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II

No. 3.—MIDDLE CAMBRIAN HOLOTHURIANS AND MEDUSÆ

With Six Plates

BY

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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-

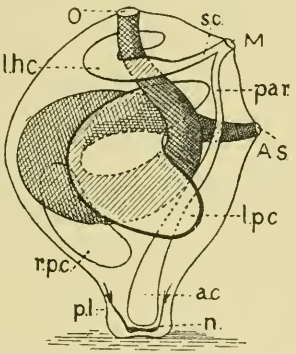

FIG. 2.—Diagrammatic reconstruction of the imagined primitive Pelmatozoic ancestor. (After Lankester, 1900, fig. 7, p. 9.[1]) O = mouth; As = anus; ac = right and left anterior portion of cœlom; rpc and lpc = right and left posterior portion of cœlom; lhc = left hydrocœl; sc = canal connecting lhc and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

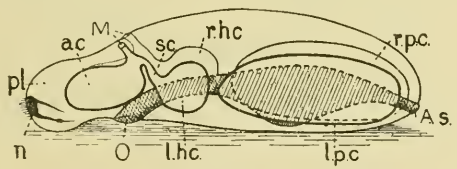

FIG. 3.—Diagrammatic reconstruction of imagined *Dipleurula* ancestor. Anterior end at left of drawing; organs of left side toward observer, and with stronger outline than those of right side. (After Lankester, 1900, fig. 1, p. 4.[2]) O = mouth; As = anus; ac = right and left anterior portion of cœlom; 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.

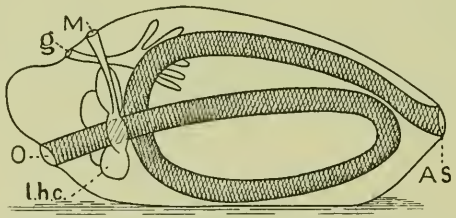

FIG. 4.—Diagrammatic reconstruction of the imagined primitive Holothurian type. (After Lankester, 1900, fig. 16, p. 18.[1]) O = mouth; As = anus; lhc = left hydrocœl; M = hydropore; g = genital opening.

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

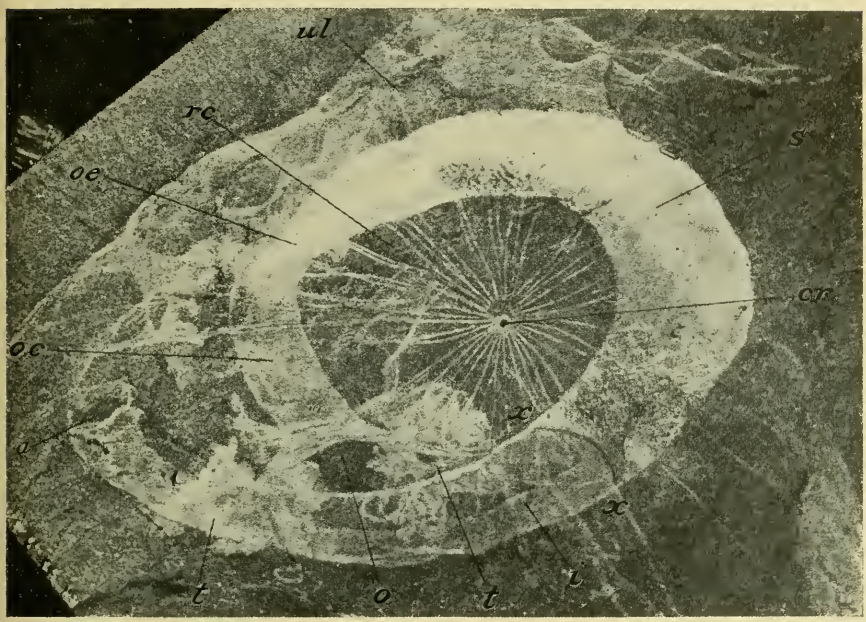

FIG. 5.—*Eldonia ludwigi.* × 2. A specimen flattened in the shale and preserving the alimentary canal, oral aperture and tentacles, water vascular system and traces of the umbrella. U. S. National Museum, Catalogue No. 57537.

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.

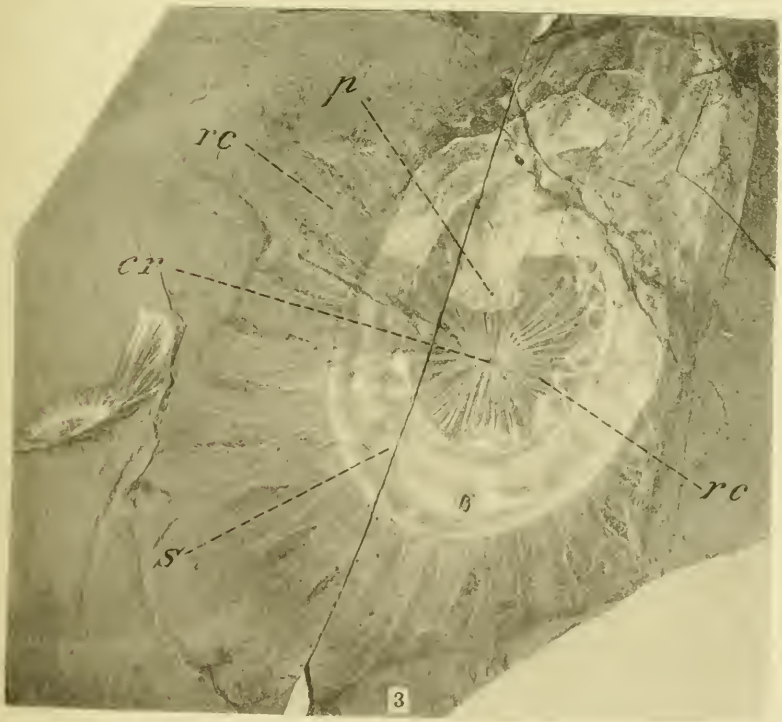
Eldonia ludwigi Walcott (see also text fig. 5 and pls. 9-12) 46

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.

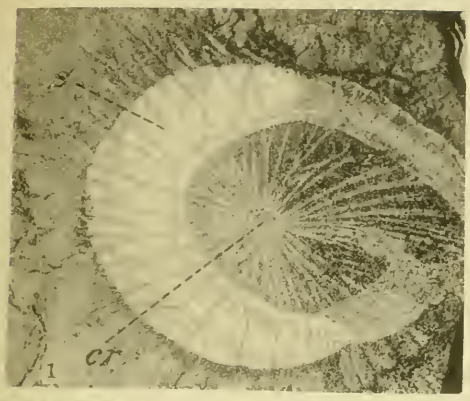
2. An individual (× 2) showing the stomach (s), radial canals, and what appears to be the umbrella at (p). U. S. National Museum, Catalogue No. 57542.

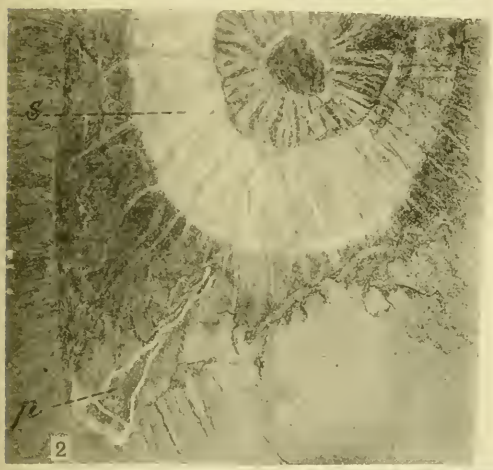
3. An individual (× 2) laterally compressed, showing radial canals, stomach (s), and on the lower side a portion of the margin of the umbrella. U. S. National Museum, Catalogue No. 57543.

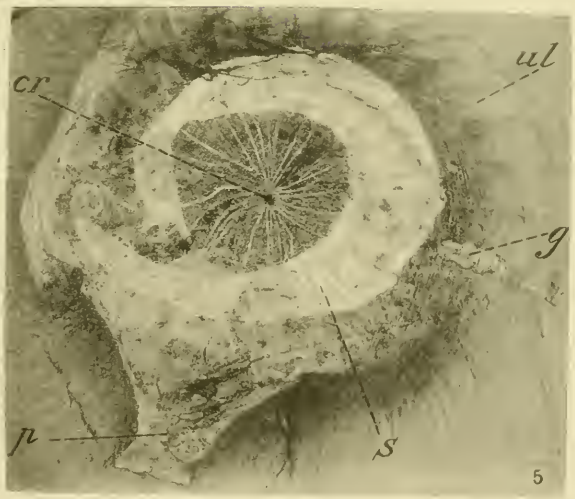
4. An individual (× 2) showing radial canals, stomach, and what appears to be the crushed-down umbrella lobe. U. S. National Museum, Catalogue No. 57544.

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

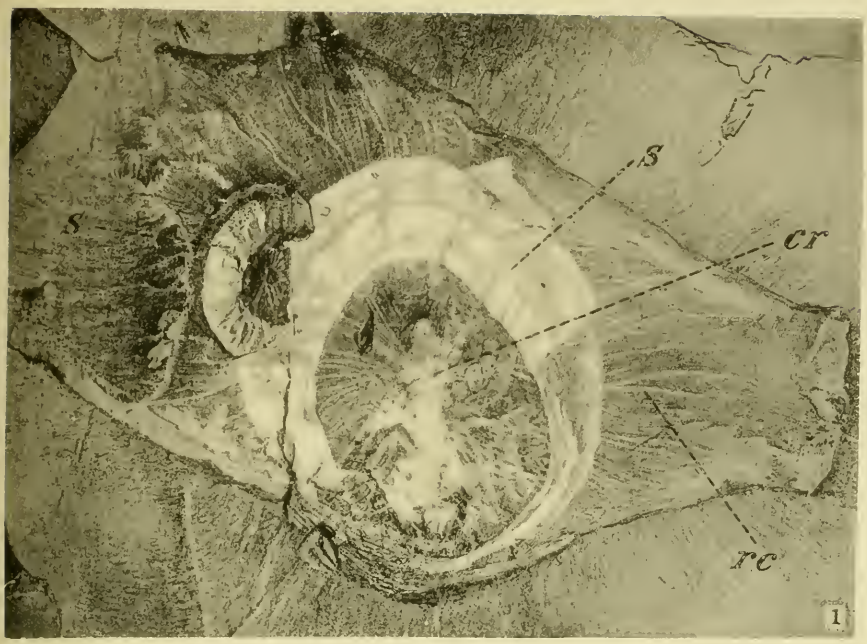
Eldonia ludwigi Walcott (see also text fig. 5 and pls. 8-9 and 11-12).... 46

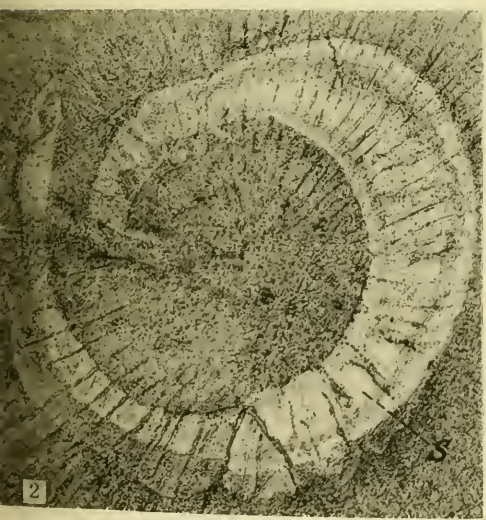
FIG. 1. A large individual very much compressed and distorted. The central ring (cr), radial canals (rc), and stomach (s) are indicated. A second specimen that lies under the large specimen is shown on the left by the convoluted stomach. Natural size. U. S. National Museum, Catalogue No. 57546.

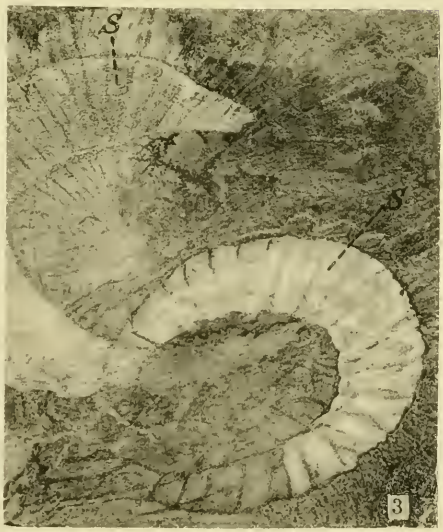
2. A specimen showing the outlines of the stomach (s) and the large central canal. × 2. U. S. National Museum, Catalogue No. 57547.

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

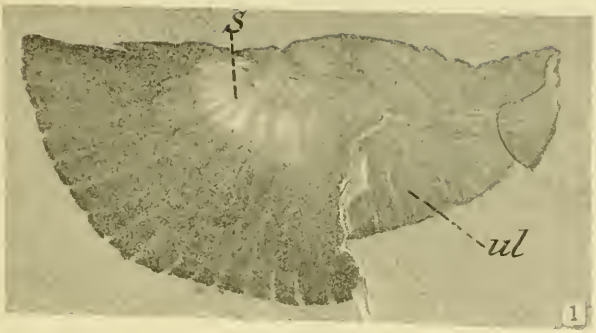
Eldonia ludwigi Walcott (see also text fig. 5 and pls. 8-10 and 12)..... 46

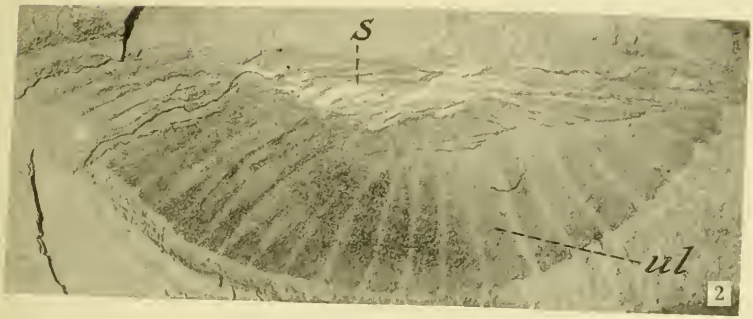
FIG. 1. An individual flattened in the shale, showing the lobate character of the umbrella. × 2. U. S. National Museum, Catalogue No. 57549.

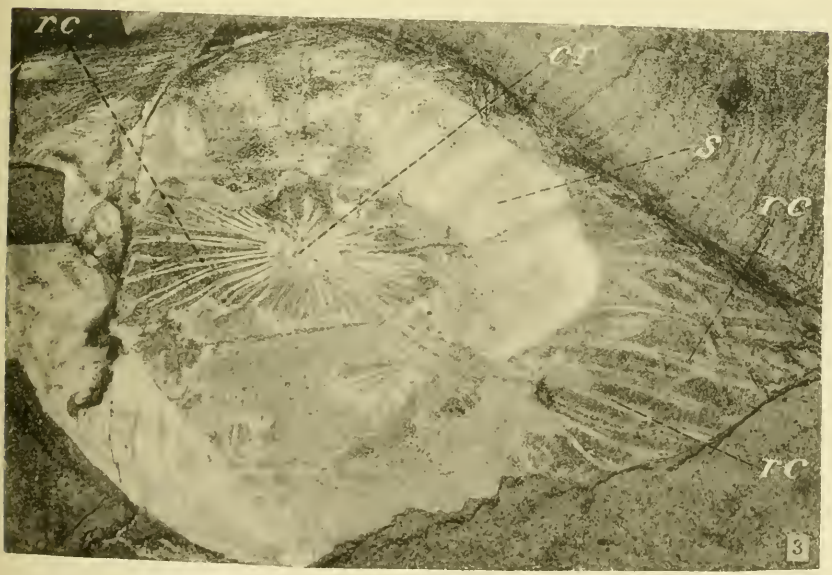
2. Another specimen with the radiating canals very closely defining the lobes. × 2. U. S. National Museum, Catalogue No. 57550.

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.

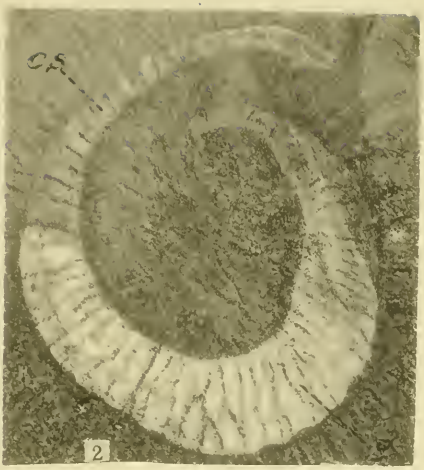
PAGE

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

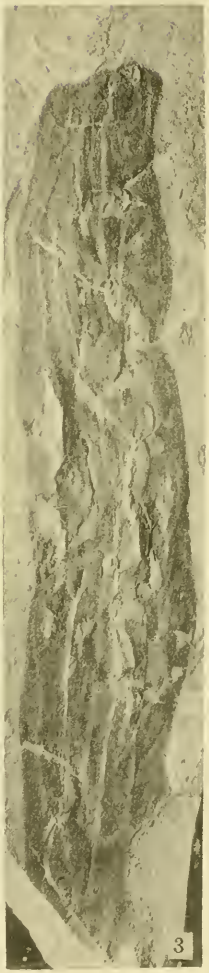
FIG. 2. A small individual showing the side view with the mouth. Natural size. U. S. National Museum, Catalogue No. 57556.

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