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II

No. 2.—MIDDLE CAMBRIAN MEROSTOMATA

With Six Plates

BY
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CAMBRIAN GEOLOGY AND PALEONTOLOGY

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INTRODUCTION

During the field season of 1910 the study of the Cambrian strata of the section of the Rocky Mountains adjacent to the main line of the Canadian Pacific Railway was continued and special attention given to the Stephen formation. Its outcrop was carefully examined for many miles along the mountain sides with the hope of finding a locality where conditions had been favorable for (a) the presence of life during deposition of sediments, (b) the subsequent changing of sediments into rock, and (c) the preservation of the rock during the vicissitudes consequent on mountain building, so that the preservation of the life of the epoch would be as complete as possible. The famous trilobite locality on the slope of Mount Stephen above Field had long been known and many species of fossils collected from it, but even there the conditions had not been favorable for the presence and preservation of examples of much of the life that, from what was known of older faunas and the advanced stage of development of the Upper Cambrian fauna, must have existed in the Middle Cambrian seas. The finding, during the season of 1909, of a block of fossiliferous siliceous shale that had been brought down by a snow slide on the slope between Mount Field and Mount Wapta, led us to make a thorough examination of the section above in 1910. Accompanied by my two sons, Sidney and Stuart, every layer of limestone and shale above was examined until we finally located the fossil-bearing band. After that, for thirty days we quarried the shale, slid it down the mountain side in blocks to a trail, and transported it to camp on pack horses, where, assisted by Mrs. Walcott, the shale was split, trimmed, and packed, and then taken down to the railway station at Field, 3000 feet below. Among the finds there were a number of specimens of a beautifully preserved Merostome which will be the subject of this paper, and the first species to be described in a preliminary manner from the new locality.

CAMBRIAN MEROSTOMATA

The only Merostomes heretofore known from Cambrian rocks are from the Upper Cambrian formations of America. The first discovered was described by James Hall in 1863[1] as *Aglaspis barrandi.* Subsequently R. P. Whitfield described a second species as *Aglaspis eatoni.*[2] This genus was subsequently referred to the sub-order Synziphosura of Packard.[3]

No Eurypterid remains were reported until in 1901 C. A. Beecher described *Strabops thacheri* from the Upper Cambrian Potosi limestone of Missouri.[4]

Both *Aglaspis* and *Strabops* indicated that at the close of Cambrian time the Merostomata had advanced a long way toward a full development of the sub-class and that a series of ancestral forms had preceded them. It has been my desire for many years to discover something of the older Merostome fauna in the Cambrian and thus, if possible, secure further connections between the pre-Cambrian Algonkian crustacean, *Beltina,*[5] and the great Merostome fauna of the Silurian.

In this paper two genera, *Sidneyia* and *Amiella,* are described: the former, from very fine material, and the latter, from one broken and imperfect individual. Both genera appear to belong to a sub-order of the Eurypterida and it may be a distinct order.

When preparing this paper I received from H. Mansuy, Geologist of Indo-China, a series of photographs of Cambrian fossils from Yunnan, and among them one of a fragment of a Merostome showing six segments of the abdomen. From their form and surface markings the species appears to belong to the genus *Amiella* described in this paper. (See p. 28.)

Classification.—The two new genera, *Sidneyia* and *Amiella,* are placed in the new sub-order Limulava of the order Eurypterida, under the new family Sidneyidae. The relations of the order and sub-order are shown in the following tabular view.

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[1] Sixteenth Ann. Rept. New York State Museum, 1863, pp. 181-182, pl. xi, figs. 7-16.

[2] Geol. Surv. Wisconsin, Vol. 4, 1882, p. 192, pl. 10, fig. 11.

[3] Memoirs National Acad. Sci., Vol. 3, 1885, p. 151.

[4] American Journ. Sci., Vol. 12, 1901, pp. 364-366, pl. 7.

[5] Bull. Geol. Soc. America, Vol. 10, 1899, p. 238, pls. 25-27.

Sub-Class MEROSTOMATA

Order Eurypterida	Sub-Order Limulava
1. Cephalo-thorax long.	1. Cephalo-thorax short.
2. Cephalo-thorax with six (6) pairs of appendages; the anterior pair chelate antennae, and the posterior pair, long, strong swimming legs.	2. Cephalo-thorax with five (5) pairs of appendages; the anterior simple antennae, the third pair multi-chelate, and the posterior pair short, the outer joint serving as a branchial organ.
3. Epistoma present in *Pterygotus* where it is narrow. Metastoma large.	3. Epistoma large. Metastoma unknown.
4. Six anterior abdominal segments bear leaf-like branchial appendages.	4. Nine anterior abdominal segments bear leaf-like branchial appendages.
5. Surface of test with scale-like ornamentation.	5. Surface of test smooth or with imbricating lines, as in many of the Trilobita.
6. Terminal segment a simple lanceolate or spatulate telson.	6. Terminal segment a caudal fin formed of a central expanded telson and one or more swimmerets on each side.

Differences other than those tabulated will probably be found when more of the detailed structure of the Limulava can be determined.

The sub-order Limulava, as represented by the genus *Sidneyia* with its four pairs of cephalo-thoracic appendages and simple antennae, approaches the Trilobita, which has a similar scheme of cephalic appendages. In both, the antennae are large and simple, jointed, sensatory organs. The branchiae of *Sidneyia* also suggest the broad, thin joints of the exopodite of the trilobite's legs with their branchial fringes. For comparison, the branchial fringes of *Neolenus serratus*, a trilobite associated with *Sidneyia inexpectans*, are illustrated on pl. 6, figs. 1 and 2.

The branchial lamellae of *Pterygotus* also have branchial fringes as well as the leaf-like, oval lamellae, as illustrated by Henry Woodward.[1]

The short cephalo-thorax of *Sidneyia* is found also in *Strabops thacheri* Beecher (p. 19) from the Upper Cambrian, a form that may have had but five pairs of movable, cephalo-thoracic appendages.

[1] Monogr. British Fossil Crustacea, Order Merostomata, 1866-1878, pl. 11, fig. 2b; pl. 12, figs. 1a, 1d.

Relations to pre-Cambrian Merostomes.—The fragmentary remains that were described under the name of *Beltina danai* were referred to the Merostomata,[1] and the genus was considered to be more or less closely related to *Eurypterus* and *Pterygotus*. All the original specimens are flattened in a calcareous shale and none of them show definite surface markings. In a collection made by Prof. Stuart Weller in the Altyn limestone in the valley of Swift Current Creek, Montana, the specimens are embedded in a very fine calcareo-arenaceous matrix, and many of them show the convexity, and some, the original surface markings. One of these (illustrated on pl. 7, fig. 4), an abdominal segment, shows the convexity and general form of the segment, and the surface is more or less roughened by what appear to be depressed tubercles.

Specimens collected from about the same horizon to the north in British Columbia, and embedded in a siliceous matrix, are more flattened than those from the Altyn limestone, but they show certain definite surface characters. Two of the specimens are illustrated on pl. 7. Fig. 2 is a portion of a cephalo-thorax, with irregular transverse ridges near the posterior margin and depressed tubercles over other portions of the surface. An abdominal segment (fig. 3) shows depressed tubercles not unlike those shown by the segment from the Altyn limestone illustrated by fig. 4.

The relations of this very ancient form to the Middle Cambrian Merostomes described in this paper are very uncertain owing to the fragmentary character of all the specimens of *Beltina* yet discovered. Most of these fragments are quite similar to fragments of *Sidneyia inexpectans* where the latter is broken up and flattened in the shale, but, as a whole, the form of all the parts of *Beltina* thus far recognized indicates a closer relationship to the Eurypterida than to the Sidneyidae.

Class CRUSTACEA

Sub-Class MEROSTOMATA (Dana) Woodward

Order EURYPTERIDA

Sub-Order LIMULAVA, new sub-order

Body elongate, with a thin epidermal skeleton either smooth or ornamented by lines or ridges. Cephalo-thorax with lateral or marginal eyes, on the ventral side with five pairs of movable appendages; mouth posterior to a large epistoma.

[1] Bull. Geol. Soc. America, Vol. 10, 1899, p. 238.

Abdomen with twelve segments, the anterior nine of which have a pair of ventral appendages to which the branchiae are attached; the posterior segment has a central spatulate-shaped section that, combined with swimmerets, forms a strong caudal fin.

The description of the branchiae will be found under the description of *Sydneyia,* the typical genus of the Limulava.

Observations.—The sub-order Limulava differs from the Eurypterida, to which it is most nearly related, in having a large epistoma similar to that of the Trilobita; in not having a metastoma, chelate antennae, and swimming cephalic appendages; and in having a broad fan-shaped caudal fin, and branchial appendages more or less unlike the lamellar branchiae of the Eurypterida and Xiphosura.

Family SIDNEYIDAE, new family

Cephalo-thorax small, without lobes, eyes marginal; ventral side with large epistoma, five pairs of movable appendages, the gnathobases of the three posterior pairs forming organs of manducation. Abdomen twelve-jointed, the three posterior segments annular and narrow, the terminal one forming, with lateral swimmerets, a fan-like tail; nine anterior segments with a pair of ventral branchial appendages on each; the three posterior segments without ventral appendages. Surface smooth or ornamented by narrow, irregular, fine, imbricating ridges.

Genus SIDNEYIA, new genus

Body elongate, broadly oval in outline, attaining as now known a length of 17 cm., covered with a thin dorsal shield or crust, divided into a short cephalon, broad anterior abdomen, and narrow posterior abdominal portion. Cephalo-thorax transverse, short, depressed convex, as compressed in the shale, with broadly rounded frontal margin and antero-lateral angles; margins smooth. Eyes reniform and situated near the postero-lateral outer margin. Ventral side with five pairs of movable appendages. The anterior pair are large, long, simple, jointed antennae; second pair, slender and jointed; third pair with numerous spines on the front side of the joints and with variously developed chelate-like outer joints (see pl. 4); fourth pair, slender and jointed; fifth pair with a large basal joint, and an outer, broad joint or palp that is fringed with fine branchial setae or spines. A large epistoma is attached to the front margin and back of it the gnathobases of the appendages, the three[1] posterior pairs of which form the organs of manducation.

[1] See description of species, *S. inexpectans* (p. 25).

Abdomen with twelve segments, the anterior nine of which each carry a pair of branchia-bearing appendages. The next two posterior segments, tenth and eleventh, are simple, annular rings, the terminal segment or telson has a central spatulate section that, with its lateral swimmeret on each side, forms a broad caudal fin.

Surface of dorsal shield smooth.

Genotype.—Sidneyia inexpectans, new species.

Stratigraphic range.—The stratigraphic range is limited, so far as known, to a thickness of 130 feet in a dark siliceous shale forming a part of the Stephen formation and described as the Ogygopsis shale in 1908.[1]

Geographic distribution.—On the slope of the ridge between Mount Wapta and Mount Field north of Burgess Pass, and about 3800 feet above Field on the line of the Canadian Pacific Railway, British Columbia, Canada.

Observations.—Sidneyia is a most interesting type and one that I should have expected to find in an Ordovician rather than in a Middle Cambrian formation. It is associated with a large fauna, part of which is enumerated in the list of thirty-two species listed under the description of the Ogygopsis shale referred to above. The stratigraphic horizon in the British Columbia Cambrian section is over 6300 feet below the summit of the Cambrian series.[2]

The short, broad, cephalo-thorax, the broad elliptical abdominal portion formed by the first nine segments, the elongate, narrow three posterior segments, the last taking the form of a broad caudal fin, all unite to give the type a scorpion-like appearance.

The genus differs from all the genera of the Eurypterida in the form of the cephalo-thorax, smooth surface, presence of a very large epistoma, non-chelate antennae, absence of a metastoma, and (with the exception in *Stylonurus*) absence of a broad posterior pair of swimming appendages; also in the arrangement of the branchiae upon the nine anterior abdominal segments and in the presence of the broad caudal fin formed of the spatulate terminal section and swimmerets of the twelfth segment.

In this preliminary study and description some detail is omitted, but this will be worked out and inserted in the final study of the genus.

The generic name *Sidneyia* is proposed in recognition of the discovery of the type specimens by my son, Sidney S. Walcott, in August, 1910.

[1] Smithsonian Miscellaneous Collections, Vol. 53, No. 5, p. 210.

[2] Idem, pp. 216, 217.

SIDNEYIA INEXPECTANS, new species

(Pl. 2, figs. 1-3; pl. 3, figs. 1-4; pl. 4, figs. 1-4; pl. 5, figs. 1-3; pl. 6, fig. 3; pl. 7, fig. 1.)

Cephalo-thorax.—Body elongate, with a thin epidermal skeleton or crust. Cephalo-thorax small, short and broad; in an entire dorsal shield having a length of 123 mm., the cephalo-thorax has a length of 15 mm. and a width of 56 mm.; surface depressed convex, as flattened in the shale; outline broadly rounded and almost transverse across the front, rounding gently at the antero-lateral angles before arching backward to the eye lobe where it curves slightly inward. The eye forms a distinct lobe a little more than one-third the length of the cephalo-thorax; it is situated close to the postero-lateral angle and has a narrow rim caused by a slight intermarginal depression. The posterior margin is transverse and without any intermarginal furrow. No traces of ocelli have been observed.

A very large transverse epistoma is attached to the ventral edge of the cephalo-thorax; in one example (pl. 5, fig. 3) it is nearly as wide as the cephalo-thorax and apparently quite as long, if not longer; the surface is smooth except for a slight intermarginal furrow which is indicated at the sides and posterior margin; the posterior outline is nearly transverse in the central portions and broadly curved at the sides; a large specimen having a width at the third abdominal segment of 87 mm. and a length of 143 mm. exclusive of the cephalo-thorax, has an epistoma 27 mm. in length and over 55 mm. in width. The ventral appendages of the cephalo-thorax will be described under the sub-heading *Appendages.*

Abdomen.—The abdomen has twelve segments as shown by fig. 1, pl. 2 and fig. 2, pl. 5. The anterior nine segments form a broad ellipse, the anterior end of which is attached to and merges into the outline of the cephalo-thorax; the length of these segments is about one-eighth of their width; the first segment terminates in a point equally converging from the front and back margins; in the second segment the convergence and curvature is greatest toward the front side and back of this the curvature of the front margin increases until there is a slight backward arching of the posterior margin so as to form a sharp point with the downward arching front margin; posteriorly the tenth and eleventh segments are nearly as long as wide, much narrower than the first nine segments and more than twice as long as the anterior segments from which they extend backward; they appear to be simple, annular rings; the twelfth or terminal segment has a central body, broadly oval in outline, that

extends backward from two-thirds to four-fifths of the distance to the posterior margin; at about half its length a wing-like extension continues backward and slightly outward to a transverse margin; on each side of the terminal segment (pl. 3, figs. 2-4), and attached to its anterior side, there is a lateral swimmeret that on the inside overlaps more or less the central terminal section and on the outside margin expands so as to form, with the central terminal section, a broad caudal fin suggestive of that occurring in the Schizopoda and Decapoda; it may be that there are more than one of the lateral swimmerets on each side, but if so they are so pressed in together as not to be distinguished. The anterior margin of each segment extends under the segment in front of it from one-fifth to one-third its length at the center, the underlap gradually narrowing to where it passes from beneath the segment near its outer termination; the anterior segment passes beneath the cephalo-thorax in the same manner.

Ventral appendages: Cephalo-thorax.—Cephalo-thorax with five pairs of movable appendages. The first or antennal pair are rather stout at the base, tapering gradually until they become very slender (pl. 2, fig. 1); the joints vary in length, they are usually a little wider than long for the first half of the length of the appendage, gradually becoming proportionately longer toward the outer end. One appendage shows over thirty joints beyond the edge of the carapace, and another from its length must have many more; each joint has a short, fine spine or fringe of spines at the anterior margin of the joint. The inner point of attachment of the first joint has not been seen as it is covered by either the epistoma or cephalo-thorax in all specimens.

The second pair of appendages is formed of long, slender joints; so far as known they extend only a little distance beyond the margin of the cephalo-thorax and terminate in a joint that has two or three short spines projecting from the outer end of it.

The simple form of the third pair of appendages is shown by fig. 1, pl. 5. They have a relatively large basal joint, the anterior inner margin of which is provided with six or more sharp spines that appear to have been used in connection with the basal joints of the fourth and fifth pair of appendages as manducatory organs. This appendage has broad, strong joints in small specimens (pl. 5, fig. 1) and in large specimens it is developed into a peculiarly constructed and complex chelate terminal section; this is formed of twelve or more joints of a forward curving appendage to which

are attached on the anterior side long spines carrying numerous smaller spines on the margin opposed to the main body of the appendage (pl. 4, fig. 4). There is also in this specimen a broad appendage of three joints attached to the outer posterior end of the basal joint. The features described are partially illustrated on pl. 4, by figs. 1-4. Fig. 3 illustrates some of the long spines where they are sufficiently separated to show the shorter secondary spines. Another unusual variation is illustrated by fig. 1. In the small specimen illustrated by fig. 2, pl. 2, it looks as though there were two jointed branches extending outward with small spines on their anterior margins. A larger series of specimens will undoubtedly enable us to interpret these chelate appendages more accurately but with our present information it seems probable that in the complex form represented by fig. 1, pl. 4, provision was made for capturing the numerous small phyllopod crustaceans and numerous annelids with which the bottom and adjacent water were abundantly supplied. It may be that the chelate, complex appendages were also used in fighting and that there was a marked difference in those belonging to the male and female.

The fourth pair of appendages so far as known have a small basal joint or gnathobase which has on its inner margin two strong spines, the form and size as compared with the gnathobases on the third and fifth pair of appendages is illustrated by fig. 1, pl. 5. The joints beyond the gnathobase are elongate and form a slender appendage that extends out beyond the third and fifth appendages. The terminal joint has three small spines projecting from its outer end.

Each of the fifth pair of appendages has a large basal joint or gnathobase, the inner margin of which is provided with short, strong spines. As far as can be determined from the material available for study, there are three or four strong, broad joints beyond the gnathobase, the outer of which are provided with fine setae or branchial filaments. The gnathobase is well shown by fig. 1, pl. 5, and the filaments on the outer joints by figs. 2 and 3, pl. 2.

Ventral appendages: Abdominal.—A number of specimens show more or less of traces of abdominal appendages on the first nine segments of the abdomen. None of these indicates the presence of a jointed appendage in any way comparable with the appendages of the cephalo-thorax, or the abdominal appendages of the trilobite. The appendages appear to be formed of clusters of branchial fringes attached to short lobes that are round or oval in outline and affixed to the ventral surface on each side of the abdomen at the outer

edge of its inner third, or they may be of a lamellated structure as shown by fig. 1, pl. 3, fig. 1, pl. 2, fig. 3, pl. 6. What is now known of these branchial clusters recalls very strongly the lamellated branchial fringes occurring in the cephalic portion of the trilobite *Calymene senaria,*[1] and in specimens of *Neolenus serratus* (see pl. 6, figs. 1 and 2) associated with *Sidneyia inexpectans.*

Observations.—In this preliminary notice of this remarkable crustacean I have not attempted to describe many minor features of the ventral appendages of the cephalo-thorax and abdomen. The combination of characters shown by the conformation of the dorsal shield and the grouping of the appendages indicates quite clearly a transition form between the Trilobita and Eurypterida. In view of larger collections being made available during the season of 1911 further description will be deferred.

Formation and locality.—Middle Cambrian: Stephen formation, Ogygopsis shale on west slope of ridge between Mount Field and Mount Wapta, about 3800 feet above Field on the line of the Canadian Pacific Railway, British Columbia, Canada.

Genus AMIELLA, new genus

What is known of this genus is contained in the description of the type species. It differs markedly in form and surface from *Sidneyia.* From *Pterygotus, Eurypterus,* and other genera of the Eurypterida it differs in the character of the surface, epistoma, and abdominal segments.

Genotype.—Amiella ornata Walcott, which is associated with *Sidneyia inexpectans* in British Columbia.

The generic name is given in honor of Dr. Henry M. Ami, of the Geological Survey of Canada.

AMIELLA ORNATA, new species

(Pl. 5, fig. 4.)

Of this species only one broken specimen of the dorsal shield is known. This shows that the body was elongate, narrow, and the abdomen formed of a number of large segments of which remains of seven are preserved; also a part of the cephalo-thorax.

Crust thin and compressed in the shale.

Cephalo-thorax.—The portion of the cephalo-thorax preserved (it may be only the epistoma) has been turned about, the dorsal shell of the cephalo-thorax having been loosened and displaced. If it is

[1] Bulletin Museum of Comparative Zoology, Vol. 8, 1881, pl. 3, figs. 1, 2.

the cephalo-thorax it has a nearly transverse posterior margin with slightly rounded lateral angles. The anterior outline is curved so as to give an inward slope to the sides and a rounded, slightly transverse section along the central portion. No traces of eyes. I am strongly inclined to the view that the part preserved is the large epistoma characteristic of the family Sidneyidae.

Abdomen.—There are traces of seven abdominal segments. In front of the epistoma? is the remnant of a segment which was largely broken away in exposing the epistoma?. The same is true of the anterior of the segments united in the abdomen; of this segment only a small fragment remains on the left side. The first fairly well preserved segment has a length of 13 mm. and a width of 30 mm. Before the anterior margin was removed it had a length of 16 mm. The next two segments are large and broad, and the last two narrow and long. All are more or less pushed one over the other so as to obscure their true proportions.

Surface.—The surface of all parts of the abdomen is ornamented by irregular, imbricating lines, roughly sub-parallel to the longitudinal axis of the abdomen, or else, toward the outer edges, sub-parallel to the gently curved outer margins of the segments. The epistoma? has much finer lines sub-parallel to its lateral margins.

Observations.—The outline of the body of this species suggests the form of *Pterygotus bilobus* Salter var. *inornatus* Woodward.[1] The surface markings are unlike those of *Pterogotus, Eurypterus,* and other genera of the Eurypterida, as are also the proportions of the abdominal segments.

Formation and locality.—Middle Cambrian: Stephen formation, Ogygopsis shale, west slope of ridge between Mount Field and Mount Wapta, about 3800 feet above Field on the line of the Canadian Pacific Railway, British Columbia, Canada.

A second species of this genus or a closely allied form occurs in the *Redlichia chinensis* zone of Indo-China. (See p. 19.) It is the oldest Merostome now known as it comes from the horizon of the Man-t'o shale formation of the upper Lower Cambrian terrane.[2]

[1] Monogr. British Fossil Crustacea, Order Merostomata; 1866-1878, pl. 10.

[2] See Willis and Blackwelder, Research in China, 1907, Vol. 1, Pt. 1, p. 26.

DESCRIPTION OF PLATE 2

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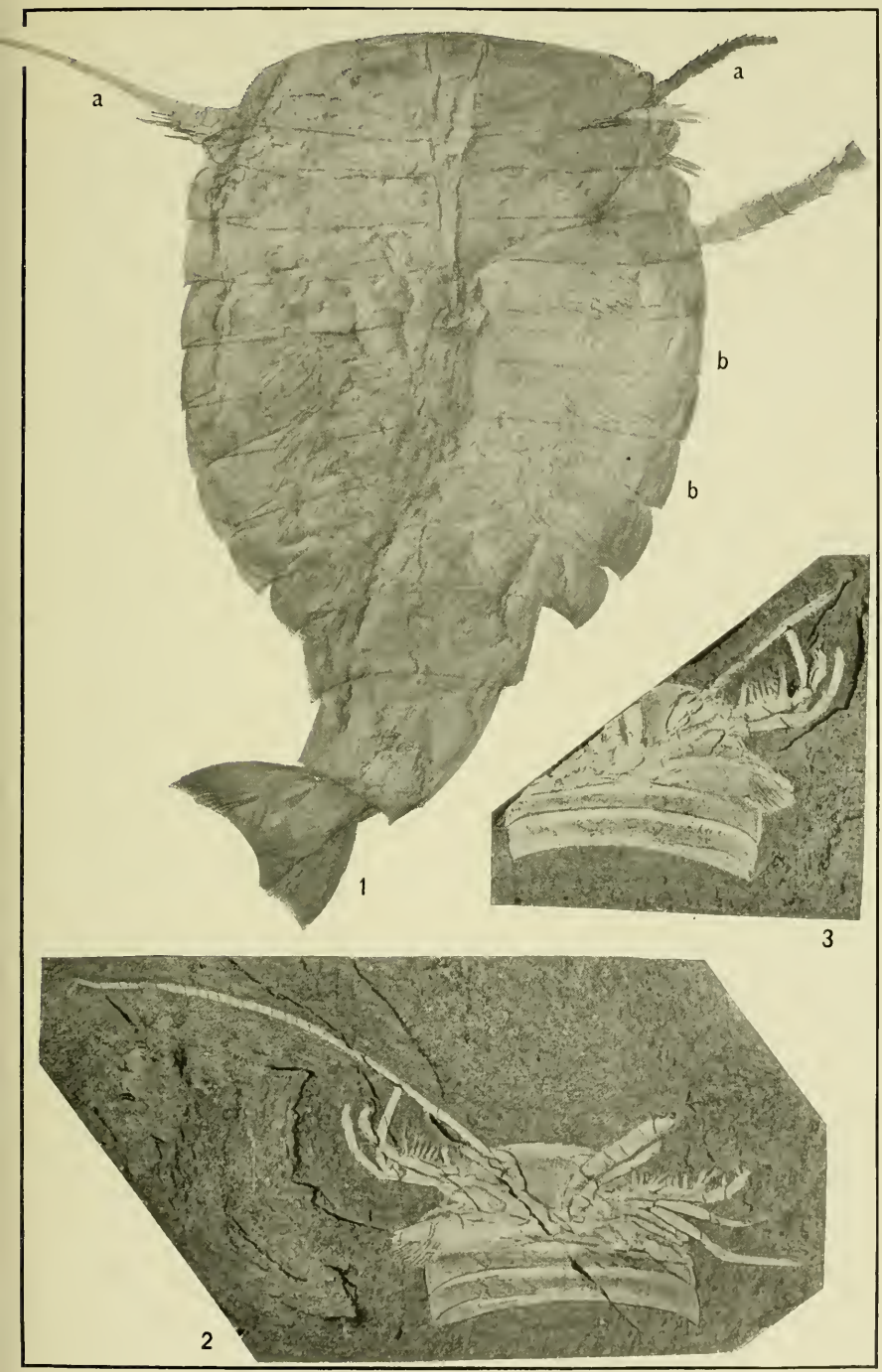
FIG. 1. A large dorsal shield (natural size) flattened and somewhat broken by compression in the shale; an antenna projects out from each side in front of the eye, and, on the right-hand side, probably the fourth appendage of the cephalo-thorax which has been pushed back under the second segment of the abdomen. U. S. National Museum, Catalogue No. 57487.

2. Enlargement of the under side of a small cephalo-thorax to which are attached the antennae and four pairs of appendages. Only a portion of the epistoma is preserved. This is the only specimen in the collection preserving the appendages of the cephalo-thorax in their approximately normal position. × 3. U. S. National Museum, Catalogue No. 57488.

3. A portion of the matrix of the specimen represented by fig. 1. × 3.

The illustration on pls. 2-7 are from photographs taken by Mr. J. M. Jessup and slightly retouched by pencil.



SIDNEYIA INEXPECTANS

DESCRIPTION OF PLATE 3

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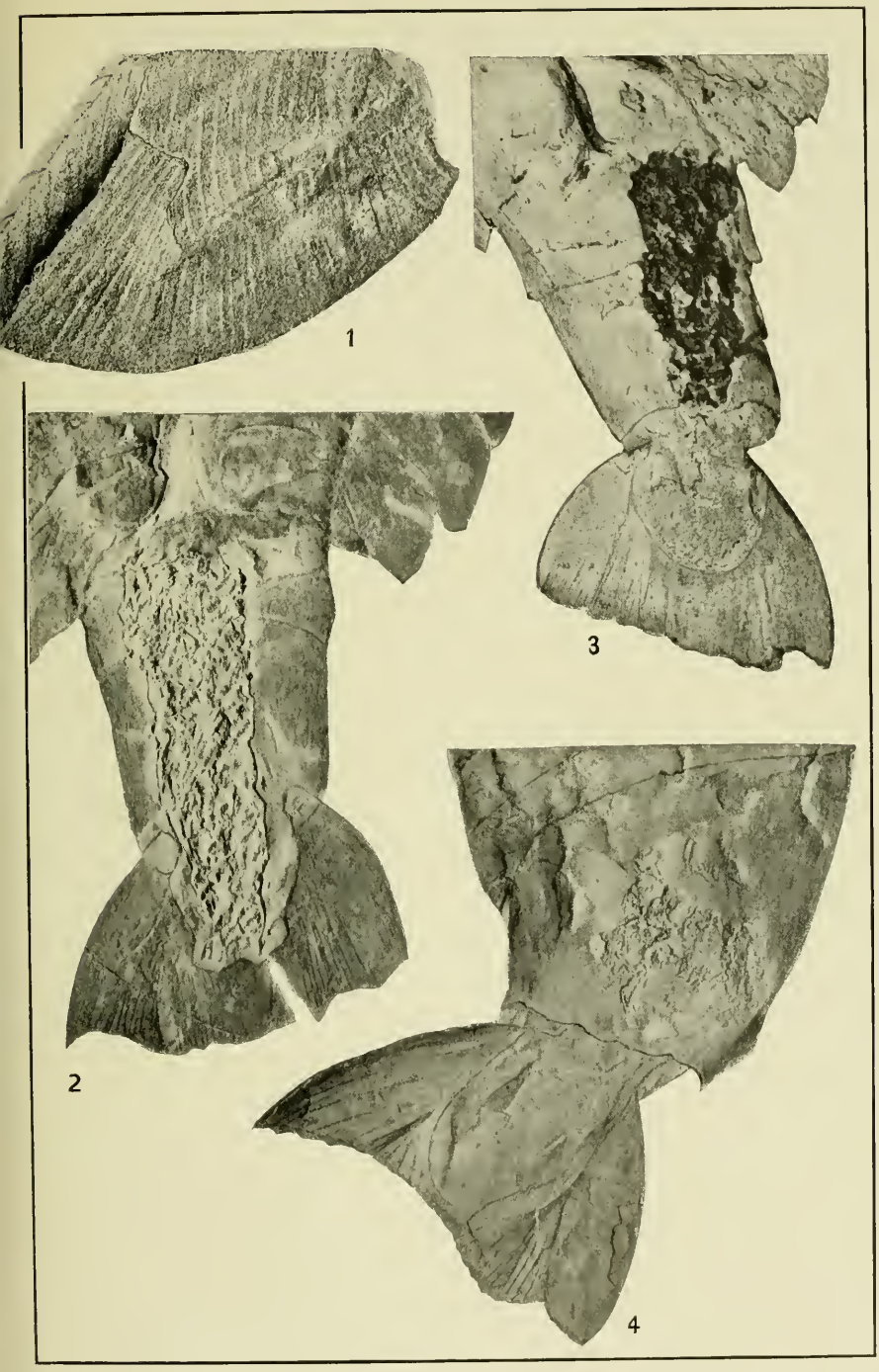
FIG. 1. A portion of a branchial leaf or lamella showing something of the structure. ×3. U. S. National Museum, Catalogue No. 57486.

2. Enlargement (×2) of the posterior segments of a specimen showing what appears to have been the contents of the alimentary canal. U. S. National Museum, Catalogue No. 57489.

3. Enlargement (×2) of the caudal fin of the specimen represented by fig. 2, pl. 5.

4. Enlargement (×2) of the caudal fin of the specimen represented by fig. 1, pl. 2.



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DESCRIPTION OF PLATE 4

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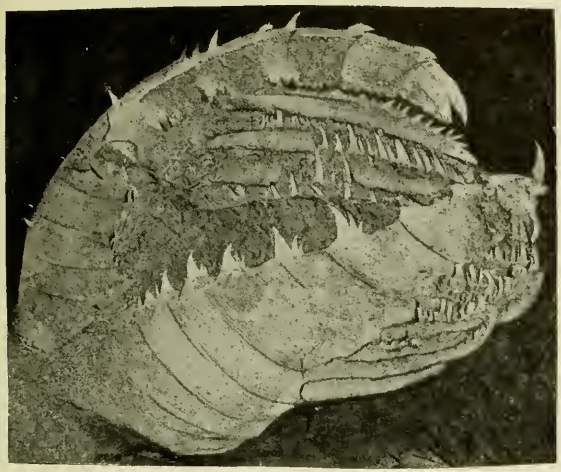
FIG. 1. Outer portion of the third pair of appendages of the cephalo-thorax (×2). In this there appears to have been a somewhat different development of parts as compared with those seen in figs. 3 and 4. U. S. National Museum, Catalogue No. 57490.

2. Another form of the outward extension of one of the third pair of appendages of the cephalo-thorax (×2). This type reaches a very large size; one has a length of 65 mm. U. S. National Museum, Catalogue No. 57491.

3. Outer extension of a part of one of the outer portions of the compound chelate termination of a third appendage (×2). The anterior arm, as shown in figs. 1 and 4, is broken away. U. S. National Museum, Catalogue No. 57492.

4. Outer portion of one of the third pair of appendages of the cephalo-thorax, showing on the jointed primary appendage large, elongated spines with spinose fringes and a short, jointed appendage attached to the posterior outer side of the gnathobase. ×2. U. S. National Museum, Catalogue No. 57493.



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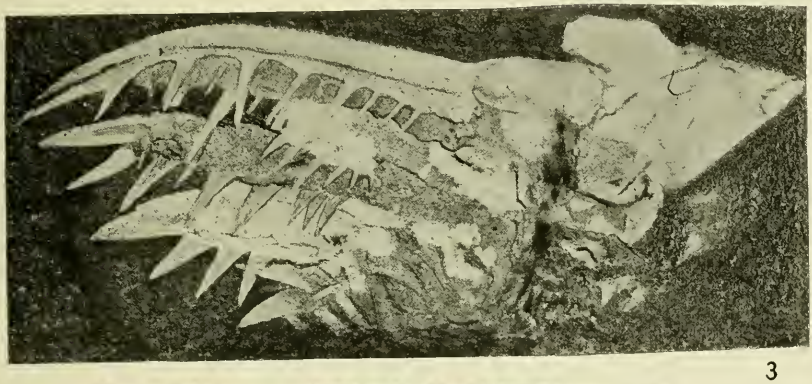

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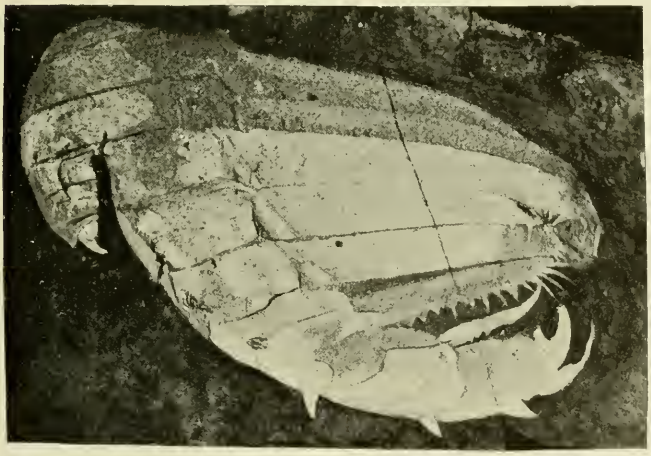

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SIDNEYIA INEXPECTANS

DESCRIPTION OF PLATE 5

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FIG. 1. The third, fourth, and fifth appendages of the cephalo-thorax, showing the gnathobases and something of the proportions of the appendages. ×3. U. S. National Museum, Catalogue No. 57494.

2. A small, nearly entire dorsal shield flattened and broken by compression in the shale. The position of the visceral cavity beneath the abdomen is faintly indicated through the thin test. Natural size. U. S. National Museum, Catalogue No. 57495.

3. A large epistoma attached to the frontal rim of the cephalo-thorax and crowded back over the two anterior segments of the abdomen. Natural size. U. S. National Museum, Catalogue No. 57496.

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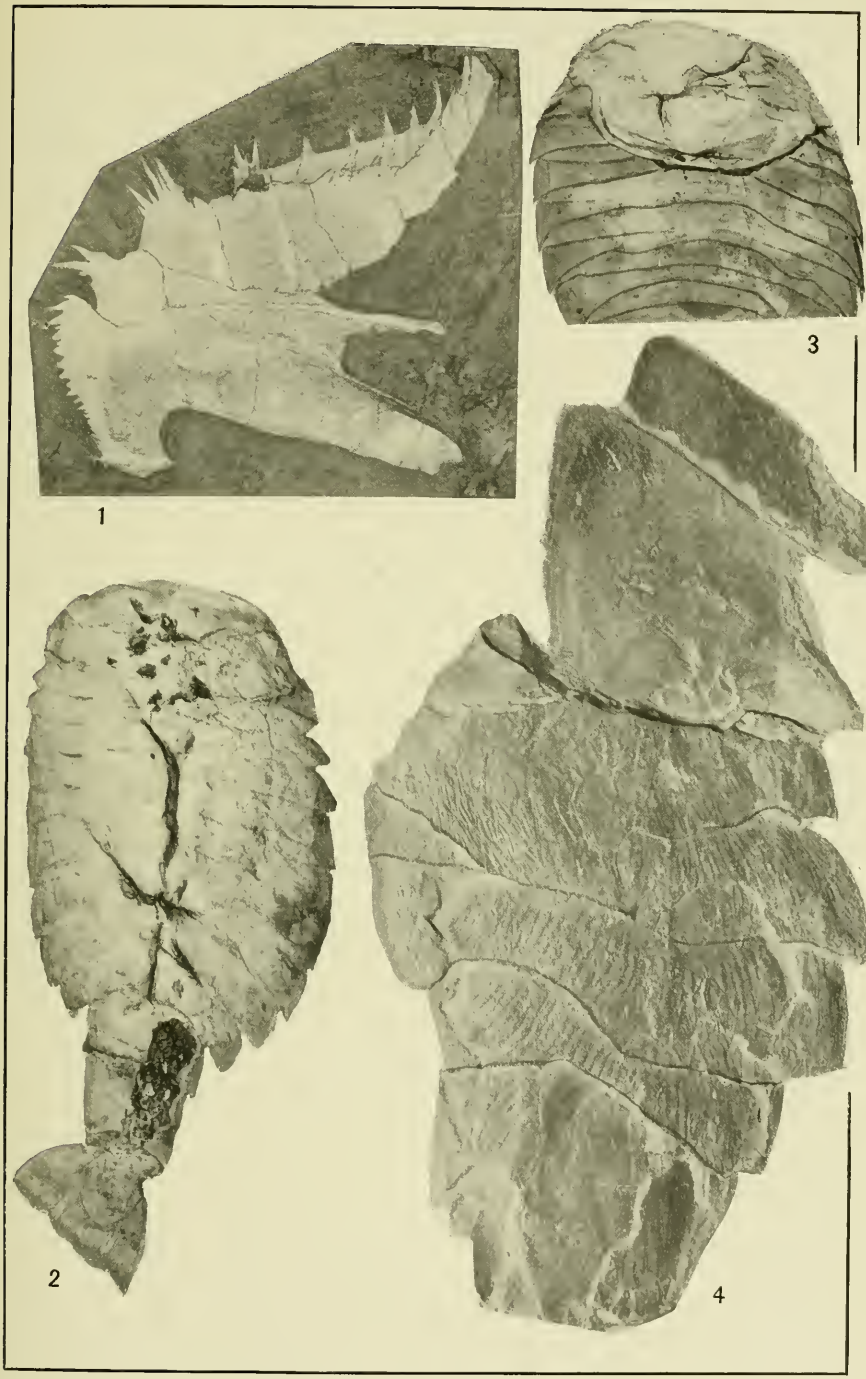
FIG. 4. Portion of a broken dorsal shield, showing parts of several abdominal segments which have been pushed one over the other. ×2. U. S. National Museum, Catalogue No. 57499.



SIDNEYIA INEXPECTANS AND AMIELLA ORNATA

DESCRIPTION OF PLATE 6

PAGE

Neolenus serratus (Rominger) 27

FIG. 1. Branchial fringes on the exopodites of the left side of the interior of a compressed dorsal test. × 1.5. Other specimens show the endopodites as slender, jointed legs. The specimen photographed was associated with *Sidneyia inexpectans*. U. S. National Museum, Catalogue No. 57500.

2. A cephalic endopodite with lamellated branchial fringe. × 3. This occurs on the opposite side of the specimen represented in part by fig. 1.

Sidneyia inexpectans Walcott 24

FIG. 3. Photograph by reflected light of a broken specimen of the dorsal shield through which may be seen traces of the branchial lamellae and fringes and some of the appendages of the cephalo-thorax. Natural size. U. S. National Museum, Catalogue No. 57497.

1

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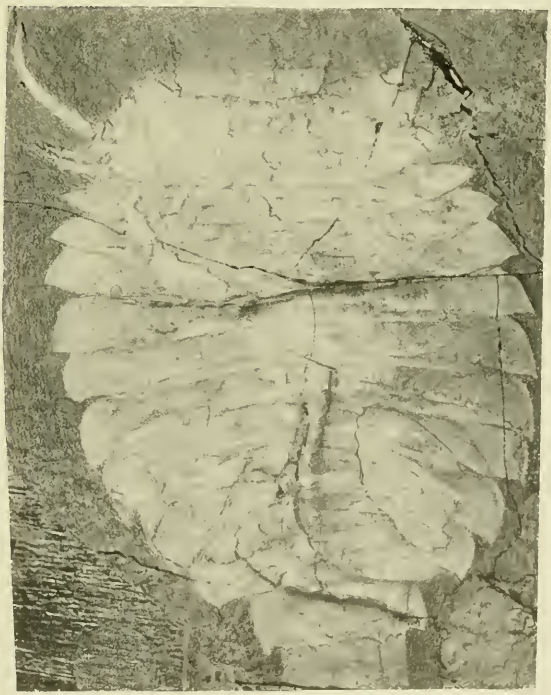


3

NEOLENUS SERRATUS AND SIDNEYIA INEXPECTANS

DESCRIPTION OF PLATE 7

PAGE

Sidneyia inexpectans Walcott 24

FIG. 1. Fragment of the ventral side of a small dorsal shield. ×2. This shows the position of the leaf-like branchiae and branchial fringes. U. S. National Museum, Catalogue No. 57498.

Beltina danai Walcott 21

FIG. 2. Fragment of the cephalo-thorax, showing the posterior margin, a low, broad furrow, and in advance of that, irregular, transverse ridges and scattered tubercles. Natural size. U. S. National Museum, Catalogue No. 57501.

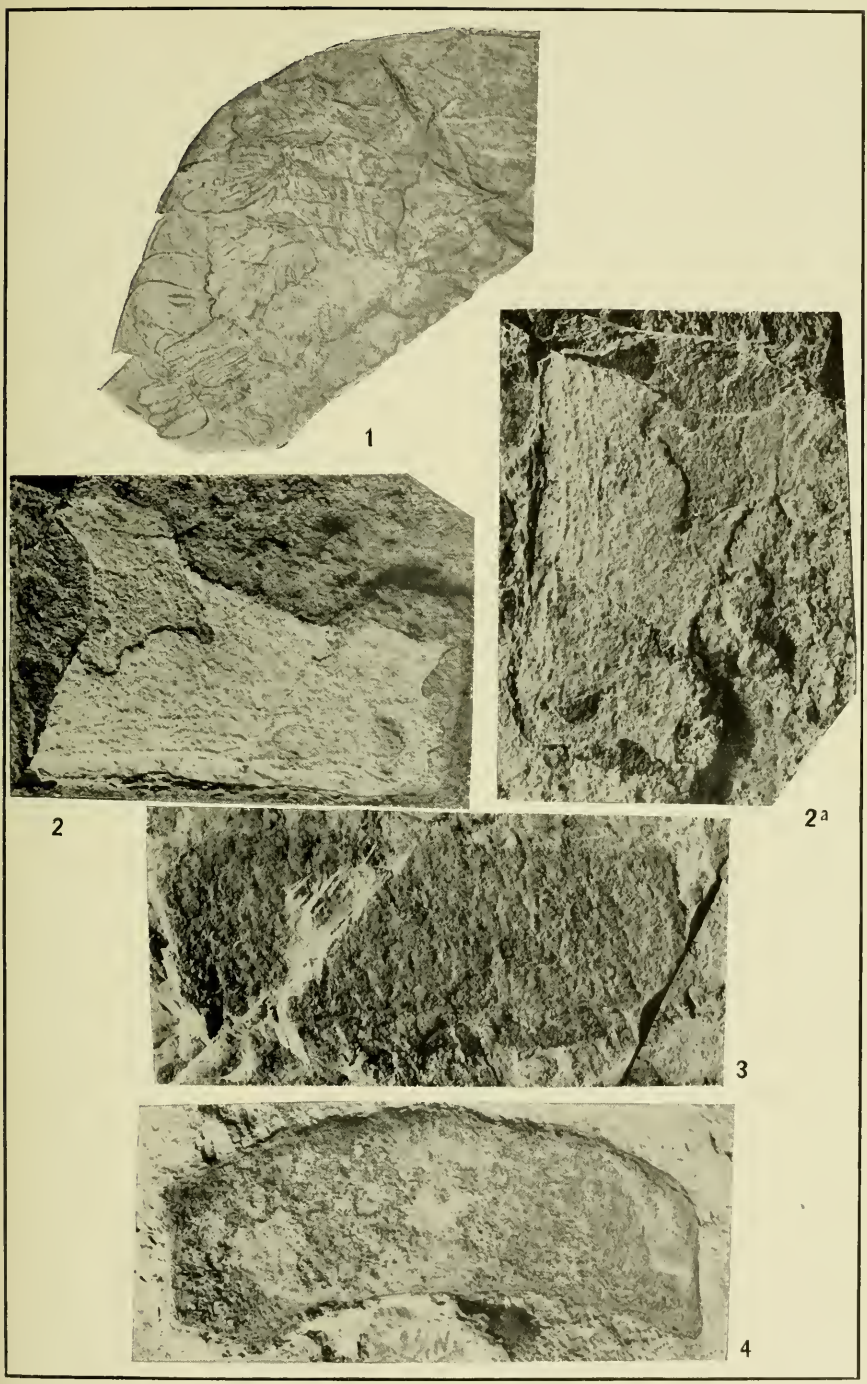
2a. An untouched photograph of the specimen represented by fig. 2.

3. An abdominal segment compressed in the siliceous shale that preserves more or less of the tuberculated surface. Natural size. U. S. National Museum, Catalogue No. 57502.

The specimens represented by figs. 2 and 3 are from locality (14z) Algonkian: near the head of Johnson Creek on the Continental Divide west of Pincher Post Office, Alberta, Canada.

4. A large abdominal segment preserving a portion of the original convexity and tuberculated surface. Natural size. U. S. National Museum, Catalogue No. 57503.

The specimen represented by fig. 4 is from locality (14y) Algonkian: Altyn limestone; southeastern base of Appekuny mountain, opposite the mouth of Canyon Creek, in Swift Current Creek valley, at second gap from eastern end of mountain, near Altyn, Montana.



SIDNEYIA INEXPECTANS AND BELTINA DANAI

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 57, NUMBER 3

CAMBRIAN GEOLOGY AND PALEONTOLOGY

II

No. 3.—MIDDLE CAMBRIAN HOLOTHURIANS AND MEDUSÆ

With Six Plates

BY

CHARLES D. WALCOTT

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CAMBRIAN GEOLOGY AND PALEONTOLOGY

II

No. 3.—MIDDLE CAMBRIAN HOLOTHURIANS AND MEDUSÆ

By CHARLES D. WALCOTT

(With Six Plates)

CONTENTS

PLATES

TEXT FIGURES

INTRODUCTION

The first paper on Middle Cambrian fossils from British Columbia included the description and illustration of some new types of Merostomes.[1] This paper contains a preliminary notice of the discovery of certain forms of Holothurians and one new Medusa.

That the tests of Trilobites and Merostomes should be finely preserved in a fine-grained, silico-argillaceous rock is rather to be expected, but with past experience in view I was not prepared to find entire Holothurians. That they are present and show many details of structure is most instructive and satisfactory, since their occurrence records for the first time, with the exception of some scattered calcareous spicules and plates, the presence of this class of organisms in any geologic formation. Any calcareous matter that may have been present in them was probably removed by solution while the animal was in the mud and before it became fossilized. That carbonic acid gas was present in the mud and immediately adjoining water is suggested by the very perfect state of preservation of the numerous and varied forms of life. These certainly would have been destroyed by the worms and predatory crustaceans that were associated with them, if the animals that dropped to the bottom on the mud or that crawled or were drifted onto it were not at once killed and preserved with little or no decomposition or mechanical destruction. This conclusion applies to nearly all parts of a limited deposit about six feet in thickness, and especially to the lower two feet of it.

The stratigraphic position of the shale carrying the fossils described is given in a section of the Ogygopsis zone of the Stephen formation published in 1908.[2]

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[1] Smithsonian Misc. Coll., Vol. 57, No. 2, 1911, pp. 18-28, pls. 2-7.

[2] Walcott, 1908, Smithsonian Misc. Coll., Vol. 53, No. 5, pp. 210 and 211.

HOLOTHURIANS

Heretofore the only paleontologic evidence of the Holothurians has been the presence, in rocks of late Paleozoic and post Paleozoic age, of the spicules of those forms having a calcareous subepidermic skeleton. To find, in the Middle Cambrian, representatives of the Actinopoda, both with and without podia, and a form indicating a second order, Paractinopoda, is a great surprise. This estab-

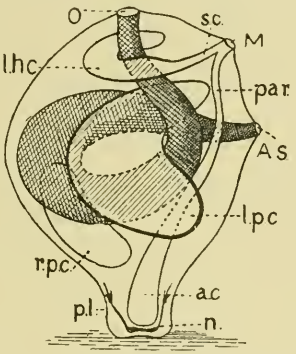

FIG. 2.—Diagrammatic reconstruction of the imagined primitive Pelmatozoic ancestor. (After Lankester, 1900, fig. 7, p. 9.[1]) O = mouth; As = anus; ac = right and left anterior portion of cœlom; rpc and lpc = right and left posterior portion of cœlom; lhc = left hydrocœl; sc = canal connecting lhc and ac; par = parietal canal; M = dorsal pore; pl = preoral lobe with nerve center n.

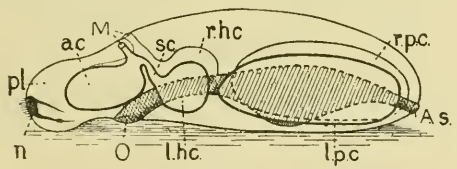

FIG. 3.—Diagrammatic reconstruction of imagined *Dipleurula* ancestor. Anterior end at left of drawing; organs of left side toward observer, and with stronger outline than those of right side. (After Lankester, 1900, fig. 1, p. 4.[2]) O = mouth; As = anus; ac = right and left anterior portion of cœlom; rpc and lpc = right and left posterior portion of cœlom; rhc and lhc = right and left hydrocœls; sc = canal connecting lhc and ac; M = dorsal pore; pl = preoral lobe with nerve center n.

lishes the very ancient origin of the Class Holothurioidea and the fact of its great differentiation in Middle Cambrian time. This is particularly true of the free swimming, pelagic form, *Eldonia ludwigi*.

Among zoologists the theoretically most primitive ancestor of the

[1] Lankester, Treatise on Zoology, pt. 3, Echinodermata, 1900, p. 9.

Echinodermata[1] is considered to have passed through a "Pelmatozoic" stage in which the animal was attached to some object by a part of its body wall, and in which the mouth and, to a less extent, the other apertures faced upward. This stage is represented by text fig. 2.

Selecting the characters common to the early stages of all Echinoderms, a diagrammatic reconstruction of this imaginary phylogenetic stage gives a marine animal with the longer antero-posterior axis parallel to the sea floor. The mouth was antero-ventral, anus posterior or postero-ventral, the two joined by an uncoiled gut with perhaps a stomachal enlargement in the middle as represented by fig. 3.

The simplest larval form among recent echinoderms, *Auricularia* of the Holothurians, differs from fig. 3 in being bent upon its ventral surface so that the mouth lies in the middle of a concavity and the anus on the ventral surface of the lobe back of the concavity. It also shows a decided change in the arrangement of the coil of the alimentary canal and the cœlomic cavities, as may be seen by comparing figs. 3 and 4.

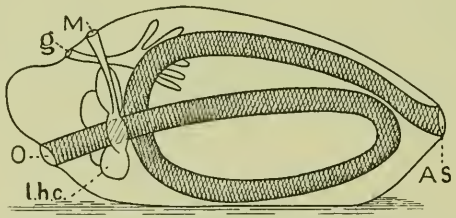

FIG. 4.—Diagrammatic reconstruction of the imagined primitive Holothurian type. (After Lankester, 1900, fig. 16, p. 18.[1]) O = mouth; As = anus; lhc = left hydrocœl; M = hydropore; g = genital opening.

I have mentioned the theoretical ancestor of the echinoderm and of one of its classes, Holothurioidea, in order to note that the zoologist has not carried his theoretical line back to the period when the ancestral form was pelagic and had not yet adjusted itself to the conditions of the littoral zone, stages which must have preceded the migration of this organism over the bottom into the deeper water. This still earlier ancestor must have been a free swimming, soft bodied animal. It undoubtedly was more simple than the free swimming *Eldonia ludwigi* described in this paper, and I can readily imagine a small bell-shaped body with a simple alimentary canal opening at both ends on the ventral surface—a medusa-like object

[1] See footnote on p. 43.

that had not yet been distorted by attachment to any foreign body as in fig. 2.[1]

Among the echinoderms of the Middle Cambrian we have heretofore known only the Cystidæ. To it we are now able to add several representatives of the more highly organized Holothurioidea. Of the six families of the Holothurioidea recognized by Ray Lankester (1900, p. 226), three are represented: two directly and one indirectly. The Holothuriidæ is represented by *Laggania cambria* and *Louisella pedunculata* and the Synaptidæ by *Mackenzia costalis*. The Pelagothuridæ is indirectly represented by *Eldonia ludwigi*.

With the thought of returning to the field and making a much more thorough search for animals of this class during the field season of 1911, I will not add to these preliminary notes or attempt to draw further deductions that may soon be strengthened or disproved. Certain obscure remains suggest the presence of other forms of the Holothurioidea that may be of essential service in working out the Cambrian representatives of the class.

Class HOLOTHURIOIDEA Siebold, 1848

Order ACTINOPODA

Family ELDONIIDAE, new family

Body medusa-like, disk-shaped. Mouth and anus ventral. Water vascular system radial from aboral pole. No podia. No respiratory trees. No calcareous skeleton.

Genus *Eldonia,* new genus, represented by one free swimming species, *Eldonia ludwigi,* new species, of Middle Cambrian age.

Genus ELDONIA, new genus

Eldonia is characterized by a depressed, umbrella-shaped, radially lobed medusa-like body, with a broad band of concentric muscle fibers on the outer half of the subumbrella surface. Mouth ventral and provided with "peltato-digitate" retractile tentacles.

---

[1] After the above was written, I talked with Dr. Austin H. Clark, who does not agree with the greater number of zoologists that the ancestors of all echinoderms were attached. He called my attention to his paper "On the origin of certain types of crinoid stems," in which he notes the prolonged free swimming stage of the larvæ of *Tropiometra* and that the larvæ of echinoderms are highly specialized and fitted for quite a different mode of existence from that of the adults. (Proc. U. S. Nat. Museum, Vol. 38, 1910, p. 213.)

The alimentary canal is large, coiled in a loose, flat spiral and divided into an oral chamber, œsophagus, stomach, and intestine, the end of the intestine opening on the ventral surface.

Specimens of the type species grew to a large size, 12 cm. in diameter. This form was gregarious and lived in large numbers in quiet waters in association with a large, free swimming crustacean fauna.

Genotype.—Eldonia ludwigi, new species.

Stratigraphic range.—Limited to a stratum of dark siliceous shale a few inches in thickness in the lower portion of the Ogygopsis zone (=Burgess shale), of the Stephen formation as described in 1908. (See footnote on page 51 of this paper.)

Geographic distribution.—On the slope of the ridge between Wapta Peak and Mount Field, north of Burgess Pass, and about 3800 feet above Field on the line of the Canadian Pacific Railway, British Columbia, Canada.

ELDONIA LUDWIGI, new species

Text fig. 5; pl. 8, fig. 3; pl. 9, figs. 1-5; pl. 10, figs. 1-3; pl. 11, figs. 1-3; pl. 12, figs. 1-3.

Body disk-formed or depressed umbrella-shaped. Exumbrella with about thirty clearly defined lobes that radiate from the center to the edge of the disk. Each lobe has a slight depression or line down the center that extends in from the outer margin from one-half to two-thirds the distance to the center (pl. 12, fig. 3). This secondary lobation gives about sixty slightly projecting, rounded lappets about the margin of the disk. In small specimens flattened sideways in the shale (pl. 11, figs. 1 and 2), the secondary lobation is emphasized so that the narrow lobes (of the 60 series) extend inward toward the center. The lobation of the exumbrella is shown by fig. 5, pl. 9; figs. 1 and 2, pl. 11; and fig. 3, pl. 12.

The surface of the subumbrella has a broad band of concentric muscle fibers that extends about half way to the center of the disk (pl. 9, fig. 5). The fibers are very fine and do not appear to be interrupted by any radiating divisions of the subumbrella surface.

From the subumbrella surface the mouth, with two short tentacles when expanded, extended downward. (See description of oral chamber and tentacles, following.)

Muscles.—Of the muscular system only the concentric muscles of the subumbrella surface have been seen, as mentioned (fig. 5, pl.

9). There were probably radial muscles and muscles of the enteric canal and tentacles, but these have not been observed.

Radial canals.—The system of radial canals is very striking, and medusa-like. They radiate from a central ring canal (cr) out to the margin of the umbrella. The tube-like character is probably best

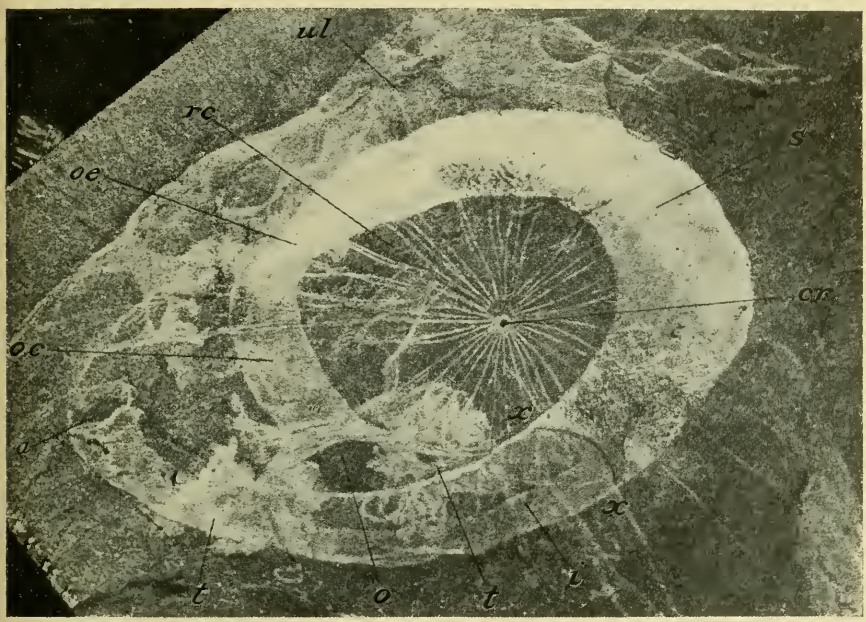

FIG. 5.—*Eldonia ludwigi.* × 2. A specimen flattened in the shale and preserving the alimentary canal, oral aperture and tentacles, water vascular system and traces of the umbrella. U. S. National Museum, Catalogue No. 57537.

ul = umbrella lobes crushed and macerated; cr and rc = central ring and radial canals of vascular system; o = oral aperture; tt = peltatodigitate tentacles; oc = oral chamber; œ = œsophagus; s = stomach; I = intestine; x = approximate point of union of stomach and intestine. The latter is better shown by fig. 2, pl. 10; and figs. 1 and 2, pl. 12.

shown by fig. 3 of pl. 11. They are usually crushed down with the alimentary canal and all traces there lost, but in several examples some of the canals may be traced across the broad canal and out on the disk beyond. On a few specimens (pl. 8, fig. 3) some of the radiating canals merge into rings that line the inner side of the margin of the alimentary canal. On the outside of the alimentary canal in this specimen the flattened radial canals appear like narrow ribbons or bands united by fine fibers that may be traces of concentric muscles. Where the outer margins of the umbrella have been macerated

and destroyed the remains of the radiating canal system appear as fine, more or less irregular, shiny lines on the dark background.

Alimentary canal.—The alimentary canal is an open spiral located concentrically in the umbrella about midway between the center and margin of the disk (pl. 9, fig. 5). It is clearly shown in over two hundred specimens in the collection. The anterior or oral end opened on the surface of the subumbrella at a point about one-half the distance between the center and the outer margin, and the posterior or anal end opened farther out toward the margin. The coil of the canal was dextral or left to right and probably nearly on the same plane except that the anterior end bent downward from the region of the œsophagus and the anal end may also have been curved slightly downward. The bending of the anterior side is indicated by fig. 5, pl. 9, and text fig. 5.

The canal appears to be more or less corrugated (pl. 9, fig. 3; and pl. 10, fig. 3). Whether this corrugation has anything to do with the radial canals or lobes of the umbrella has not been satisfactorily determined, except that the radial lobation and the divisions formed by the slight constrictions causing the corrugation appear to be more or less in accord in size and position. The corrugations show more clearly on the outer margin of the canal. The canal is beautifully outlined on the dark, smooth shale by the glistening silver-like luster of the stomach section and the less prominent but distinct outlines of the oral and intestinal sections.

The canal is divided into four sections that, compared with the typical holothurian alimentary canal, may be considered as the oral chamber, œsophagus, stomach, and intestine.

The oral chamber is indicated (fig. 5, pl. 9) at the inner end of the spiral alimentary canal. The chamber extends from the outer end to the constriction indicating the œsophagus a little beyond the dotted line leading from the center out to the letters " cr ". This chamber is also more or less clearly shown by fig. 3, pl. 8; fig. 1, pl. 9; and text fig. 5. (In this description it must be constantly recalled that we are dealing with specimens flattened in the shale.)

The outer opening of the oral chamber is best shown by fig. 5, pl. 9. A number of specimens show that from each side of the flattened opening there is a short projecting arm which supports a cluster of short tentacles, or, if we interpret the short arm as a strong tentacle, with a disk to which are attached digits, the whole tentacle being retractile and capable of being withdrawn into the oral chamber. Some of the specimens suggest a three-lobed disk (text fig. 5). With

the material now available it is not perfectly clear how many of the "peltato-digitate" tentacles originally existed. Two only have thus far been seen on each of several beautifully preserved specimens. It may be that five will be found, two of which will be fully developed and three immature or atrophied.

The constriction indicating the œsophagus is present in many specimens. In fact, the canal always narrows at this point even though the oral chamber is not expanded in front of it. The elongated constriction of the œsophagus is well shown by text fig. 5.

The stomach is the prominent and best preserved part of the animal. It occupies the largest part of the alimentary canal and appears to have had strong, more or less corrugated walls, and invariably to contain traces of the food in it at the time of the animal's death. This is shown by nearly all of the figures on plates 8-12. The length of the stomach is indicated by figs. 1 and 4, pl. 9; fig. 2, pl. 10; and figs. 1 and 2, pl. 12. Side views of the compressed stomach are shown by fig. 3, pl. 9; and figs. 1 and 2, pl. 11.

The strong walls of the stomach are indicated by fig. 2, pl. 10, also by the fact of its preservation when the remaining portions of the animal have disappeared. Upward of two hundred specimens, in various conditions of preservation, were found in the collections of 1910, and in all of these the stomach was clearly defined. In the simplest form only the outline of the stomach was preserved (fig. 3, pl. 10; and figs. 1 and 2, pl. 12), but there are all the gradations between this and instances where nearly the entire animal is preserved (fig. 3, pl. 8; and fig. 5, pl. 9).

The posterior end of the stomach is located where the alimentary canal usually contracts abruptly in size and the shiny area of the stomach terminates. This is illustrated very definitely by fig. 2, pl. 10; also by figs. 1 and 4, pl. 9; and figs. 1 and 2, pl. 12.

The intestine is usually as long as and less than one-half the diameter of the stomach. In some examples the canal shows traces of matter inside of it (pl. 9, fig. 1; and pl. 10, fig. 2). The intestine contracts at its posterior end (pl. 12, figs. 1 and 2), but as yet the actual anal aperture has not been observed.

Genital organs.—The only suggestion of a genital organ is shown on fig. 5, pl. 9, at (g) where a three-lobed body is pressed in with the subumbrella surface.

Dimensions.—The largest specimen is represented by fig. 3, pl. 12. The right and left sides have been partly folded under and lost, but by taking the average width of the lobed umbrella outside of the

alimentary canal the diameter of the umbrella must have been about 12 cm. That the greater number of specimens were smaller is proven by the size of the spiral alimentary canal.

Occurrence.—All of the specimens found were in a layer of shale averaging two inches in thickness, and usually on the middle split of the layer. Trilobites of the genus *Ptychoparia,* several phyllopod crustaceans, and sponges occur in the same layer and often on the same surface with *Eldonia ludwigi.*

Observations.—To the zoologist acquainted with the Holothurioidea more questions will be raised by this remarkable fossil than I have answered in text or illustration. Perhaps the best way to present the case will be to relate my experience. When collecting in the summer of 1910, the specimens were noted as remains of a new and beautiful medusa. The following November the material was partially unpacked and examined, photographs made of several specimens, and at the Pittsburg meeting of the Geological Society of America, December 29, 1910, a brief description illustrated by lantern slides was given. The medusa was still appealed to, to explain the general structure, but only by considering the large, coiled, elongate body as a commensal annelid could the medusa view be retained. In March, with all the material unpacked and available, a preliminary study was made of the numerous associated annelids and the supposed commensal annelid, and the conclusion was reached that neither the medusa nor the commensal annelid view could be sustained. Dr. Austin H. Clark suggested that as the spiral alimentary canal was characteristic of the Echinodermata, it might be that this form was allied to the free swimming *Pelagothuria.* This led to a comparison with *Pelagothuria natatrix* Ludwig.[1] I finally concluded that our new form was related to the holothurians, but that it was quite unlike *Pelagothuria,* the only described free swimming holothurian, and far more unlike the typical forms of the class. Except for the presence of the large spiral alimentary canal I should have returned to the medusa view at this point. There was no *a priori* reason why a holothurian should not have a medusa-like form, as noted by Dr. A. G. Mayer,[2] but I found that the body of *Pelagothuria* was cylindrical; the disk an enlargement of the body at the base of the tentacles; and that the mouth opened at the dorsal surface, and the anus at the end

[1] Mem. Mus. Comp. Zool., Vol. 17, 1894, No. 3, p. 114.

[2] Medusæ of the World; Publication No. 109, Carnegie Institution of Washington, 1910, Vol. 3, p. 499.

of the proboscis-like lower portion of the body. In contrast the Middle Cambrian type had a true medusa-like umbrella; concentric subumbrella muscle band; spiral subhorizontal alimentary canal, with mouth and anus off to one side of the center; and, judging from what is known of the umbrella-like body, opening at the ventral surface. The water vascular system indicated by the central ring (cr) and numerous radiating canals (rc) (pl. 8, fig. 3; and pl. 9, figs. 1 and 5), also serves to give the Cambrian form a character unlike that of *Pelagothuria*.

That the mouth and anus should open on the ventral surface is not unexpected, and the development of the radiate structure of the smaller canal system is also the result of the animal's gradually shifting the relations of its parts to each other, in the course of adjustment to its pelagic habitat.

The finding of a true medusa at the same locality, *Peytoia nathorsti* (pl. 8, figs. 1 and 2), also many free swimming crustaceans, indicates that the environment and food supply were favorable to a free swimming holothurian. The presence at the same locality of typical holothurians is very instructive, although they occur three to four feet lower down in the shales.

The specific name is given in honor of Dr. H. Ludwig, who has done such splendid work on the holothurians dredged by the Albatross.[1]

Formation and locality.—Middle Cambrian: (35k) Burgess shale[2]

[1] Mem. Mus. Comp. Zool., Vol. 17, 1894, No. 3, pp. 1-184, pls. 1-19.

[2] BURGESS SHALE

This name is proposed as a geographic name for a shale to which the term of Ogygopsis shale was given in 1908 (Smithsonian Miscellaneous Collections, Vol. 53, p. 210). It is proposed to call it the Burgess shale of the Stephen formation.

Type locality.—Burgess Pass east of Mount Burgess and on the west slope of Mount Field and the ridge extending to Wapta Peak. About 3000 feet above and from three to five miles on the trail from the town of Field on the Canadian Pacific Railway, British Columbia, Canada. The Burgess formation occurs to the southward across the Kicking Horse Canyon in the side of Mount Stephen.

Derivation.—From Burgess Pass, the type locality.

Character.—Argillaceous, calcareous, and silico-argillaceous shales.

Thickness.—On the west slope of Mount Field, 420 feet; on the northwest slope of Mount Stephen, about 150 feet.

Stratigraphic position.—Above thin bedded, dark gray, and bluish-black limestones of the Stephen formation, and beneath a thin bedded limestone

of the Stephen formation; west slope of ridge between Mount Field and Wapta Peak, one mile northwest of Burgess Pass, above Field on the Canadian Pacific Railway, British Columbia, Canada.

Collected by Mr. and Mrs. C. D. Walcott, and B. Stuart and Sidney S. Walcott.

Family HOLOTHURIIDÆ

Genus LAGGANIA, new genus

Of this species only one specimen and its matrix is known. This indicates that the body was elongate, pear-shaped, and slightly flattened on the ventral surface. Mouth ventral, near the anterior end, and surrounded by a ring of plates. Surface marked by longitudinally radiating lines. Traces of tube feet occur on the ventral surface.

Genotype.—*Laggania cambria,* new species.

Stratigraphic range.—Limited to a parting in a stratum of dark siliceous shale .2 feet in thickness in the lower portion of the Ogygopsis zone (=Burgess shale) of the Stephen formation as described in 1908. (See the footnote on page 51 of this paper.)

Geographic distribution.—On the slope of the ridge between Wapta Peak and Mount Field, north of Burgess Pass, and about 3800 feet above Field on the line of the Canadian Pacific Railway, British Columbia, Canada.

LAGGANIA CAMBRIA, new species

Plate 13, fig. 1.

There is not much that can be added to the brief generic description. The body of the animal is so completely flattened that the tube feet are obscured, the outline of the ventral sole lost, and the concentric bands almost obliterated. It is not practicable to make out the arrangement of the plate-like structure surrounding the mouth, as the calcareous plates, if ever present, have disappeared.

The surface shows indistinct concentric bands, each one of which is crossed by fine longitudinal lines.

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

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below the massive, arenaceous limestones of the Eldon formation that cap Mount Burgess, Mount Field, and Mount Stephen.

Organic remains.—Middle Cambrian: large and varied fauna characterized by crustacean remains on the slope of Mount Field and the Ogygopsis trilobite fauna on the northwestern slope of Mount Stephen.

Genus LOUISELLA, new genus

Elongate, cylindrical body tapering toward the anterior and posterior ends. Flattened on the ventral surface. With numerous tube feet or podia in two longitudinal rows, and what may be papillæ on two peltate extensions at the posterior end. Mouth and anus unknown but probably terminal.

Genotype.—Louisella pedunculata, new species.

The stratigraphic range and geographic distribution are the same as for *Laggania* (p. 52).

LOUISELLA PEDUNCULATA, new species

Plate 13, fig. 4.

Only one specimen of this species is known. The main outlines of its description have been given under the genus. Although the specimen is flattened in the rock the ventral sole is beautifully outlined by the marginal row of podia on each side. This probably results from the thickening of the body wall along the ventral side.

The two peltate extensions at the posterior end suggest very strongly the presence of numerous papillæ along their margins as in the recent *Scotoplanes insignis* Theel.[1] A somewhat similar but obscure fringe occurs at the anterior end which may indicate tentacles or papillæ.

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

Family SYNAPTIDÆ[2]

Body cylindrical and elongated. Mouth and anus terminal. Calcareous ring surrounding the œsophagus. Tentacles pennate or digitate. Without podia or radial canals.

The above outline describes the family as far as it is necessary to include all that is known of *Mackenzia costalis* within it. Future discoveries may afford data by which to draw it closer to this family, or to remove it to a new one, probably the latter. At present nothing is known of spicules in the Cambrian species.

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[1] Voyage of H. M. S. Challenger, Zoology, Vol. 4, Holothurioidea I, pl. 7, figs. 1-3.

[2] See Treatise of Zoology, by E. Ray Lankester; pt. 3, p. 234, for definition of family.

Genus MACKENZIA, new genus

Body elongate, cylindrical. Anterior end with a circle of plates about it (as preserved as casts on the rock). Posterior end slightly contracted, mouth terminal. Anus unknown but probably terminal. Tentacles and interior structure unknown.

Genotype.—Mackenzia costalis, new species.

The stratigraphic range and geographic distribution are the same as for *Laggania* (p. 52).

FIG. 6.—*Synaptula hydriformis* (Lesseur). Adult animal. Natural size. (After Clark, 1907, pl. 6, fig. 5.[1])

This rare form was first placed among the annelids when the collection was unpacked, but with the study of the material preparatory to photographing the different species it was removed to the holothurians. The cylindrical form, circle of plates, and banded appearance at once suggested a fossil resembling *Synaptula hydriformis* (Lesseur) but without its beautiful tentacles.[1]

[1] Clark, H. L., 1907, Smithsonian Contributions to Knowledge, Vol 35, pl. 6, fig. 5.

MACKENZIA COSTALIS, new species

Plate 13, figs. 2 and 3.

Body elongate, cylindrical, and contracting at each end. Marked by from eight to ten longitudinal bands that are outlined by narrow, slightly elevated lines as shown in fig. 3, pl. 13. The anterior end has a ring of what appear to be narrow plates surrounding a central opening. The interpretation of the ring is that it formerly surrounded the œsophagus near its outer end and that the outer margin of the œsophagus with the tentacles has been removed. The posterior end is contracted slightly. No trace of the anal opening has been seen.

Surface smooth so far as determined.

Two specimens have been found and photographs of both are reproduced (natural size) by figs. 2 and 3, pl. 13.

As mentioned under the genus, the body of this species has the general form of the body of *Synaptula hydriformis* (Lesseur).

No traces of calcareous deposits have been observed, except possibly in the ring about the anterior end. In this the calcareous matter, if it was originally present, has been removed. My present impression is that nearly all calcareous matter was removed by solution in the mud deposit prior to its consolidation and alteration into rock.

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

SCYPHOMEDUSÆ

Order RHIZOSTOMÆ

Family Undetermined

Genus PEYTOIA, new genus

All that is known of this genus is given under the description of the species *P. nathorsti.*

The relation of the genus to the Order Rhizostomæ is shown by its

(a) Discoidal bell without known annular furrow or pedalia,

(b) Margin of bell cleft into lappets,

(c) Absence of tentacles, and

(d) Mouth probably with adradial arm-like processes.

The presence of so highly organized a medusa in the central part of the Middle Cambrian terrane is not surprising in view of the numerous traces of Medusæ in strata of Lower Cambrian age.

Genotype.—*Peytoia nathorsti,* new species.

Stratigraphic range.—Limited to a stratum of dark siliceous shale 2 feet in thickness in the lower portion of the Ogygopsis zone (=Burgess shale) of the Stephen formation as described in 1908. (See footnote on page 51 of this paper.)

Geographic distribution.—On the west slope of the ridge between Wapta Peak and Mount Field, north of Burgess Pass, and about 3800 feet above Field on the line of the Canadian Pacific Railway, British Columbia, Canada.

PEYTOIA NATHORSTI, new species

Plate 8, figs. 1 and 2.

Of this medusa we have three specimens of the impression made by the subumbrella lobes. The flattened disk has a broadly elliptical outline with the outer margin slightly indented where the outward curving ends of the lobes unite so as to indicate very short, rounded lappets.

There are thirty-two lobes arranged in a quadrate series. This includes four large lobes, one extending outward on each side of the quadrate central opening, and seven narrow lobes between the broad lobes in each quadrant. The inner ends of the lobes terminate so as to form a quadrate opening with one of the broad lobes at the center of each side. Each lobe has two short, broad points that project inward a short distance. These points appear to have been the points of attachment of the parts about the mouth, or possibly oral arms.

No traces of a concentric muscle band.

A few radial lines parallel to the margins of the lobes serve to define a narrow band on each side of each lobe. A trace of the canal system of the subumbrella is shown by the cast of small anastomosing canals extending out on some of the radial lobes to the outer margin.

Dimensions.—The largest disk has a diameter of 63 mm. on its longer axis, and 51 mm. on the shorter. The central quadrate opening is 21 by 17 mm., exclusive of the projecting points.

Observations.—The three specimens of this species occur in partings of the siliceous shale in association with annelids and crustaceans that indicate that they were deposited on the bottom in quiet water, and were not left on a beach between tides. The subumbrella disk

had considerable substance to it, as it has left a very clear impression and the lobes still retain a slight convexity.

Among fossil medusæ some of the many lobed specimens of *Laotira cambria* Walcott[1] might be compared with this species on account of the numerous lobes of the umbrella disk, but beyond that there are no points in common between them. The large quadrate opening of the subumbrella may be compared with the quadrate mouth of *Medusina costata* (Torell),[2] but here the comparison ends, as the genital hollows in *P. nathorsti* are not preserved and the subumbrella of *M. costata* is not well defined.

It is hoped that during the field season of 1911 more perfect specimens of *P. nathorsti* may be found.

The associated fossils are *Eldonia ludwigi, Ptychoparia cordillerœ, Neolenus serratus, Sidneyia inexpectans,* and numerous undescribed annelids and phyllopod crustaceans.

The specific name is given in honor of the distinguished Swedish paleontologist, Dr. A. G. Nathorst.

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

[1] Fossil Medusæ: Monograph U. S. Geol. Survey, Vol. 30, 1908, pl. 8.
[2] Idem, pl. 30, fig. 1.

DESCRIPTION OF PLATE 8

cr. Central ring.
p. Digitate tentacle.
rc. Radial canals.
s. Stomach.

PAGE

Peytoia nathorsti Walcott 56

FIG. 1. Subumbrella view of the type specimen of the genus and species. Natural size. The four large lobes are marked ×. U. S. National Museum, Catalogue No. 57538.

A portion of an annelid, *Ottoia prolifica,* n. g. and n. sp., is shown above the medusa.

2. Subumbrella view of a second specimen that differs in detail from the specimen represented by figure 1. It also shows the short spines about the oral aperture more clearly. Natural size. U. S. National Museum, Catalogue No. 57539.

Both specimens illustrated are compressed in the shale and show no traces of canals or other portions of the medusa within the subquadrate central area.

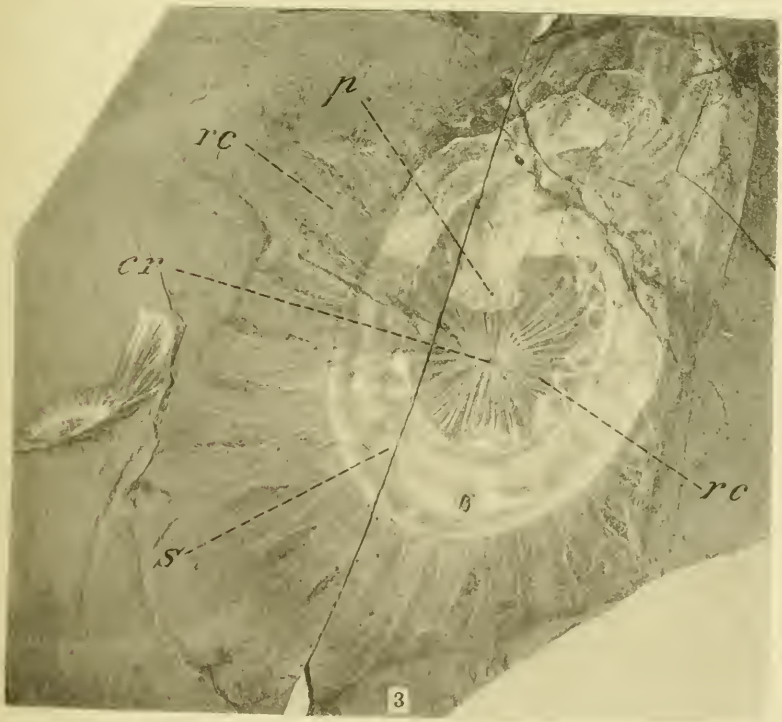
Eldonia ludwigi Walcott (see also text fig. 5 and pls. 9-12) 46

FIG. 3. An individual preserved as a thin film in the shale. Natural size. U. S. National Museum, Catalogue No. 57540.

This shows a digitate tentacle (p) and radial canals (rc) extending to and beyond the central stomach (s). The peripheral margin of the umbrella is not definitely outlined. Traces of the radial canals are seen crossing the stomach on the left side.

A small individual compressed so as to give a partial side view, is shown on the left. This preserves traces of radial canals and stomach.

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale 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, British Columbia.



MIDDLE CAMBRIAN MEDUSA AND HOLOTHURIAN

DESCRIPTION OF PLATE 9

cr. Central ring.
g. Gonad ?
rc. Radial canals.
s. Stomach.
ul. Umbrella lobes.

PAGE

Eldonia ludwigi Walcott (see also text fig. 5 and pls. 8 and 10-12)..... 46

FIG. 1. Central portions of an individual preserving the stomach (s), and the radial canals crossing it from side to side. The outline of the intestine is shown on the right of the light-colored stomach and below on the right the oral chamber and at its mouth traces of two digitate tentacles. × 2. U. S. National Museum, Catalogue No. 57541.

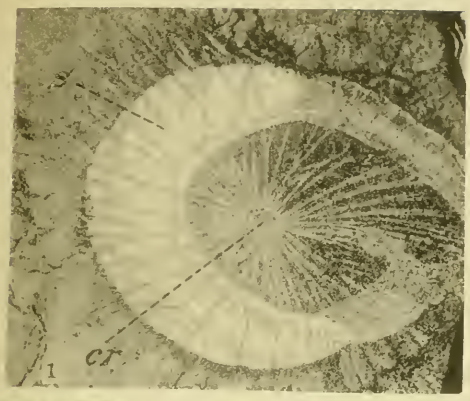
2. An individual (× 2) showing the stomach (s), radial canals, and what appears to be the umbrella at (p). U. S. National Museum, Catalogue No. 57542.

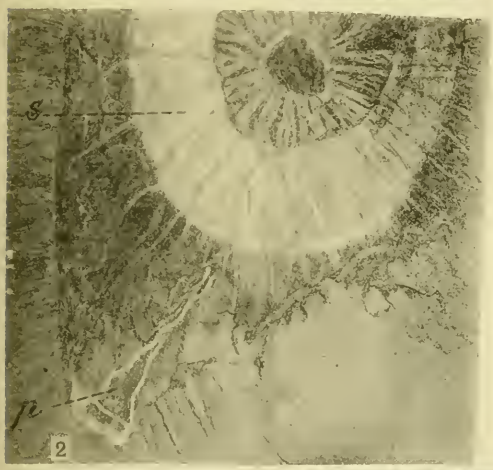
3. An individual (× 2) laterally compressed, showing radial canals, stomach (s), and on the lower side a portion of the margin of the umbrella. U. S. National Museum, Catalogue No. 57543.

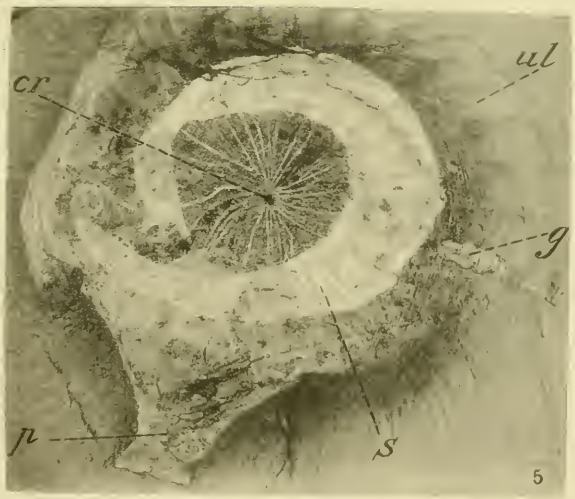
4. An individual (× 2) showing radial canals, stomach, and what appears to be the crushed-down umbrella lobe. U. S. National Museum, Catalogue No. 57544.

5. An individual showing the stomach (s) and radial canals (rc), lobed margin of the umbrella (ul and p), and concentric muscle fibers of the subumbrella surface, and on the right side at (g) what appears to be a gonad. Natural size. U. S. National Museum, Catalogue No. 57545.

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale 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, British Columbia.







MIDDLE CAMBRIAN HOLOTHURIAN

DESCRIPTION OF PLATE 10

cr. Central ring.
rc. Radial canals.
s. Stomach.

PAGE

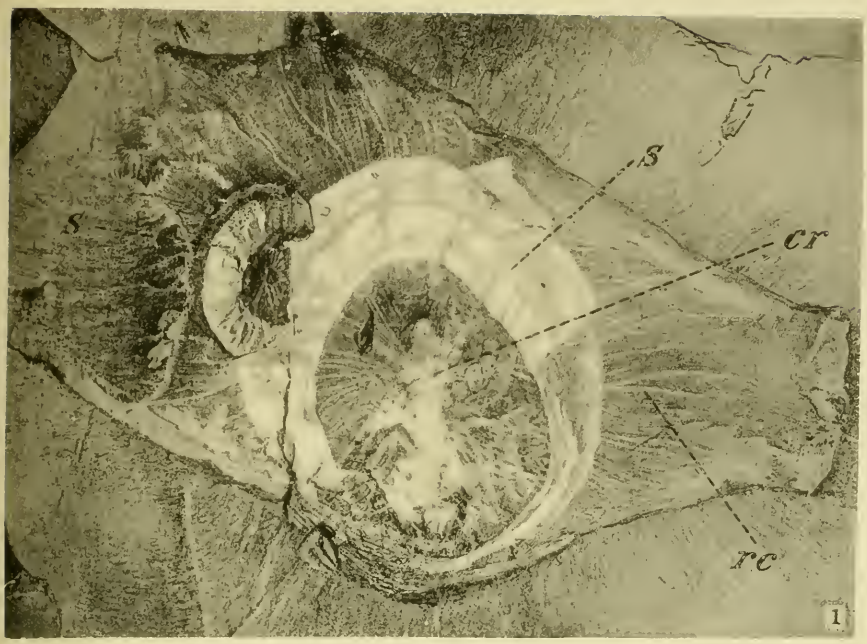
Eldonia ludwigi Walcott (see also text fig. 5 and pls. 8-9 and 11-12).... 46

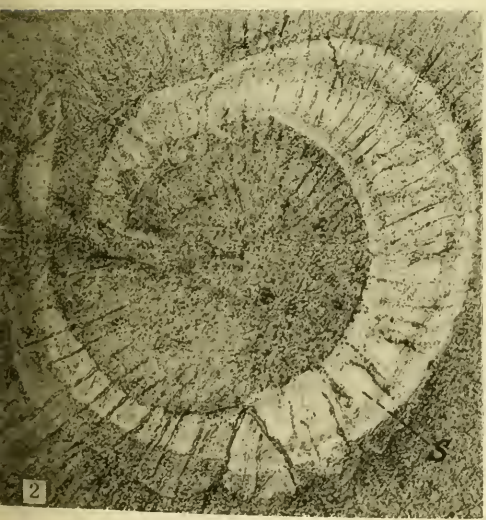
FIG. 1. A large individual very much compressed and distorted. The central ring (cr), radial canals (rc), and stomach (s) are indicated. A second specimen that lies under the large specimen is shown on the left by the convoluted stomach. Natural size. U. S. National Museum, Catalogue No. 57546.

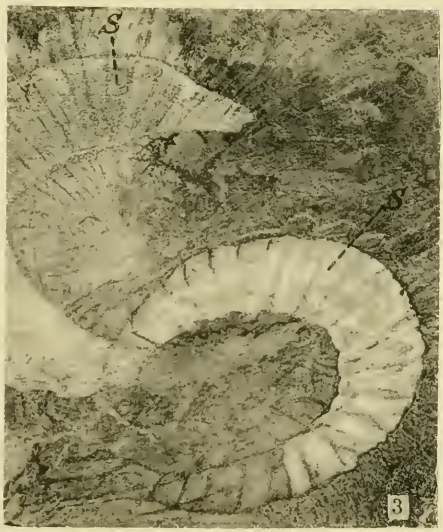
2. A specimen showing the outlines of the stomach (s) and the large central canal. × 2. U. S. National Museum, Catalogue No. 57547.

3. Two specimens of the stomach with traces of the umbrella. The strong annulation of the stomach is shown by the specimen on the lower right side. × 2. U. S. National Museum, Catalogue No. 57548.

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale 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, British Columbia.







MIDDLE CAMBRIAN HOLOTHURIAN

DESCRIPTION OF PLATE 11

cr. Central ring.
rc. Radial canals.
s. Stomach.

PAGE

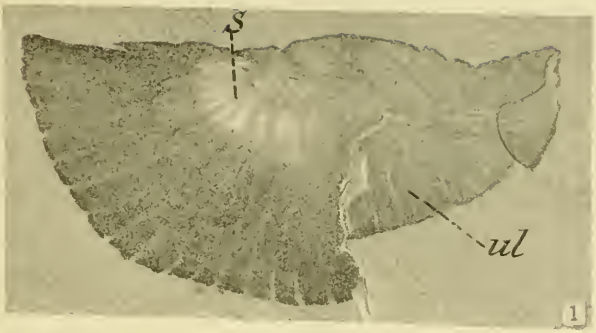
Eldonia ludwigi Walcott (see also text fig. 5 and pls. 8-10 and 12)..... 46

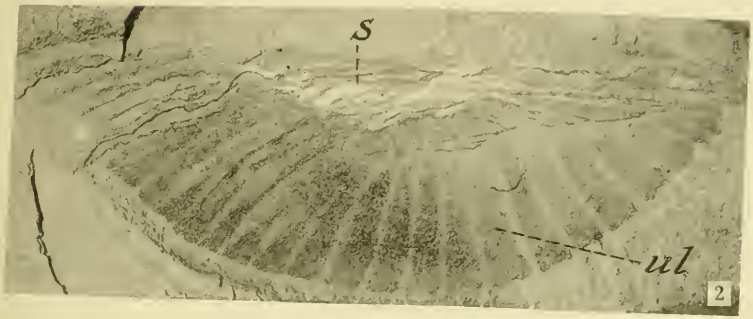
FIG. 1. An individual flattened in the shale, showing the lobate character of the umbrella. × 2. U. S. National Museum, Catalogue No. 57549.

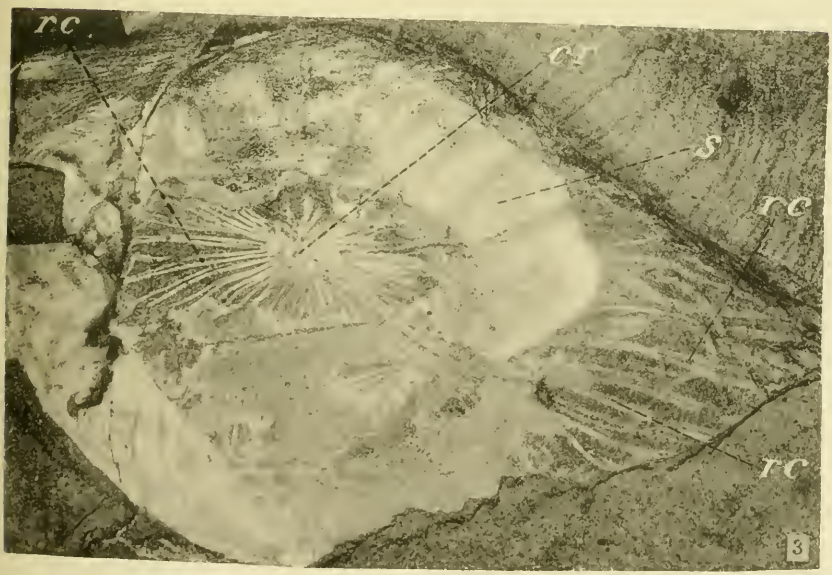
2. Another specimen with the radiating canals very closely defining the lobes. × 2. U. S. National Museum, Catalogue No. 57550.

3. A fragmentary specimen that shows the radial canals (rc) and central ring (cr) with unusual clearness. × 2. U. S. National Museum, Catalogue No. 57551.

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale 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, British Columbia.







MIDDLE CAMBRIAN HOLOTHURIAN

DESCRIPTION OF PLATE 12

s. Stomach.
cs. Intestine.
ul. Umbrella lobes.

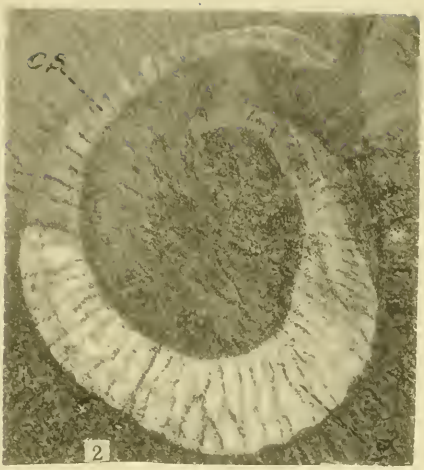
PAGE

Eldonia ludwigi Walcott (see also text fig. 5 and pls. 8-11)..... 46

FIGS. 1 and 2. Two specimens showing corrugated stomach, intestine, and traces of the radial canals of the umbrella. × 2. U. S. National Museum, Catalogue Nos. 57552 and 57553, respectively.

3. A large specimen slightly reduced in size. This shows a portion of the lobes of the umbrella (ul), traces of the radial canals in the lobes, and the stomach (s). U. S. National Museum, Catalogue No. 57554.

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale 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, British Columbia.



MIDDLE CAMBRIAN HOLOTHURIAN

DESCRIPTION OF PLATE 13

PAGE

Laggania cambria Walcott..... 52

FIG. 1. Ventral view, natural size. m = mouth. U. S. National Museum, Catalogue No. 57555.

Mackenzia costalis Walcott..... 55

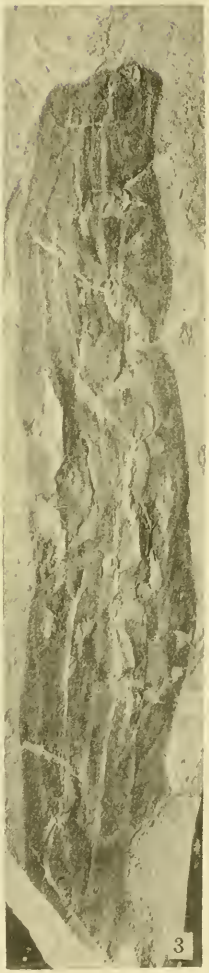
FIG. 2. A small individual showing the side view with the mouth. Natural size. U. S. National Museum, Catalogue No. 57556.

3. A fragment of a large specimen that may belong to this species. Natural size. U. S. National Museum, Catalogue No. 57557.

Louisella pedunculata Walcott..... 53

FIG. 4. An individual flattened in the shale. × 2. The series of small tube feet are flattened down on the surface, but show quite clearly in a double row. U. S. National Museum, Catalogue No. 57558.

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale 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, British Columbia.



MIDDLE CAMBRIAN HOLOTHURIANS