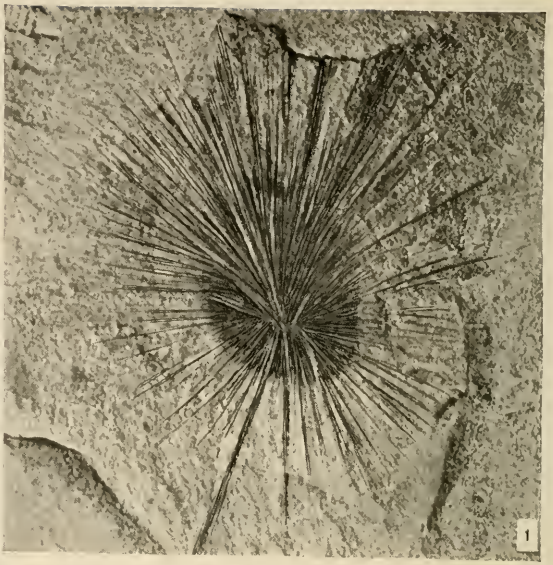
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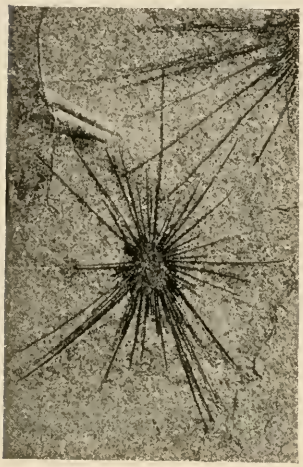
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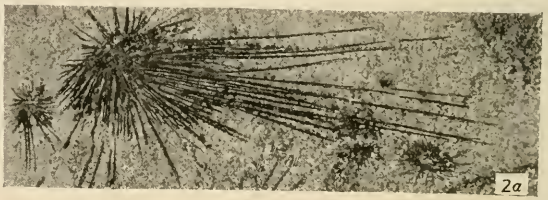
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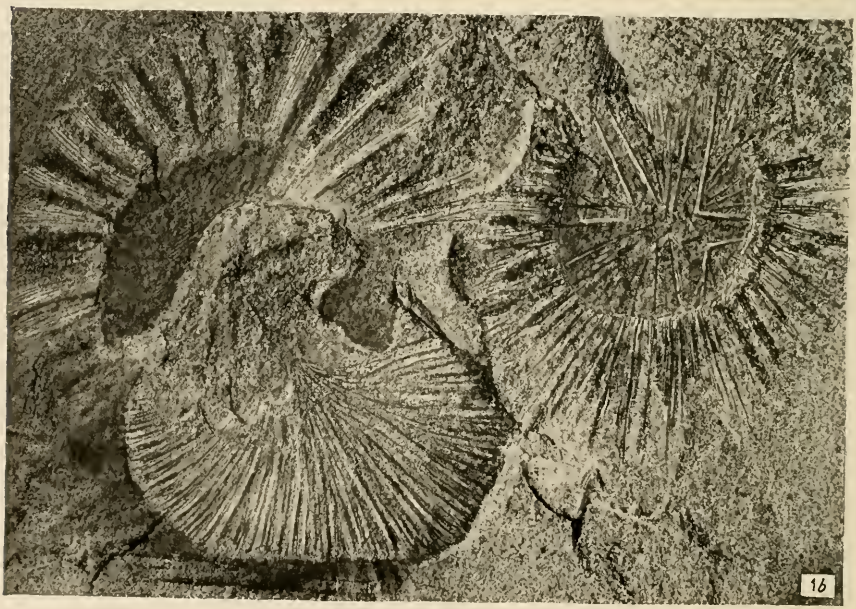

1b

1. Choia carteri Walcott
2. Choia ridleyi Walcott

DESCRIPTION OF PLATE 73

PAGE

Choia carteri Walcott (see pls. 72 and 75) 292

FIG. 1. (× 2.) A thoroughly flattened specimen with unusually well-preserved long spicules. The lower side of disk is indicated by the mat of fine spicules over the larger spicules. U. S. National Museum, Catalogue No. 66482.

1*a*. (× 3.) A broken specimen showing a portion of the convex lower side and radiating from beneath it the strong long spicules of the upper side of the sponge. U. S. National Museum, Catalogue No. 66483.

1*b*. (× 3.) Three injured specimens, two showing the upper side and one (×) the fine spicules of the lower side. U. S. National Museum, Catalogue No. 66484.

Choia ridleyi Walcott (see pl. 74, figs. 1, 1*a*) 294

FIGS. 2, 2*a*. (× 4.) Disks illustrating the long spicules of the upper side. U. S. National Museum, Catalogue No. 66486.

The specimens represented on this plate are all from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

DESCRIPTION OF PLATE 74

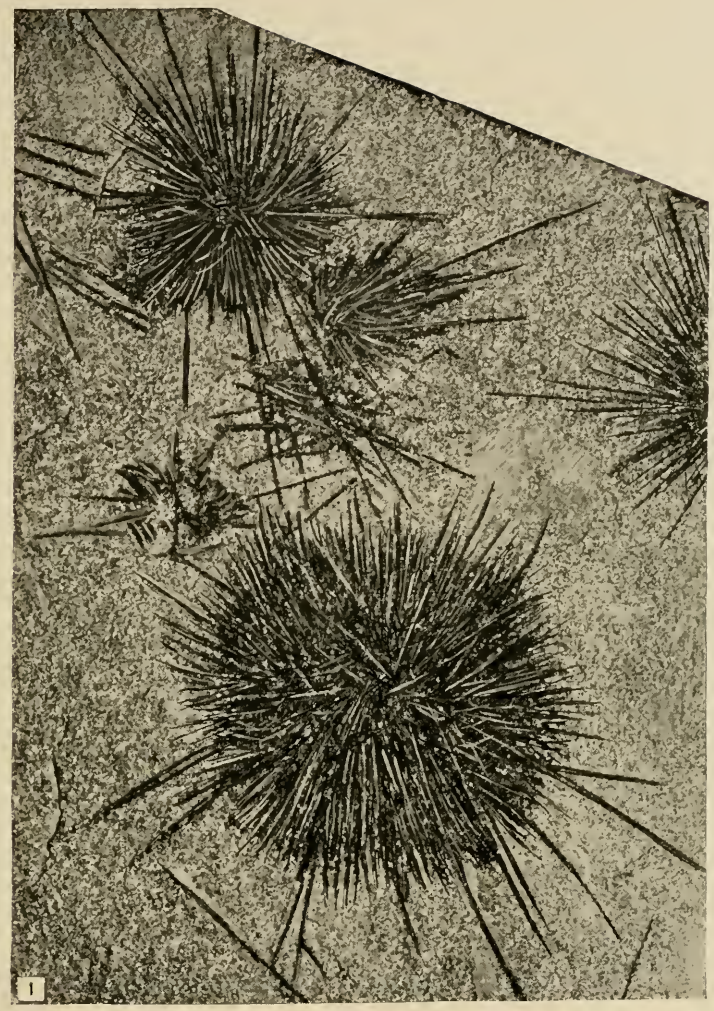
PAGE

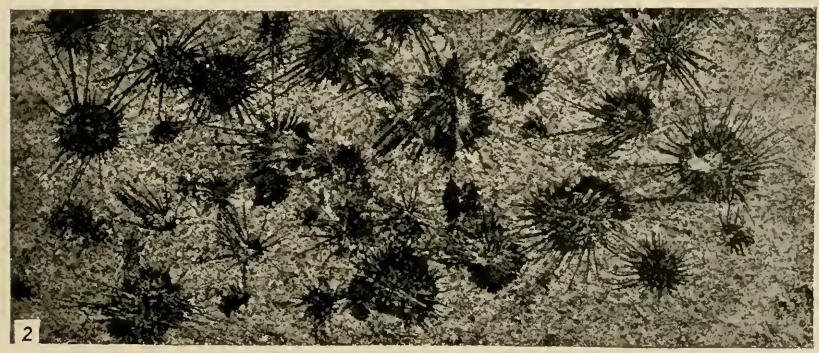
Choia ridleyi Walcott (see pl. 73, figs. 2, 2*a*) 294

FIG. 1. (×8.) Enlargement of some of the disks on the specimen represented by fig. 1*a*.

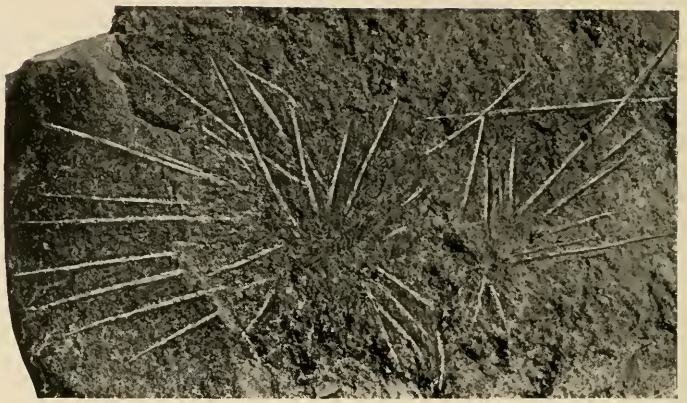
1*a*. (×2.) A group of disks on a fragment of shale. U. S. National Museum, Catalogue No. 66487.

The specimen represented on this plate is from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.





CHOIA RIDLEYI Walcott



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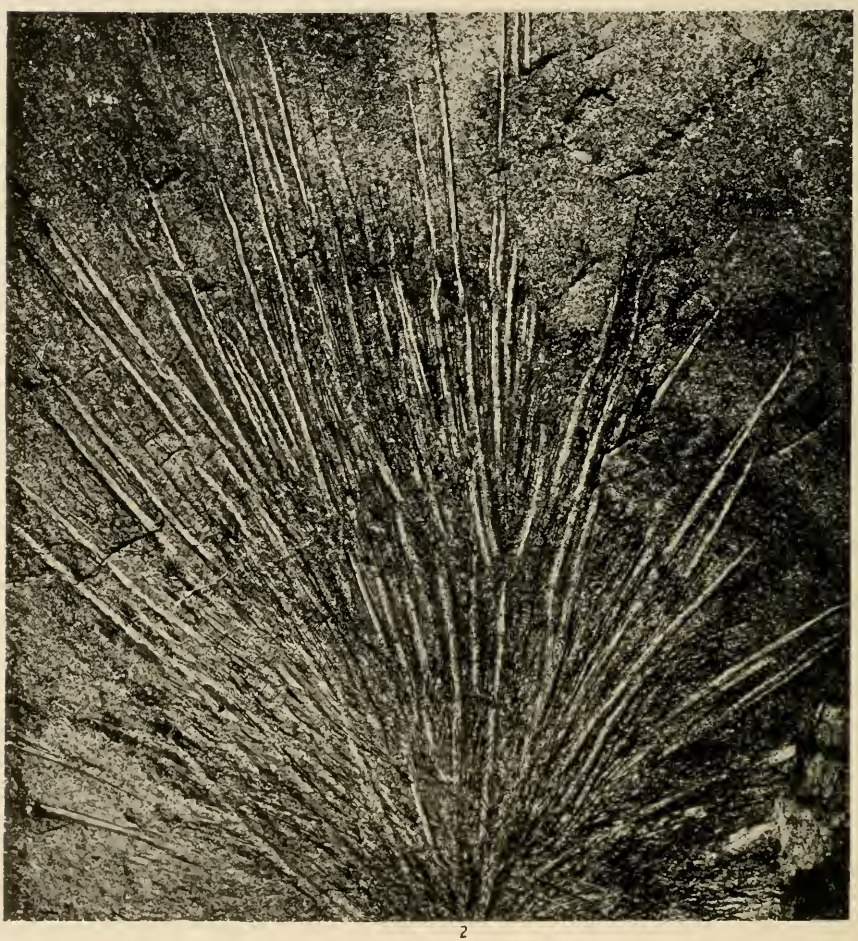


2

1. Chola utahensis Walcott
2. Chola carteri Walcott

DESCRIPTION OF PLATE 75

PAGE

Choia utahensis Walcott 295

FIG. 1. (Natural size.) Weathered specimen on the surface of shaly limestone. The fine spicules are nearly all gone, and the large ones much damaged. U. S. National Museum, Catalogue No. 66488.

From locality 3y, Middle Cambrian: about 2,150 feet (655.3 m.) above the Lower Cambrian and 2,250 feet (685.8 m.) below the Upper Cambrian in the shaly limestones forming 1d of the Marjum limestone, 2.5 miles (4 km.) east of Antelope Springs in ridge east of Wheeler Amphitheater, House Range, Millard County, Utah.

Choia carteri Walcott (see pls. 72 and 73) 292

FIG. 2. (×6.) Lower side of a specimen with many short irregularly arranged spicules matted down on the radiating spicules. U. S. National Museum, Catalogue No. 66485.

From locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

DESCRIPTION OF PLATE 76

PAGE

Choia hindei (Dawson) 295

FIG. 1. (Natural size.) Edge of a large disk with large radiating spicules. U. S. National Museum, Catalogue No. 66489.

1*a*. (×6.) Enlargement of a portion of the disk with fine spicules. U. S. National Museum, Catalogue No. 66490.

The specimens represented by figs. 1, 1*a* are from locality 392g, Middle ? Cambrian (probably between the Middle and Upper Cambrian): Black shales at Little Metis, province of Quebec, Canada.

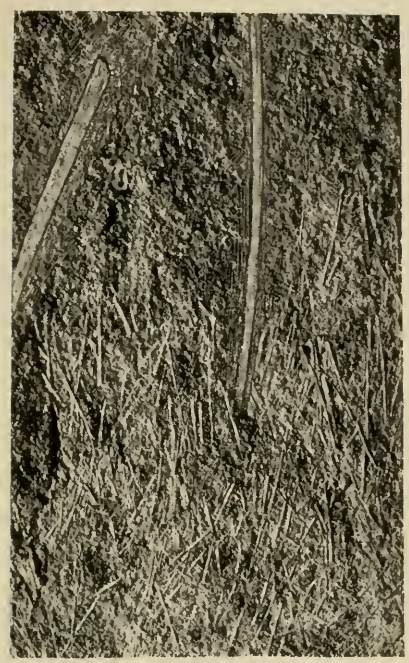
Hazelia palmata Walcott (see pl. 69) 282

FIG. 2. (×4.) A small frond with irregular and obliquely crossed skeletal strands of spicules. U. S. National Museum, Catalogue No. 66491. (35k.)

Hamptonia bowerbanki Walcott (see pls. 77, 78) 297

FIG. 3. (Natural size.) A small specimen. U. S. National Museum, Catalogue No. 66492.

The specimens represented by figs. 2 and 3 are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.



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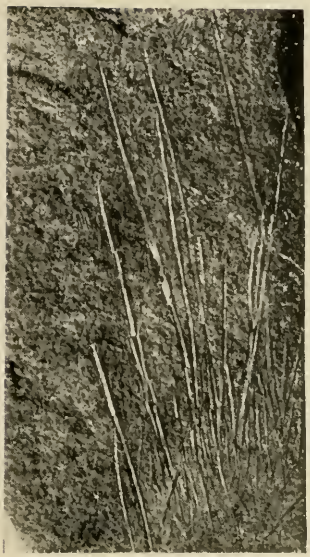

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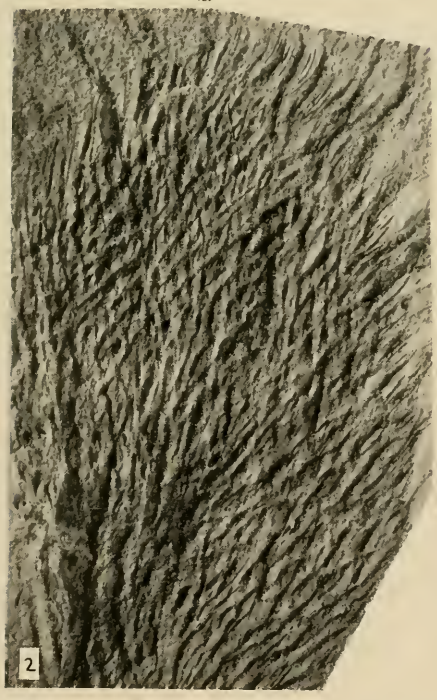


2

3

1. Chola hindei (Dawson)
2. Hazelia palmata Walcott
3. Hamptonia bowerbanki Walcott

HAMPTONIA BOWERBANKI Walcott

DESCRIPTION OF PLATE 77

Hamptonia bowerbanki Walcott (see pls. 76 and 78)..... 297

FIG. 1. (×6.) Enlargement of a portion of the surface of specimen represented by fig. 1, pl. 78, to illustrate spicules.

From locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

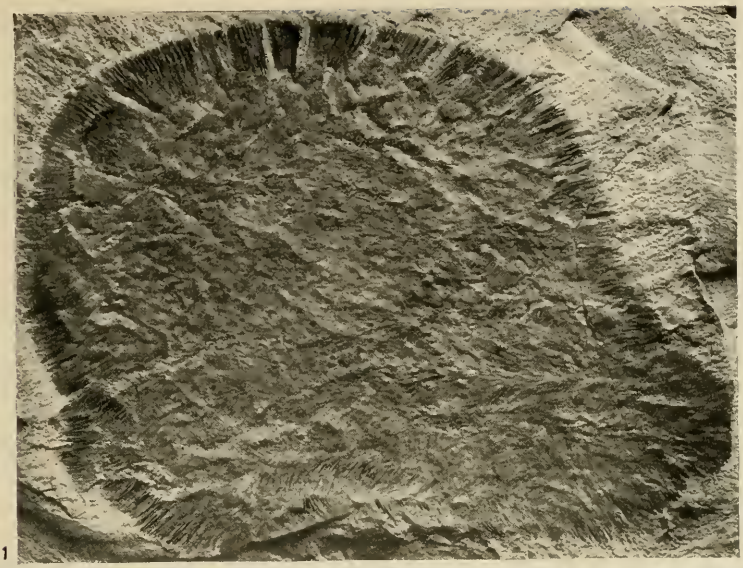
DESCRIPTION OF PLATE 78

Hamptonia bowerbanki Walcott (see pls. 76, 77) 297

FIG. 1. (Reduced to one-half size.) Outline of a large sponge 200 mm. in its greatest diameter. U. S. National Museum, Catalogue No. 66493.

1*a*. (×6.) Portion of the spicular surface of the outer portion of a large sponge to illustrate marginal fringe of spicules. U. S. National Museum, Catalogue No. 66494.

The specimens represented on this plate are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.



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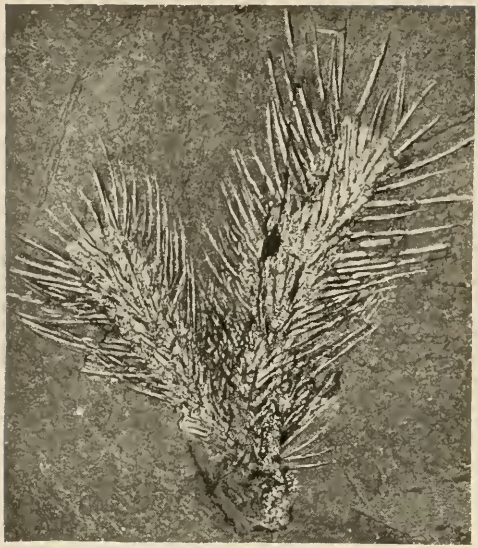
1a

HAMPTONIA BOWERBANKI Walcott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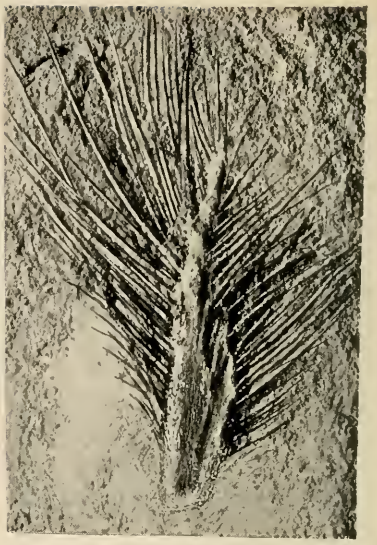
1a


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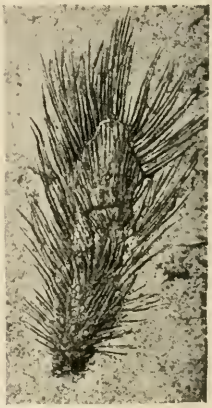
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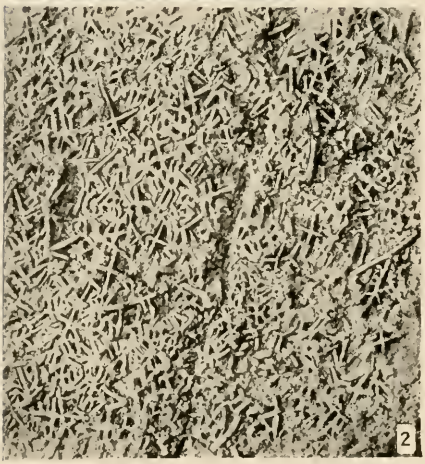
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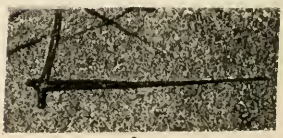
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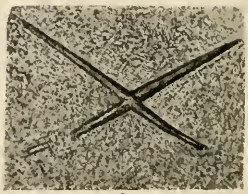

2b


2c

1. Pirania muricata Walcott
2. Protospongia erixo Walcott

DESCRIPTION OF PLATE 79

PAGE

Pirania muricata Walcott..... 298

FIG. 1. (×2.) A branching specimen flattened in the shale. U. S. National Museum, Catalogue No. 66495.

1*a*. (×3.) Specimen split longitudinally so as to show interior tube and walls. U. S. National Museum, Catalogue No. 66496.

1*b*. (×3.) A broken specimen illustrating the exterior layer of the body. U. S. National Museum, Catalogue No. 66497.

1*c*. (×2.) A fragment of the outer wall with a few long spicules attached to it. The plate-headed spicule is shown on the lower margin. U. S. National Museum, Catalogue No. 66498.

The specimens represented by figs. 1, 1*a-c* are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

1*d*. (×2.) A small specimen with center crushed in and spicules crowded toward the top. U. S. National Museum, Catalogue No. 66499.

1*e*. (×2.) A specimen with spicules radiating from all portions of the surface. This may be a variety of *Pirania muricata*. U. S. National Museum, Catalogue No. 66500.

The specimens represented by figs. 1*d* and 1*e* are from locality 14s, Middle Cambrian: *Ogygopsis* zone of the Stephen formation; about 2,300 (701 m.) above the Lower Cambrian and 3,540 feet (1,089 m.) below the Upper Cambrian in the *Ogygopsis* zone of the Stephen formation, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad, British Columbia.

Protospongia crixo, new species..... 353

FIG. 2. (×3.) Scattered and weathered spicules on surface of limestone without any mesh structure. U. S. National Museum, Catalogue No. 15309.

2*a*, 2*b*, 2*c*. (×3.) Single spicules weathered out on surface of limestone; these show variation in form, also the manner of the union of the rays at the center. U. S. National Museum, Catalogue No. 15309.

The spicules of this species resemble those of *P. hicksi* but differ in the manner of the union of the rays at the center and in the more rounded rays. Fig. 2 is composed of a great mass of small spicules with a few larger ones; there is no evidence of the mesh structure of the wall, but it was probably similar to that of other species of the genus.

The specimens represented by figs. 2, 2*a-c* are from locality 55a, Middle Cambrian: Shaly limestone at top of Eldorado limestone, east slope of Prospect Mountain in New York Canyon, Eureka Mining District, Eureka County, Nevada.

DESCRIPTION OF PLATE 80

PAGE

Protospongia fenestrata Salter..... 304

FIG. 1. (×2.) Large, slender spicules that may have belonged to an anchoring rope. U. S. National Museum, Catalogue No. 18377.

1*a*, 1*b*. (×3.) Scattered cruciform spicules on surface of black shale. U. S. National Museum, Catalogue No. 18377.

The specimens represented by figs. 1, 1*a-b* are from locality 318h, Middle Cambrian: Shales in the Menevian at St. Davids, South Wales.

2. (×2.) Group of small spicules that have the same characters of those of fig. 1*a*. U. S. National Museum, Catalogue No. 66501.

From locality 5g, Middle Cambrian: Spence shale; 100 feet (30.5 m.) above Brigham formation; dark argillaceous shales and blue black calcareous shales, 155 feet (30.5 m.) above Brigham formation; dark argillaceous shales and blue black calcareous shales, 155 feet (47.2 km.), forming 4a of typewritten Malad section, Two Mile Canyon, 3 miles (4.8 km.) southeast of Malad, Oneida County, Idaho.

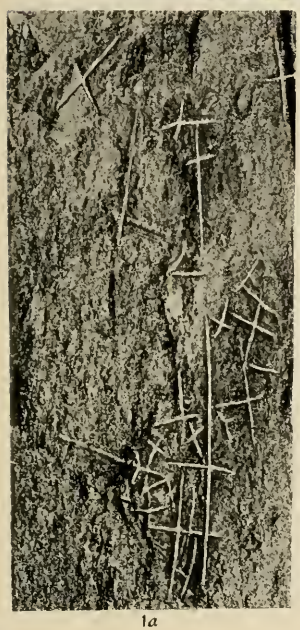
Protospongia hicksi Hinde..... 307

FIG. 3. (Natural size.) Portion of the spicular mesh of the sponge wall formed of the large primary and the secondary and tertiary cruciform spicules. U. S. National Museum, Catalogue No. 66502.

3*a*. (×2.) Enlargement of the specimen represented by fig. 3.

3*b*. (×2.) Portion of the wall of this species matted down on fragments of *Tuponia flexilis*. U. S. National Museum, Catalogue No. 66456.

The specimens represented by figs. 3, 3*a* are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field on the Canadian Pacific Railway, British Columbia.



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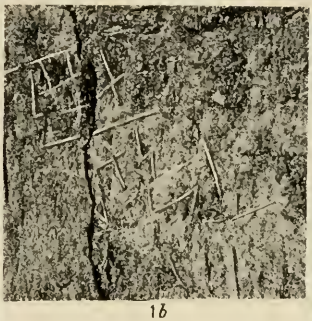

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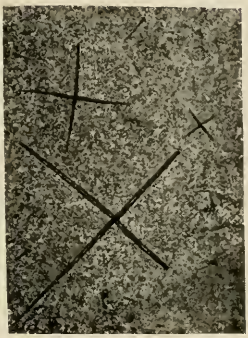

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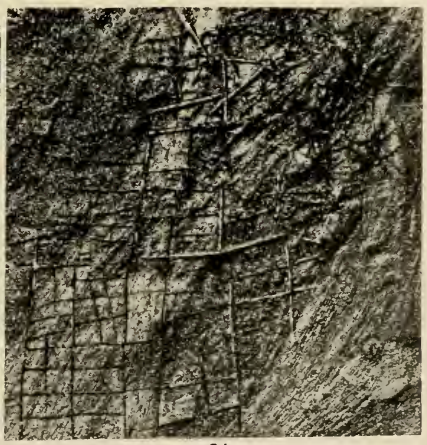
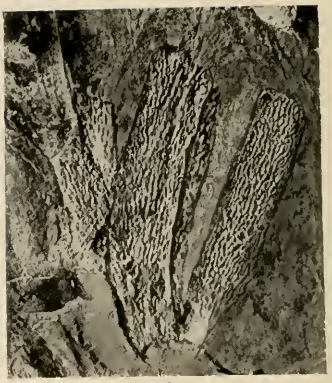


3b

1, 2. Protospongia fenestrata Walcott
3. Protospongia hicksi Walcott

1



2

1c

1a

2b

2a

1b

1 Diagoniella hindei Walcott
2. Vauxia dignata Walcott

DESCRIPTION OF PLATE 81

PAGE

Diagoniella hindei Walcott..... 310

FIGS. 1, 1*a*. (×3.) Enlargement of two of the specimens shown on fig. 1*c*.

1*b*. (×4.) Enlargement of a specimen preserving some of the cruciform spicules. U. S. National Museum, Catalogue No. 66504.

1*c*. (Natural size.) Three specimens on a small piece of shale. U. S. National Museum, Catalogue No. 66503.

Vauxia dignata Walcott..... 321

FIG. 2. (Natural size.) A specimen with two main branches and traces of five others. U. S. National Museum, Catalogue No. 66505.

2*a*. (×4.) Ridged surface of specimen represented by right-hand branch of fig. 2.

2*c*. (×6.) Fragment of a branch preserving rough outer surface, also where the latter is removed the outline of the irregular latticed skeleton. U. S. National Museum, Catalogue No. 66506.

The specimens represented on this plate are all from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field on the Canadian Pacific Railway, British Columbia.

DESCRIPTION OF PLATE 82

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Vauxia bellula Walcott 320

FIG. 1. (Natural size.) A long slender tube illustrating typical form of the species when flattened on the shale. U. S. National Museum, Catalogue No. 66507.

1*a*. (Natural size.) A slender tube with the epidermal layer removed so as to show the skeletal layer of spicules. U. S. National Museum, Catalogue No. 66508.

1*b*. (×6.) Enlargement of the surface of fig. 1*a* to illustrate the mesh-like structure of the skeletal layer and the close union of the spicules by the cementing of the points of the opposing rays and apparent blending of the canals of the opposing rays.

Vauxia gracilenta (see pl. 83 and text fig. 9) 318

FIG. 2. (×3.) A distorted and somewhat macerated fragment of a branching sponge. U. S. National Museum, Catalogue No. 66509.

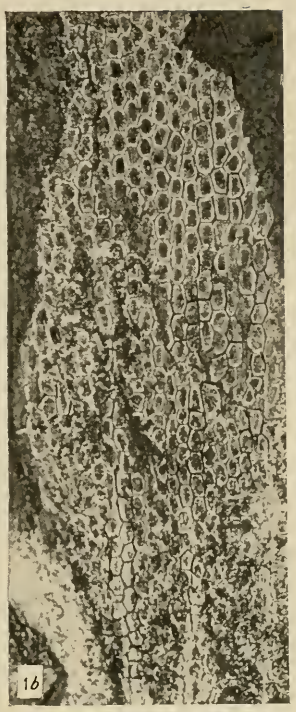
2*a*. (Natural size.) A specimen having a main stem, three branches and one secondary branch. U. S. National Museum, Catalogue No. 66510.

2*b*. (×2.) A small branching form with secondary branches. U. S. National Museum, Catalogue No. 66511.

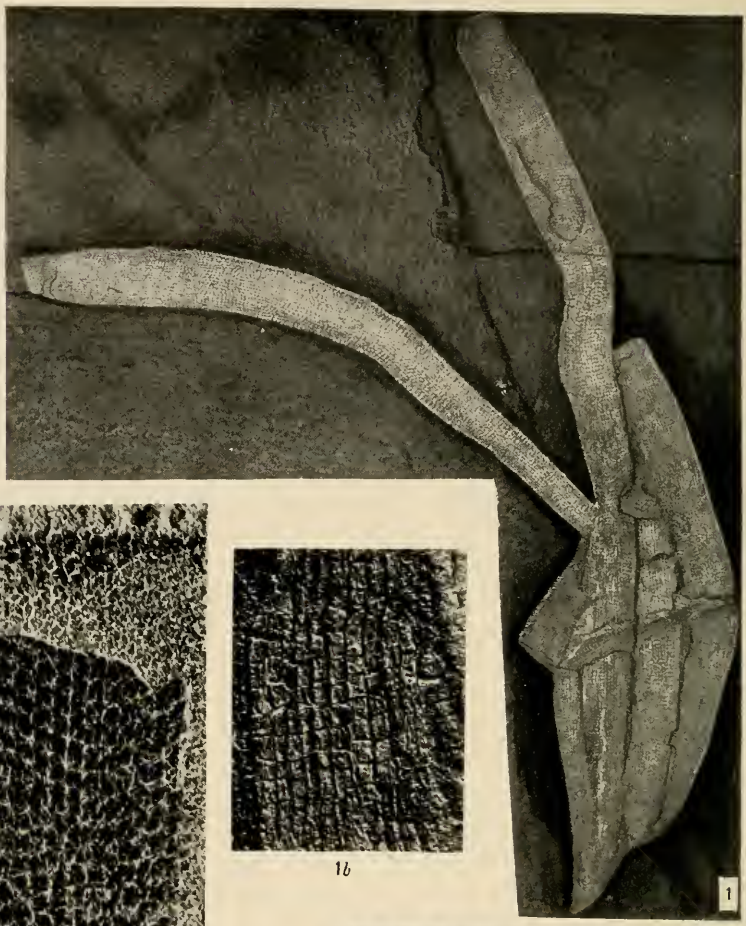
2*c*. (Natural size.) A closely branched sponge with small branches. U. S. National Museum, Catalogue No. 66512.

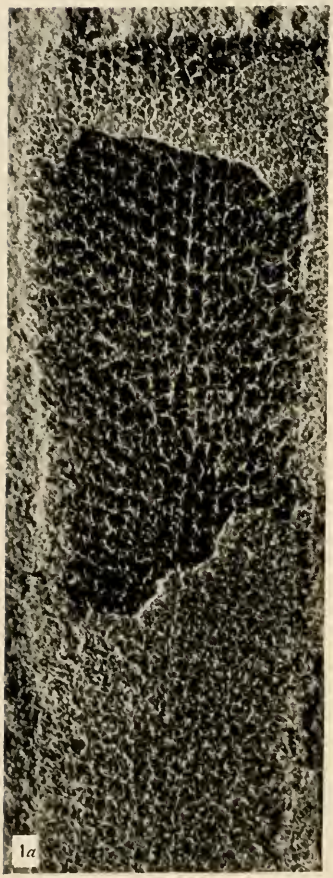
2*d*. (×3.) A macerated fragment showing the spicular layer. U. S. National Museum, Catalogue No. 66513.

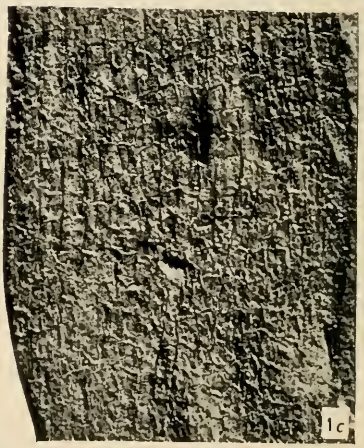
All of the specimens represented on this plate are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.



1. Vauxia bellula Walcott
2. Vauxia gracilenta Walcott







VAUXIA GRACILENTA Walcott

DESCRIPTION OF PLATE 83

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Vauxia gracilenta Walcott (see pl. 82 and text fig. 9) 318

FIG. 1. (Natural size.) A large branching specimen with the base broken away by fracture of the shale. U. S. National Museum, Catalogue No. 66514.

1*a*. (×6.) Spicular layer of a slender stem, 70 mm. in length and 6 mm. in width at the upper end. U. S. National Museum, Catalogue No. 66515.

1*b*, 1*c*. (×6.) Spicular layer of a specimen with the outer dermal layer removed. U. S. National Museum, Catalogue No. 66516.

The specimens represented on this plate are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

DESCRIPTION OF PLATE 84

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Vauxia densa Walcott..... 320

FIG. 1. (Natural size.) A large branching form with transverse undulations of growth. U. S. National Museum, Catalogue No. 66517.

1*a*. (Natural size.) A slightly curved corrugated single stem, but whether broken off from a branching form is not known. U. S. National Museum, Catalogue No. 66518.

1*b*. (× 6.) Enlargement of the lower portion of specimen represented by fig. 1, to illustrate the spicular structure.

1*c*. (× 6.) Spicular layer on a specimen that has been worn or macerated prior to its being embedded in the sediment. U. S. National Museum, Catalogue No. 66519.

The specimens represented on this plate are all from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

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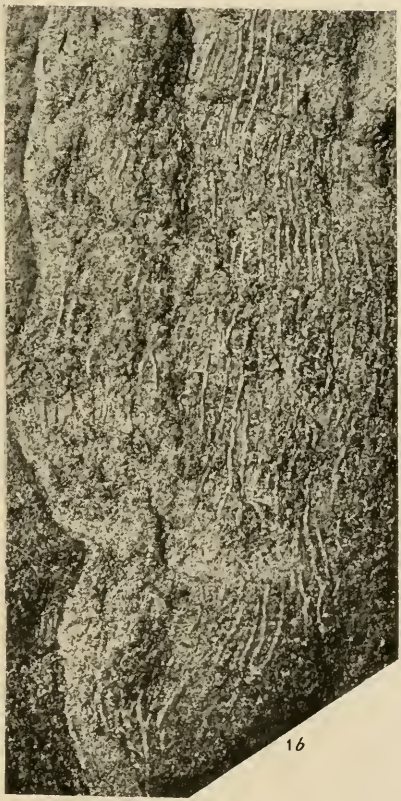

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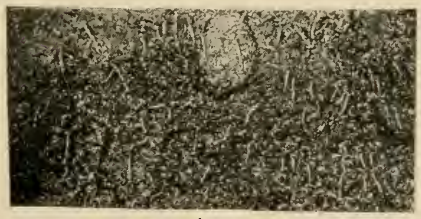

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VAUXIA DENSA Walcott

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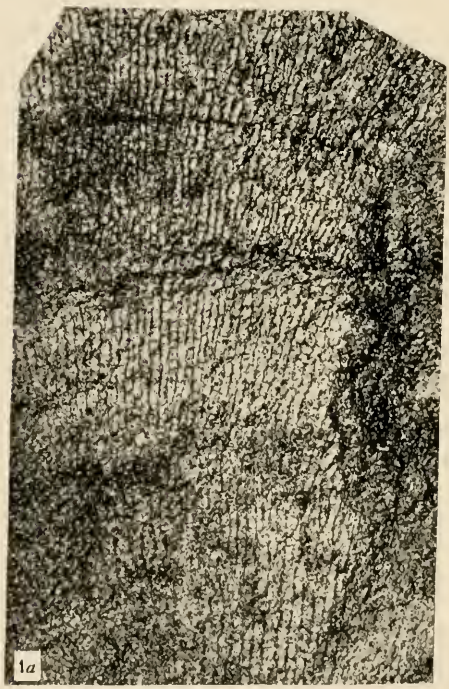

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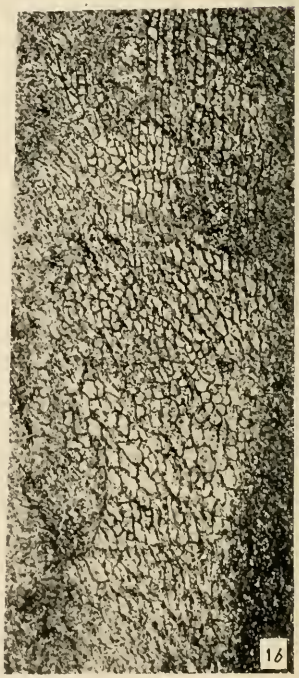

1b

VAUXIA (?) VENATA Walcott

DESCRIPTION OF PLATE 85

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Vauxia (?) venata Walcott 322

FIG. 1. (Natural size.) Sponge flattened on the surface of the shale; the base and three of the divisions of the frond are preserved and the base of a fourth division. U. S. National Museum, Catalogue No. 66520.

1*a*, 1*b*. (×6.) Enlargement of a portion of the surface of the two divisions on the left and upper side of the specimen represented by fig. 1, to illustrate the vertical and transverse spicular strands.

The specimen represented on this plate is from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

DESCRIPTION OF PLATE 86

PAGE

Eiffelia globosa Walcott 324

FIG. 1. (Natural size.) A specimen preserving something of the general form of the body. The top margin is broken and irregular. U. S. National Museum, Catalogue No. 66521.

1*a*. (× 3.) A globular specimen flattened in the shale and showing the shallow cup-shaped area (osculum) at the summit. U. S. National Museum, Catalogue No. 66522.

1*b*. (× 3.) Enlargement of a group of large and small spicules that are flattened on the shale. U. S. National Museum, Catalogue No. 66523.

Chancelloria cros Walcott (see pl. 88) 329

FIG. 2. (× 6.) A group of spicules preserving the shape of the body and main rays and indications of the breaking off of the supernumerary rays extending at right angles to the plane of the 6 or 7 principal rays. U. S. National Museum, Catalogue No. 66524. (See fig. 1*f*, pl. 88.)

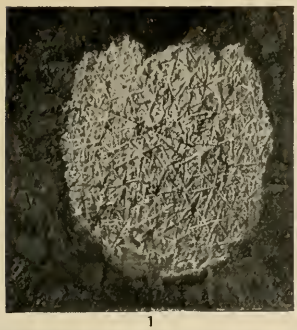
2*a*. (× 6.) Separate spicules flattened on the surface of the shale. U. S. National Museum, Catalogue No. 66525.

The specimens represented by figs. 1, 1*a-b*, 2, 2*a* are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

2*b*. (× 4.) Portion of probable inner wall of the body flattened on the surface of the shale with delicate spicules broken and crushed. U. S. National Museum, Catalogue No. 66529.

2*c*. (× 6.) Spicules with 9 rays, a hollow on one side of the central disk and a broken off or atrophied ray indicated on the opposite side. U. S. National Museum, Catalogue No. 66530.

The specimens represented by figs. 2*b*, 2*c* are from locality 14s, Middle Cambrian: *Ogygopsis* zone of the Stephen formation, at the great "fossil" bed on the northwest slope of Mount Stephen, above Field, on the Canadian Pacific Railroad, British Columbia.



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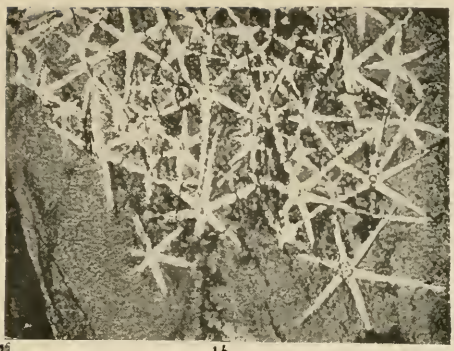

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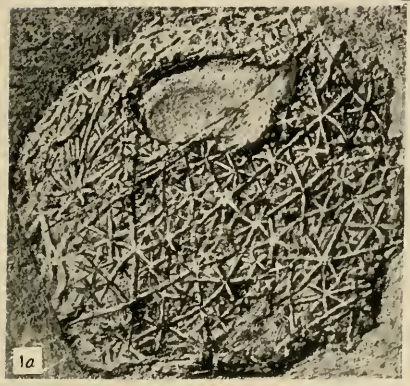
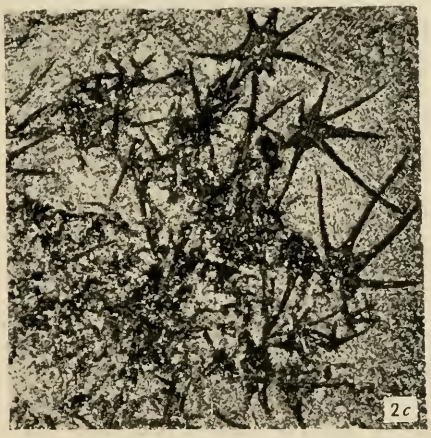


1a

2

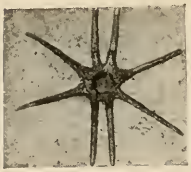
2a

2b



2c

1. Elffelia globosa Walcott
2. Chancelloria eros Walcott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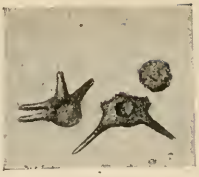
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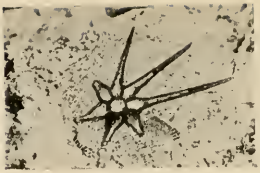
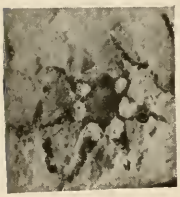

2c


2d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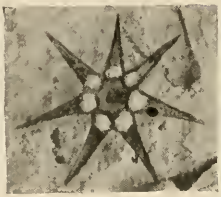
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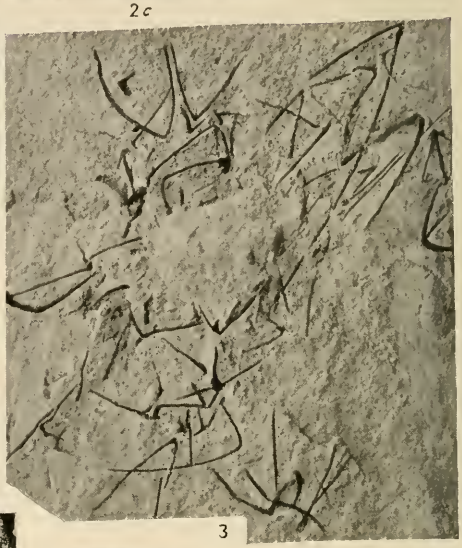
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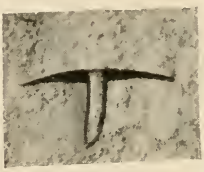
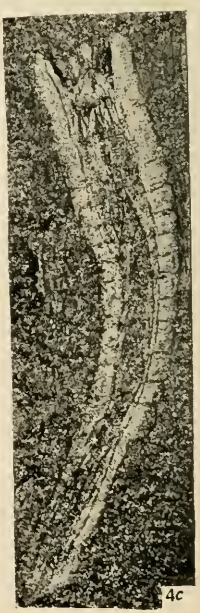
2e


2b


4a


4b


4


4c

1. Chancelloria libo Walcott
2. Chancelloria drusilla Walcott
3. Chancelloria yorkensis Walcott
4. Takakkawia lineata Walcott

DESCRIPTION OF PLATE 87

PAGE

Chancelloria libo Walcott..... 332

FIGS. 1, 1*a*. (×3.) Partially eroded spicules on surface of limestone. U. S. National Museum, Catalogue No. 66532.

From locality 89, Upper Cambrian: Conasauga formation; limestone in Murphrees Valley, Blount County, Alabama.

Chancelloria drusilla Walcott..... 331

FIGS. 2, 2*a*. (×3.) Cast of a seven-rayed spicule in siliceous nodule; the round cavity at the base of each transverse ray is represented by a minute ball attached to the cast just outside the margin of the central disk. U. S. National Museum, Catalogue No. 66533.

2*b*. (×3.) Cast in siliceous nodule of a spicule showing the large axial ray and two of the transverse rays, the effect being that of a section of an umbrella. U. S. National Museum, Catalogue No. 66534.

2*c*. (×3.) Cast of a spicule showing the central disk and seven rays. U. S. National Museum, Catalogue No. 66535.

2*d*. (×3.) Sketch of side view of fig. 2*c* to show the manner in which the center is elevated by the downward slope of the rays.

2*e*. (×3.) Sketch of a side view of a spicule showing central disk, axial ray and outline of transverse rays. U. S. National Museum, Catalogue No. 66536.

The specimens represented by figs. 2, 2*a-c* are from locality 89x, Middle Cambrian: Conasauga shales; argillaceous shale with embedded siliceous nodules, Livingston, Coosa Valley, Floyd County, Georgia.

Chancelloria yorkensis Walcott..... 332

FIG. 3. (×3.) Scattered spicules on surface of argillaceous shale. U. S. National Museum, Catalogue No. 66537.

The specimen represented by fig. 3 is from locality 48d, Middle Cambrian: York formation; argillaceous shales in railroad cut alongside of Gas House, city of York, York County, Pennsylvania.

Takakkawia lineata Walcott..... 277

FIG. 4. (×2.) A nearly entire specimen. U. S. National Museum, Catalogue No. 66539.

4*a*. (×3.) Specimens with vertical bands finely preserved. U. S. National Museum, Catalogue No. 66538.

4*b*. (×4.) Specimen illustrating vertical bands, twisted strand spicules and tufts of fine spicules. U. S. National Museum, Catalogue No. 66541.

4*c*. (×3.) A slightly curved specimen with longitudinal spicules displaced. U. S. National Museum, Catalogue No. 66540.

The specimens represented by figs. 4, 4*a-c* are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

DESCRIPTION OF PLATE 88

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Chancelloria eros Walcott (see pl. 86) 329

FIG. 1. (Natural size.) A long, slender specimen with the spicules showing clearly on the outer surface. U. S. National Museum, Catalogue No. 66526.

1*a*. (× 4.) Enlargement of part of the surface of fig. 1, near the upper end to illustrate the two surface rays of the spicules.

1*b*. (× 2.) Large broken spicules that were probably along the upper margin of the sponge. U. S. National Museum, Catalogue No. 66531.

The specimen represented by fig. 1*b* is from locality 14s, Middle Cambrian: *Ogygopsis* zone of the Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian and 3,540 feet (1,089 m.) below the Upper Cambrian, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad, British Columbia, Canada.

1*c*. (× 3.) A broken-down surface illustrating spicules with 2, 3 and 4 of their rays exposed. The 6- and 7-rayed spicules are shown in fig. 1*f*. U. S. National Museum, Catalogue No. 66527.

1*d*. (Natural size.) The upper end of a form similar to that represented by fig. 1. U. S. National Museum, Catalogue No. 66528.

1*e*. (× 3.) Enlargement of the surface of fig. 1*d* to illustrate portion of spicules showing at the surface.

1*f*. (× 6.) Portion of what may be the inner wall of the cortex where the rays of the spicules are on one plane and not curved to the extent they are in the spicules of the outer wall (ectosome). U. S. National Museum, Catalogue No. 66524. (See fig. 2, pl. 86.)

All of the specimens represented by figs. 1, 1*a*, 1*c-f* are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

1

1b

1a

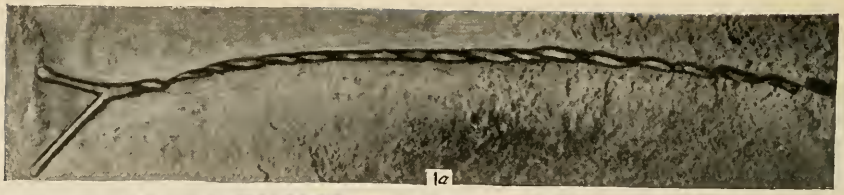
1f

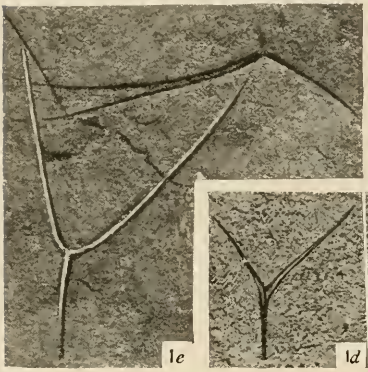
1d

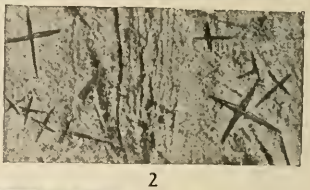
1c

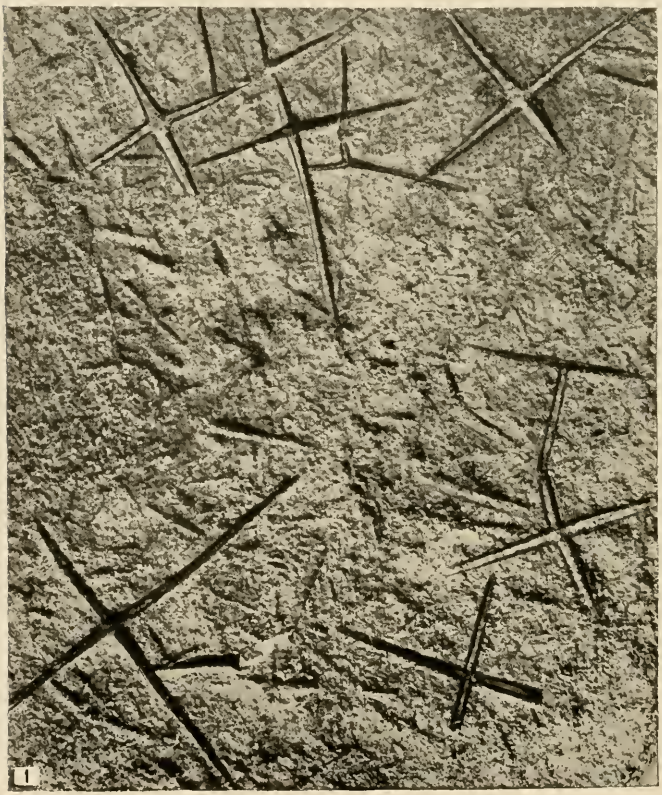
1e

CHANCELLORIA EROS Walcott









1. Kiwetinokia utahensis Walcott
2. Kiwetinokia spiralis Walcott

DESCRIPTION OF PLATE 89

PAGE

Kiwetinokia utahensis Walcott..... 313

FIG. 1. (×3.) Portion of a group of cruciform spicules that were displaced from their natural arrangement and are now scattered over the surface of a shaly limestone; long, slender spicular rods occur with the same group of spicules. U. S. National Museum, Catalogue No. 66542.

The specimen represented by fig. 1 is from locality 11q, Middle Cambrian: Marjum formation; about 2,300 feet (701 m.) above the Lower Cambrian, and 660 feet (203 m.) below the Upper Cambrian, in the limestone forming 1c of the Marjum formation, 2.5 miles (4 km.) east of Antelope Springs, in west face of ridge east of Wheeler Amphitheater, House Range, Millard County, Utah.

1*a*. (×3.) A rod formed of two long spicules twisted together with a Y at one end formed possibly by the ends of the two spicules of the rod; these ends or branches are enlarged toward the end and of unequal length; there is also an enlargement of the rod where the two branches join it. U. S. National Museum, Catalogue No. 66452.

1*b*. (×2.) A triradiate (protriaene) spicule from the same layer as specimens represented by fig. 1*a*. U. S. National Museum, Catalogue No. 66544.

The specimens represented by figs. 1*a*, 1*b* are from locality 3e, Middle Cambrian: Ophir formation; Ophir City, Oquirrh Range, Utah.

1*c*. (×3.) Cruciform spicules lying on the surface of limestone shale. U. S. National Museum, Catalogue No. 66545.

1*d*. (×3.) A triradiate spicule associated with the spicules illustrated by fig. 1*c*.

The specimen represented by figs. 1*c*, 1*d* is from locality 5g, Middle Cambrian: Spence shale; 100 feet (30.5 m.) above the Brigham formation; dark argillaceous shales and blue-black calcareous shales, 155 feet (47.2 m.), forming 4a of [typewritten] Malad section; Two Mile Canyon, 3 miles (4.8 km.) southeast of Malad, Oneida County, Idaho.

1*e*. (×2.) Large triradiate spicules that probably belong to a different species; numerous small, cruciform spicules occur with them. U. S. National Museum, Catalogue No. 66546.

The specimen represented by fig. 1*e* is from locality 3x, Middle Cambrian: Marjum formation; about 2,200 feet (670.6 m.) above the Lower Cambrian and 810 feet (249 m.) below the Upper Cambrian in the limestones forming 1d of the Marjum formation, 2.5 miles (4 km.) east of Antelope Springs, in ridge east of Wheeler Amphitheater, House Range, Millard County, Utah.

Kiwetinokia spiralis Walcott..... 314

FIG. 2. (×6.) Small cruciform spicules, which are all that is known of the body spicules referred to this species. U. S. National Museum, Catalogue No. 66547.

2*a*. (×20.) Spiral rod associated with the spicules represented by fig. 2, illustrating the spiral structure and the spicules composing it.

2*b*. (×10.) Portion of two spiral rods that are associated with the spicules represented by fig. 2.

The specimens represented by figs. 2, 2*a*, 2*b* are all on same surface of one specimen, from locality 10z, Middle Cambrian: Marjum formation; about 2,900 feet (88.4 m.) above the Lower Cambrian and 1,500 feet (457.2 m.) below the Upper Cambrian in the central part of the limestone forming 1a of the Marjum limestone, in the long cliff about 2 miles (3.2 km.) southeast of Marjum Pass, House Range, Millard County, Utah.

DESCRIPTION OF PLATE 90

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Tuponia lineata Walcott (see pls. 62, 63) 272

FIG. 1. (Natural size.) A macerated specimen preserving four of the longitudinal bands of spicules which project above the upper end so as to give a peculiar appearance to the specimen. U. S. National Museum, Catalogue No. 66777.

1*a*. (× 3.) Enlargement of the specimen represented by fig. 1.

Hazelia delicatula Walcott (see pl. 70) 284

FIG. 2. (Natural size.) A small cup-shaped frond on which the openings (pores) in the dermal surface are quite clearly indicated. U. S. National Museum, Catalogue No. 66778.

2*a*. (× 2.) Enlargement of the specimen represented by fig. 2.

4. (× 2.) An elliptical frond with an elevated center of growth that is somewhat doubtfully referred to this species. U. S. National Museum, Catalogue No. 66779.

Hazelia mammillata Walcott 286

FIG. 3. (Natural size.) Fragment of a frond and the only specimen now known of the species. U. S. National Museum, Catalogue No. 66780.

3*a*. (× 2.) Enlargement of specimen represented by fig. 3 to more clearly show the oscula and pores.

The specimens illustrated on this plate represent the additional material of special interest collected in July, 1919. They are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia, Canada.

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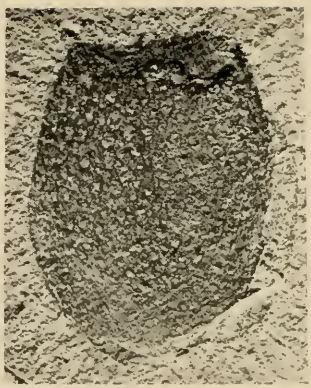

2a

2

1a

3

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4

1. Tuponia lineata Walcott
2 and 4. Hazelia delicatula Walcott
3. Hazelia mammillata Walcott