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ADDENDA TO DESCRIPTIONS OF BURGESS SHALE FOSSILS

(With 23 Plates)

BY
CHARLES D. WALCOTT
(With Explanatory Notes by Charles E. Resser)

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PREFATORY STATEMENT

Shortly after his discovery of the remarkable Burgess shale fossils in British Columbia in 1910, Dr. Charles D. Walcott described the more striking species of the major classes of animals and plants represented, to bring to the attention of the scientific world their exceptionally well preserved anatomic details. Subsequent quarrying at the locality yielded many additional specimens of the described forms as well as examples of rarer species not secured in the first season's work.

During my 13 years' association with Doctor Walcott he frequently dwelt upon the fact that he considered his papers on the Burgess shale forms rather in the nature of announcements than as completed studies of these wonderfully preserved fossils. He always intended to return to the study of the described species and to publish more detailed descriptions and interpretations of their form and structure. However, the stress of war times and advancing years prevented a realization of this hope. Nevertheless, from time to time, he had photographs prepared or made notes of his observations regarding structure, all of which were preserved with the collections.

At the request of the National Museum authorities I have assembled these notes and illustrations for publication so that they may not be lost to science. It must be remembered that none of the statements, and particularly none of the interpretations, in the following pages should be regarded as Doctor Walcott's final opinion, since he recognized many of them as tentative. He more than once stated that fully 15 years' work remained to be done on the 35,000 Burgess shale specimens in the National Museum's collections.

All generic and specific names, having been created by Doctor Walcott, are, of course, to be credited to him, and not to us jointly.

In order to show clearly exactly what Doctor Walcott wrote and, on the other hand, what I have added—chiefly by way of explanation—two type faces are used. Doctor Walcott's manuscript is printed in 10-point type, while the explanations added by me appear in the smaller 8-point type.

Charles E. Resser.

INTRODUCTION

It is obvious that one person cannot cover, even in a very cursory manner, the entire field of Cambrian stratigraphy and paleontology, especially with such rich faunas as the Burgess shale extant. Again, in the case of the Burgess shale faunas, none but a trained student in biology can do more than merely assign specific and generic names to the gross forms. Further, it is doubtful if any biologist, however versatile, could by long years of study perceive everything to be learned from these wonderful fossils. In view of these facts it has seemed advisable to encourage specialists to study the various classes represented rather than attempt to monograph the subject as a whole. Accordingly, such a study by Dr. G. E. Hutchinson has recently been printed[1] and one by Dr. Rudolf Ruedemann has been submitted for publication.[2] In this way we may hope to carry on the work suspended by the passing of the discoverer of these unique forms.

The following descriptions either were prepared entirely by Doctor Walcott or are based on notes and illustrations left by him.

Formation and locality.—For every species described in this paper, the formation and locality are as follows: Middle Cambrian, Burgess shale: (Loc. 35k) on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, near Field, British Columbia.

DESCRIPTION OF GENERA AND SPECIES

MARGARETIA, new genus

The characters of this strange organism are presented in the specific description or shown in the illustrations.

Genotype.—*M. dorus,* new species.

MARGARETIA DORUS, new species

Plate 1, figs. 1-6

More than 70 specimens of this peculiar organism have been assembled from the Burgess shale collections. In the following description comparisons are made with algae. Other notes by Doctor Walcott, apparently his latest, together with suggestions by Mr. A. H. Clark, and particularly the presence in the same drawer of specimens of *Titanideum suberosum,* indicate that Doctor Walcott's latest opinion was that *M. dorus* might really be an Alcyonarian.

Description.—Mass forming a thin membranous perforated sheet, narrow at the base and expanding to a width of 1.5 cm. in 2 cm. distance; length of narrow base about 1.5 cm. and of wider portion 4 cm.; the perforations are elongate oval and apparently arranged on longitudinal and obliquely transverse lines; tegument presumably

[1] Restudy of Some Burgess Shale Fossils. Proc. U. S. Nat. Mus., vol. 78, art. 11, pp. 1-24, pl. 1, year ?

[2] Some New Middle Cambrian Fossils from British Columbia. To be printed in the Proc. U. S. Nat. Mus.

leathery as it is a black film with irregular, broken, longitudinal lines with more or less scaly edges.

Microscopic structure undetermined.

Observations.—The perforations in the tegument are not unlike those of the living alga *Agarum turneri* Post and Ruprecht, and one might imagine that a fragment of the strong frond of this species is similar to *M. dorus,* but the resemblance is only general; the perforations of *M. dorus* are more uniform than those of the beautifully perforate living alga *Kallymenia perforata* Agardh, which also has a far more delicate tegument.

Holotype and paratypes.—U. S. N. M., Nos. 83922, 83923a-e.

REDOUBTIA Walcott 1918

REDOUBTIA POLYPODIA Walcott

Plate 2, figs. 2-3

Redoubtia polypodia Walcott, 1918, Smithsonian Misc. Coll., vol. 68, no. 12, p. 5, fig. 5.

The holotype is refigured since it was first published in the popular account of field explorations issued annually by the Smithsonian Institution, which does not reach paleontologists generally.

Accompanying the original figure is the following statement, "An elongate creeping holothurian with numerous tube feet and tentacles."

Whether the second specimen really represents the same species appears somewhat doubtful inasmuch as the tube feet are smaller and more numerous. The larger appendages above the specimen, as posed on the plate, are parts of another animal.

Holotype and paratype.—U. S. N. M., Nos. 83924 and 83925.

PORTALIA Walcott 1918

PORTALIA MIRA Walcott

Plate 3, figs. 2-3

Portalia mira Walcott, 1918, Smithsonian Misc. Coll., vol. 68, no. 12, p. 6, figs. 6, 7.

Another holothurian first figured in the explorations account for 1918 is also refigured, to give it wider availability. This form differs from the preceding *Redoubtia polypodia* in having fewer and longer tube feet and in their apparently different grouping.

Holotype.—U. S. N. M., No. 83927.

MISKOIA Walcott 1911[1]

MISKOIA PLACIDA, new species

Plate 2, fig. 1

Comparing this form with *M. preciosa* Walcott, the genotype, the new species is stouter and shorter. As none of the specimens referred to the type species preserves the rear end, it is not possible to determine whether the lobate termination of *M. placida* is also characteristic of the first species. The annulations of the body are clearly marked in the specimen illustrated, particularly on the counterpart, which is a mold of the exterior. Teeth are shown around the mouth as bright, shiny, curved, chitinous hooks.

Holotype.—U. S. N. M., No. 83928.

CANADIA Walcott 1911

CANADIA SPINOSA Walcott

Plate 4; plate 5; plate 6, figs. 1-2

Canadia spinosa Walcott, 1911, Smithsonian Misc. Coll., vol. 57, no. 5, p. 118, pl. 23, figs. 4-7.

Original description.—" Body slender, formed of 20 to 21 segments that, when flattened on the shale, are a little longer than wide; each segment has a pair of parapodia with a dorsal and ventral bundle of strong non-jointed setae. The setae are finely illustrated by figures 4, 6, and 7. Head minute, with a pair of large tentacles curving outward from the front anterior margins; a bundle of fine setae occurs on each side of the head back of the base of the large tentacles. A straight slender enteric canal is indicated on several specimens. Mouth and anus not seen, but probably at or near the end of the annelid.

" *Dimensions.*—The largest adult specimen has a length of 34 mm., with a width of the body at the seventh segment from the head of 1.5 mm."

Fortunately many additional specimens of this interesting spiny worm were found after 1911. Those first illustrated give a fairly good conception of the general features; however, illustrations of additional specimens may show features particularly desired by the biological student at places where the other specimens are faulty.

Plesiotypes.—U. S. N. M., Nos. 83929a-e.

[1] Walcott, C. D., Smithsonian Misc. Coll., vol. 57, no. 5, p. 114, pl. 18, figs. 1-5, 1911.

CANADIA SETIGERA Walcott

Plate 7, figs. 1, 4; plate 8, fig. 3

Canadia setigera Walcott, 1911, Smithsonian Misc. Coll., vol. 57, p. 119, pl. 23, figs. 1-3.

Canadia setigera Walcott, 1916, Ann. Rep. Smithsonian Inst., 1915, pl. 12, figs. 1-3.

The original description states that "this species differs from *C. spinosa* in being more elongate, slender, and with much smaller bundles of finer setae." It is further stated that a series of 36 specimens shows gradation between the two types originally illustrated. It seems, however, that in reality several distinct forms are included in the species as now constituted.

Plesiotypes.—U. S. N. M., Nos. 83930a-c.

CANADIA GRANDIS, new species

Plate 9, fig. 10

A single wide *Canadia* that shows the body annulations very well and that has numerous setae seems to differ from *C. spinosa* mainly in the larger bundles of setae.

Holotype.—U. S. N. M., No. 83932.

CANADIA IRREGULARIS Walcott

Plate 6, figs. 4-6; plate 7, fig. 3

Canadia irregularis Walcott, 1911, Smithsonian Misc. Coll., vol. 57, p. 120.

Original description.—"A slender species not over 20 mm. in length. The setae are irregular in size and appearance and suggest partially worn macerated specimens of the slender forms of *C. setigera.*"

The specimens on which this description was based are now illustrated for the first time. A study of the figures, however, causes some doubt to arise regarding specific differentiation from *C. grandis.*

Lectotype and paratypes.—U. S. N. M., Nos. 83933 and 83934a and b.

CANADIA SPARSA Walcott

Plate 6, fig. 3

Canadia sparsa Walcott, 1911, Smithsonian Misc. Coll., vol. 57, p. 119.

Original description.—"A slender form with only two strong setae on each very short parapodia. Finer setae may occur but they are not shown in the one specimen."

This form is another that was not illustrated in 1911. In this case two questions may be raised: First, the specific identity of all the specimens seems doubtful, and second, the generic reference to *Canadia* is also uncertain.

Holotype.—U. S. N. M., No. 83935.

CANADIA DUBIA Walcott

Plate 7, fig. 2; plate 8, figs. 1-2; plate 9, fig. 8

Canadia dubia Walcott, 1911, Smithsonian Misc. Coll., vol. 57, p. 119.

Original description.—"This species is proposed to include a small chaetiferous annelid not over 10 mm. in length. One specimen shows a bundle of very fine setae on each side near the head."

Four of the original specimens are illustrated.

Cotypes.—U. S. N. M., Nos. 83936a-d.

CANADIA SIMPLEX, new species

Plate 9, fig. 9

A tiny organism that appears as a slender tube with a termination surrounded by a ring of setae constitutes the material to which Doctor Walcott attached this name.

Holotype.—U. S. N. M., No. 83937.

WIWAXIA Walcott 1911

WIWAXIA CORRUGATA (Matthew)

Plate 3, fig. 1

Orthotheca corrugata Matthew, 1899, Trans. Roy. Soc. Canada, 2d ser., vol. 5, sec. 4, p. 42, pl. 1, fig. 3.

Orthotheca corrugata Walcott, 1908, Canadian Alpine Journ., vol. 1, no. 2, p. 246, pl. 1, fig. 11.

Wiwaxia corrugata Walcott, 1911, Smithsonian Misc. Coll., vol. 57, no. 5, p. 123, pl. 21, figs. 1-4.

A particularly fine example of this remarkable spined worm turned up in some of the more recent collections. Its picture is included since it may represent a relatively undistorted specimen with most of the plates retained.

Plesiotype.—U. S. N. M., No. 83938.

OTTOIA Walcott 1911

OTTOIA MINOR Walcott

Plate 9, figs. 1-7

Ottoia minor Walcott, 1911, Smithsonian Misc. Coll., vol. 57, p. 129, pl. 22, figs. 5-6.

Original description.—"This species differs from *O. prolifica* in its proportionally more slender form when elongated and straighter outline both when elongated and contracted. The hooks are also much

finer and extend farther back on the anterior end. The annular lines and interspaces are also finer and more irregular."

Several specimens, among the many found subsequent to 1911, preserve some of the structure features very well, and illustrations were prepared by Doctor Walcott to show them. However, it is very doubtful whether the forms shown on plate 9, figures 2 and 4, belong to this species.

Plesiotypes.—U. S. N. M., Nos 83939a-g.

PIKAIA Walcott 1911

PIKAIA GRACILENS Walcott

Plate 8, figs. 4-5

Pikaia gracilens Walcott, 1911, Smithsonian Misc. Coll., vol. 57, p. 132, pl. 20, figs. 1-2.

Original description.—"Body elongate, slender, and tapering at each end. It is formed of many segments that are defined by strong annular shiny lines. Head small with two large eyes and two tentacles as shown by figure 1. Back of the head the first five segments carry short parapodia that appear to be divided into two parts.

"The enteric canal extends from end to end without change in character. It is relatively large along the central portions and tapering toward the ends. Judging from such specimens as the one illustrated by figure 2, its annulations correspond in size with those of the body.

"Surface apparently smooth. Two entire adult specimens and several fragments of others indicate a length of about 5 cm."

Two additional figures are presented at this time.

Plesiotypes.—U. S. N. M., Nos. 83940a-b.

SELKIRKIA Walcott 1911

SELKIRKIA MAJOR (Walcott)

Plate 10

Orthotheca major Walcott, 1908, Canadian Alpine Journ., vol. 1, p. 246, pl. 1, fig. 11.

Selkirkia major Walcott, 1911, Smithsonian Misc. Coll., vol. 57, p. 120, pl. 19, fig. 6.

This species was first described from the Stephen formation on Mount Stephen. Later Doctor Walcott found apparently the same shell at the Burgess Pass quarry, but in this instance the soft body of the animal was preserved and therefore, in the 1911 discussion, he removed it from the Hyolithidae to the polychaetous annelids.

Photographs of two exceedingly well preserved individuals with the body extending beyond the shell are printed here for the first time.

Plesiotypes.—U. S. N. M., No. 83941a-b.

AYSHEAIA Walcott 1911

AYSHEAIA PEDUNCULATA Walcott

Plate 11

Aysheaia pedunculata Walcott, 1911, Smithsonian Misc. Coll., vol. 57, p. 117, pl. 23, figs. 8-9.

Aysheaia pedunculata Hutchinson, 1930, Proc. U. S. Nat. Mus., vol. 78, art. 11, p. 14.

This fossil has perhaps attracted wider attention than any other. Recently G. E. Hutchinson, of Yale University, studied this peculiar form and concluded that *Aysheaia* is an extinct Onychophora. Unfortunately, Mr. Hutchinson did not see the two individuals here illustrated, as they were buried away among numerous specimens of *Ottoia*. As the present assemblage of material progressed they came to light and are now illustrated, especially as they are perhaps the best preserved specimens available.

At the time these photographs were found among the notes Doctor Walcott intended using in further publications relating to this animal, two letters were discovered, both suggesting that *Aysheaia* may be an Onychophora or a Peripatus. The first letter, dated September 21, 1911, was written by Prof. W. M. Wheeler of Harvard University, and reads as follows:

"I wish to thank you for your very interesting publications on the Middle Cambrian Annelids. On plate 23, I noticed two figures of *Aysheaia pedunculata*. This creature bears the most extraordinary resemblance to *Peripatus*, except for the head, and judging from the figures the 'head' may be something which does not belong to the fossil. I have just shown these figures to Mr. C. T. Brues, who has been working on *Peripatus*, and he also was struck with the remarkable resemblance. Is there any possibility that it might be *Peripatus* instead of an Annelid? If this should prove to be the case it would be a matter of the very greatest interest."

The second letter dated October 25, 1911, was written by Prof. Charles Schuchert, of Yale University, and contains the following:

"The other point is one that Lull has called my attention to and refers to figures 8 and 9 of plate 23 which you call *Aysheaia pedunculata*. The question that I want to ask is, have you considered it as a possible Onychophora or related to *Peripatus?* Of course if one looks at your illustrations and compares them with the illustration of *Peripatus* given by Parker and Haswell in their Text-book of Zoology, page 607, in the edition of 1910, one can see considerable differences and yet there are in your figures several points in common to make one wonder whether you have not a marine ancestor of this land-living arthropod."

This rather lengthy historical account is presented to show that at least three authorities arrived at the same conclusions independently.

Plesiotypes.—U. S. N. M., Nos. 83942a-b.

LEANCHOILIA Walcott 1912

LEANCHOILIA SUPERLATA Walcott

Plate 12; plate 13, figs. 1-2; plate 14, figs. 4-5

Leanchoilia superlata Walcott, 1912. Smithsonian Misc. Coll., vol. 57, p. 170, pl. 31, fig. 6.

Original description.—"Body elongate, with clearly defined head shield and nine strong body segments up to the point where the

posterior part of the body is broken off. The anterior pointed end of the head is broken off in such a manner that the presence of a frontal appendage is suggested. The large opening on the side of the head indicates a large pedunculated eye comparable with that of *Opabinia regalis* (pl. 28, fig. 1).

"*Appendages.*—Of the head appendages, the antennae are the best preserved. These are large and composed of several strong joints, of which three now show from beneath the carapace; the second of these bears a long slender branch on its inner margin, and the third two branches, one of which is similar to that of the second joint. These two branches appear to be composed of one very long slender joint followed at the end by several short small joints that curve upward and presumably gave the branches flexible extremities; the third and lower branch has a similar slender proximal joint that at its outer end has three slender, jointed branches. This structure makes a very effective clasper of each of the antennae. Back of the right antennae are two narrow appendages that may be the ends of one of the third and fourth pairs of head appendages.

"The thoracic legs terminate in flat, elongate, broad, lanceolate joints. The terminal joint is about three-fifths the entire length of the leg, and has a fringe of strong setae on its outer and posterior margin. The condition of preservation is such that the details of structure of the other portions of the leg cannot clearly be determined."

The illustrations presented herewith apparently were prepared by Doctor Walcott to exhibit the detailed structure of this interesting crustacean.

Plesiotypes.—U. S. N. M., Nos. 83943a-g.

LEANCHOILIA MAJOR, new species

Plate 13, fig. 3

Several specimens, of which the best is illustrated, were labeled *Leanchoilia major* by Walcott. Just why he should have chosen this specific name is not readily apparent as these individuals are not sufficiently larger than *L. superlata* to warrant the designation. In fact there is but little difference between this form, which happens to be flattened out horizontally, and the specimen shown in figure 2, plate 13, referred to the genotype.

Holotype.—U. S. N. M., No. 83944.

NARAOIA Walcott 1912

NARAOIA COMPACTA Walcott

Plate 13, fig. 4; plate 14, figs. 1-3; plate 15, figs. 2-3

Naraoia compacta Walcott, 1912, Smithsonian Misc. Coll., vol. 57, no. 6, p. 175, pl. 28, figs. 3, 4.

Many specimens of this interesting form have been found since its preliminary description in 1912, but none shows the cephalic ap-

pendages in position or an uninjured trunk limb. The carapace is thicker than that of *Burgessia bella* and the body is firmly attached to the fused segments forming the posterior dorsal shield, and there is a close union between the body of the cephalic region and the carapace

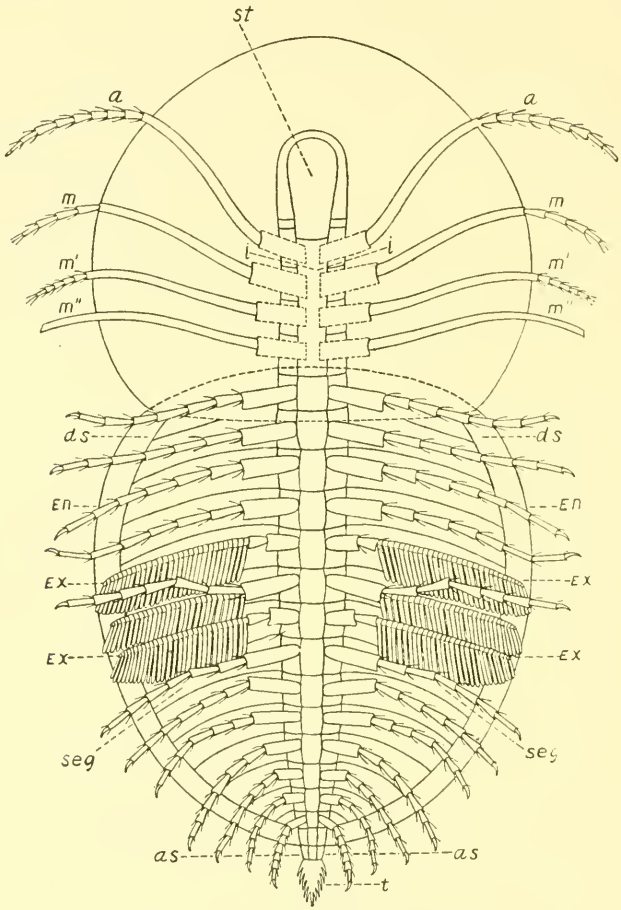

FIG. 1.—*Naraoia compacta* Walcott.

a, antennae; *as*, anal segment; *ds*, reflex margin of posterior carapace; *en*, endopodite; *ex*, exopodite; *i*, intestine; *m*, mandible; *m'*, maxilla; *m''*, maxillula; *seg*, segmented posterior carapace; *st*, stomach; *t*, telson.
(About × 5.) Diagrammatic outline of ventral view of appendages, etc.

that extends from the anterior ventral margin of the latter back to the line of the anterior margin of the posterior dorsal shield. In the restoration (text figs. 1, 2) I have made an attempt to incorporate all information available.

Exoskeleton.—The dorsal exoskeleton as seen from its dorsal side is formed of a carapace and a posterior segmented shield. The true cephalic carapace or shell fold is attached to the cephalic somites near its anterior portion, probably as in the recent Apodidae or the associated *Burgessia* and also along the line of the body as far back as the anterior margin of the posterior dorsal carapace. The carapace is not known to have had a reflected anterior margin with a labrum at-

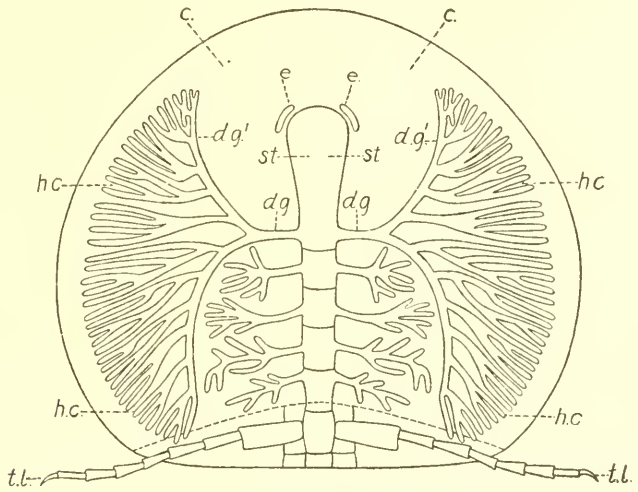

FIG. 2.—*Naraoia compacta* Walcott.

c, carapace; *g*, digestive glands; *d.g.*, lateral digestive glands; *e*, eye; *h.c.*, hepatic caeca; *st*, stomach; *t.l.*, thoracic limb.
(About × 5.) Diagrammatic outline of the digestive organs.

tached as in *Burgessia*, but it may have had, as none of the specimens shows the ventral side of this part in an uninjured condition. The carapace is broader than long, with a somewhat uniformly rounded outline except posteriorly where it is nearly transverse; it probably had a ventral as well as dorsal membrane between which the great hepatic caeca were located very much as are the shell glands in the Apodidae.[1] For some unknown reason the anterior portion of the carapace is usually distorted by being crowded back so as to wrinkle and shorten it.

The large shield of the posterior part of the exoskeleton is composed of 14 fused segments with a narrow border. It has the appearance of the many-segmented pygidium of the trilobite belonging

[1] In no other manner can I explain the wonderful preservation of the digestive tubes and caeca.

to the genera *Ogygopsis* or *Orria*,[1] except that the median lobe is not as strongly marked. These two genera are mentioned as they occur in correlative Middle Cambrian formations and one of them in the Stephen formation which is nearly contemporaneous with the Burgess shale. The dorsal carapace and shield also appear similar in outline to the dorsal exoskeleton of the freshly hatched young of *Limulus polyphemus* as figured by Packard.[2] The posterior shield has each of the thoracic body segments, excepting the two posterior which project beyond it, attached directly to it, and it forms the dorsal side of the exoskeleton of the body segments. The exoskeleton of the free posterior segments and telson, of the cephalic segments, and of the ventral side of the trunk segments was so exceedingly delicate as to leave only a slight trace on the shale. Both the anterior carapace and posterior segmented shield were very thin and readily distorted.

The anterior carapace slightly overlapped the posterior shield and the two were closely held together by the strong body as evidenced by their rarely being found separated. The telson is short and marked by fine short spines.

Dimensions.—The largest specimen had a length of about 40 mm., the carapace being shortened by compression. A specimen that has been slightly narrowed by compression has the following dimensions:

	mm.
Length of carapace	16
Width of carapace	15
Length of posterior dorsal shield	17
Width of posterior dorsal shield	14

Eyes.—The eyes are represented by two small crescent-shaped bright spots a little in advance of the anterior end of the stomach as illustrated by the restoration (fig. 2). The position and form correspond quite closely to the paired eyes of the recent *Apus lucasanus* Packard.[3]

Cephalic appendages.—The antennae are uniramous, short jointed, and slender in their distal portion, and have a large proximal joint; the intermediate joints are unknown. Of the cephalic limbs only slight indications were found of the proximal joints of three pairs, and a few terminal joints extending from beneath the carapace, nothing of their original form being preserved. All traces of cephalic ap-

[1] Smithsonian Misc. Coll., vol. 64, no. 5, figs. 1 and 2, pl. 66, 1916.

[2] Mem. Boston Soc. Nat. Hist., vol. 2, pl. 5, figs. 25, 25*d*, 1871.

[3] Twelfth Ann. Rep., U. S. Geol. and Geog. Surv. Territories, Hayden, Pt. 1, pl. xvi, fig. 2, 1883.

pendages are posterior to the hepato-pancreatic tubes passing from the stomach to the hepatic caeca.

There is no clearly defined line between the cephalic and trunk limbs, but from the relations of the limbs in *Burgessia* and *Marrella* it is assumed that it is between the third pair of cephalic limbs and the supposed first pair of trunk limbs. The specimens are too much obscured by the compression they have undergone to permit of recognition of the detailed structure of the limbs.

Thoracic limbs.—The specimen represented by figure 3, plate 14, has the distal ends of 17 thoracic or trunk limbs projecting beyond the left margin of the posterior shield; the shield in this specimen has not more than 14 fused segments outlined on it, so it is probable that the three anterior limbs belong with the body segments between the anterior segment of the posterior shield and the third pair of cephalic limbs. Another alternative is that the distal portion of the two anterior limbs extending beyond the margin of the shield belong to the maxilla and maxillula, which would leave only one pair of limbs from the segment anterior to the posterior shield and posterior to the cephalic limbs. The limbs were so subject to displacement, however, that any deduction is very uncertain. The distal portion of the thoracic or trunk limbs shows an endopodite with a slightly curved terminal spine with a slender section back of it corresponding to the slender distal joint of the endopodite of *Marrella* and *Burgessia;* and then the joints broaden towards the coxopodite with slight indications of five joints between the distal joint and coxopodite.

The exopodite is represented by many slender filaments that were attached to a multi-jointed arm or support similar in appearance to that of the exopodite of *Marrella.* The filaments are relatively broad, as they occur flattened on the shale. There are strong indications of large coxopodites, but none show their original form or the exact point of attachment of endopodite or exopodite, and the joints of the endopodites have been so crushed down as to be no longer definitely recognizable. The exopodites were nearly as long as the endopodites, and the filaments of the former are usually extended out to the end of the endopodites or beyond.

Digestive organs.—The exact location of the mouth is unknown, but from the apparent position of the antennae and proximal joints of the cephalic limbs, it was posterior to the point of entrance of the hepatic tubes, back of which the intestine was large with minor hepatic caeca opening into it through four small tubes, all of which are anterior to the posterior dorsal shield as indicated in the diagrammatic restoration (fig. 2); beneath the posterior dorsal shield the intestine is

slightly constricted at the union of the trunk segments and extends back to the anal segment which protrudes posteriorly from beneath the shield; the gullet connecting the mouth and the stomach must have extended forward and upward.

The large hepatic glands and caeca are somewhat similar to those of *Burgessia bella* (text fig. 5); a short, strong tube with a well-marked anterior and posterior tube leads out from the stomach, and branching from these lateral tubes are a series of hepatic caeca. The small hepatic caeca are located between the long posterior tubes of the hepatic glands and the intestine and posterior to the main hepatic tube.

Owing to the excellent state of preservation of many of the specimens showing the hepatic caeca it is probable that they were situated between the dorsal and ventral membrane of the carapace and thus held in position and protected from destruction; that they are preserved at all is one of the wonders of this remarkable Burgess shale fauna.

Functions of appendages.—These were presumably the same as for similar organs in *Marrella* and *Burgessia,* and the mode of occurrence is essentially the same.

Diagrammatic restorations.—The diagrammatic restoration (fig. 2) presents the outline of the carapace and posterior shield with the stomach, intestine, hepatic tubes and caeca of the digestive system outlined, also the thoracic trunk, the telson and the thoracic limbs as far as known and interpreted. The data for this diagram are very good except the jointing of the endopodites and the exact form of the coxopodites and proximal joints of the exopodites. In figure 1, the endopodites on each side have been omitted and the exopodites drawn in so as to show their structure and position above the endopodites and below the ventral membrane of the posterior dorsal shield. The sixth limb has both the endopodite and exopodite attached; this should be compared with the thoracic limb of *Marrella splendens* (text fig. 9).

We know so little of the cephalic limbs of *Naraoia compacta* that I hesitate to give a diagrammatic sketch of them, and it would not be of even tentative value if we did not have the cephalic limbs of *Marrella* and *Burgessia* for suggestion; from the latter and from the evidence afforded by a few specimens, the outline of figure 1 is drawn.

Comparison with crustaceans.—*Naraoia* has many characters in common with the trilobite and some in common with *Marrella, Burgessia,* and *Waptia,* which will be spoken of in the discussion of this group of genera.

Plesiotypes.—U. S. N. M., Nos. 83945a-e.

NARAOIA SPINIFER, new species

Plate 15, fig. 1

Three specimens referred to this species are known, of which the one figured shows best the spines on the margin of the posterior dorsal shield; another preserves both the carapace and dorsal shield, the latter having marginal spines while the carapace has a smooth margin. On the third specimen the test of the dorsal shield is nearly all exfoliated on the left side so as to expose the body, several of the fringed exopodites, and coming from beneath them the distal portions of the endopodites.

This species differs from *Naraoia compacta* in having eight short, small spines on the outer margin of the dorsal shield equally spaced between the anterior margin and a large posterior median spine; all three of the known specimens of the posterior dorsal shield are also larger than those of *N. compacta,* as they average 25 mm. in length exclusive of the posterior median spine. The one specimen preserving the carapace indicates that it was similar to the carapace of *N. compacta,* the recognized differences between the two species being confined to the posterior dorsal shield.

Holotype.—U. S. N. M., No. 83946.,

BURGESSIA Walcott 1912

BURGESSIA BELLA Walcott

Plate 15, figs. 4-7; plate 16; plate 17; plate 18, fig. 1

Burgessia bella Walcott, 1912, Smithsonian Misc. Coll., vol. 57, no. 6, p. 177, pl. 27, figs. 1-3; pl. 30, figs. 3-4.

Since the publication of the original description of *Burgessia bella* Walcott, a large number of more or less well preserved specimens have been collected from the Burgess shale, a few of which preserve details of structure that make it possible to draw a diagrammatic restoration indicating the increase in our information of the cephalic and thoracic appendages (text figs. 3, 4).

Exoskeleton.—The exoskeleton is very delicate and the carapace is so thin as to be almost membranaceous. The segment to which the telson is attached appears to be partly covered ventrally by a heart-shaped plate that is attached to the anterior margin of the segment or to the posterior limb-bearing segment of the thorax; it suggests a supra-anal plate.

There appear to be five cephalic, eight thoracic, and one abdominal segment, also a long, slender telson with numerous joints. One example 21 mm. in length has 30 joints.

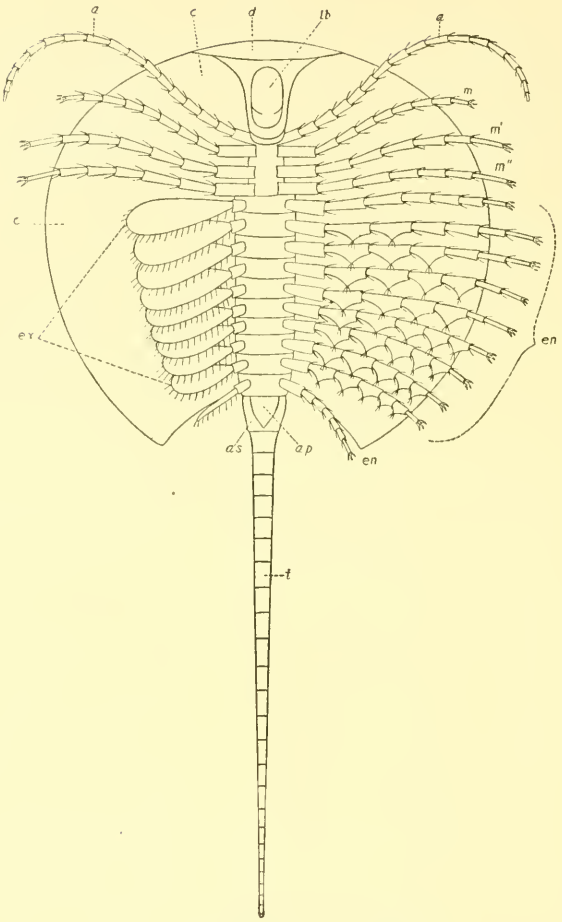

FIG. 3.—*Burgessia bella* Walcott.

a, antennae; *ap*, anal plate; *as*, anal somite; *c*, carapace; *d*, doublure; *en*, endopodite; *ex*, exopodite; *lb*, labrum; *m*, mandibles; *m'*, maxillae; *m''*, maxillulae; *t*, telson.

(About × 7.) Diagrammatic outline of ventral side with appendages. Much of the data on which this figure is based are shown by the specimens illustrated on plates 16 and 17. The exact form and position of the proximal joints of the cephalic limbs is unknown, but their general outline and position are about as outlined. The thoracic limbs, especially the endopodites, are well preserved in several specimens, but the exopodites are rarely seen and then only as faint and delicate impressions on the shale. The protopodites are fairly well defined, also the trunk segments and telson. The posterior endopodite and exopodite both differ from those anterior to them.

Carapace.—Carapace semicircular, with a deep notch on the posterior side. It appears to have had an upper (dorsal) and lower (ventral) membrane between which the irregular ramifications of the hepatic caeca were located. The shell glands, so conspicuous in the Apodidae, have not been recognized in *Burgessia.*

Labrum.—The labrum is attached to the reflected anterior rim (doublure) of the ventral side of the carapace and extends back nearly one-third its length; the labrum is rounded posteriorly and has a shallow obliquely transverse furrow on each side just in advance of its posterior margin; it was thin, readily distorted by pressure and is rarely preserved; one of the best examples is illustrated by figure 3, plate 17; it appears to have covered the anterior portion of the mouth.

Eyes.—The eyes are indicated by a minute round spot on each side of the dorsal median axis of the carapace and a short distance within the anterior margin.

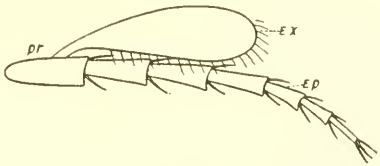

FIG. 4.—Diagrammatic outline of a thoracic limb of *Burgessia.*

pr, protopodite; *en*, endopodite; *ex*, exopodite.
The outline is based on the examination of many specimens aided by the known form of the endopodite of *Marrella* which is somewhat similar.

Dimensions.—The average length of the larger specimens is about 10 mm. A few are 12 and many are 6 to 8 mm. in length exclusive of the long telson. The relative proportions of the carapace, thorax, and abdomen are indicated by the diagrammatic restoration (text fig. 3).

Cephalic appendages.—These consist of well-marked antennae (figs. 3, 4) and three pairs of limbs situated between the antennae and the hepato-pancreas tubes; there is evidence that the basal or proximal joints of the cephalic limbs are relatively large and the remaining joints slender, but their exact position in relation to the labrum and their details of form and structure are not determined. It is quite probable that they represent the mandibles, maxillulae, and maxillae very much as in *Marrella,* and I have so represented them in the diagrammatic restoration of the ventral view of the species (text fig. 3).

Thoracic limbs.—The ten pairs of biramous thoracic limbs are uniform in character with the exception of the posterior pair, which are

relatively smaller and more slender. Each limb has a strong proximal joint (coxopodite) to which the endopodite is attached; the latter is formed of four stout joints and two slender joints with two or three short spines at the end of the distal joints; the four joints between the proximal and slender sixth joint may have a flattened extension on the ventral side as in the endopodite of *Marrella* that gives them a greater transverse diameter, and this may also occur in the sixth joint; the distal joint is slender and probably cylindrical; the exopodite has not been seen attached to the protopodite, but from a number of specimens showing their position there is little doubt of their having been attached as on the thoracic limb of *Marrella*. The exopodite is an elongate oval, apparently unjointed lobe as seen in the specimen represented by figure 4, plate 17; a fringe of fine, short filaments occurs on the ventral and outer margins; the delicate structure and small size makes it difficult to determine its exact nature, but as far as known it recalls the exopodite of *Neolenus*. One specimen indicates that there may have been an anterior support for the exopodite that extended beyond the flat filamentous lobe and terminated in two minute spines; the proximal portion of the endopodites has been flaked off in this specimen so as to expose the exopodites; the slender distal extensions may belong to the exopodites or they may be the ends of the endopodites of the opposite side flexed under. I am inclined, however, to think that they belong with the exopodites. What may be a modified exopodite has been seen in one specimen; it projects from beside the posterior thoracic endopodite and consists of a central axis with seven sharp spines projecting from its posterior side and a terminal spine; or it may be an endopodite showing the edges of plate-like joints in the same manner as those of *Marrella splendens* (pl. 22, figs. 6, 7).

Digestive organs.—The mouth was situated at the ventral side and probably bounded in front by the labrum and on the sides by the mandibles; the mouth presumably opened into a gullet that passed into a large stomach apparently divided or forked anteriorly; from the rear of the stomach a straight intestine extended back to the anus. A strong, relatively large tube is given off from each side of the stomach at about the fifth segment; these have strong branches at the proximal end, one extending forward and another backward, both of which have short bifurcating branches on both the outer and inner sides. In nearly all well-preserved specimens the large tube and often the large connecting tubes are rounded as though they were distended when buried in the sediment; this would accord with the view that these were large digestive glands that contained food in process of

digestion, the ultimate or hepatic caeca secreting a digestive juice as in *Lepidurus* and other crustaceans having such glands.[1]

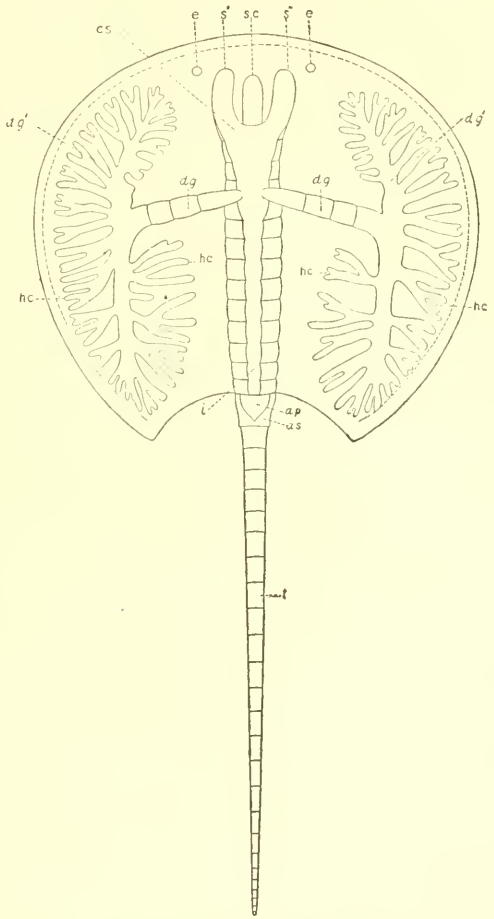

FIG. 5.—*Burgessia bella* Walcott.

ap, anal plate; *as*, anal somite; *cs*, central stomach; *d. g.*, digestive glands; *d. g'.*, lateral digestive glands; *e*, eye; *h. c.*, hepatic caeca; *i*, intestine; *s'* and *s''*, anterior lobes of stomach; *sc*, anterior central lobe of stomach; *t*, telson.

(About × 7.) Diagrammatic outline of digestive organs. Most of the data on which this figure is based are shown by the specimens illustrated on plate 16, figures 1, 3 and 4. The exact relations of the anterior central lobe of the stomach to the central stomach are unknown as there appears to be a line separating them.

The anus is supposed to have been at the last thoracic segment beneath the platelike structure shown on figure 3, plate 17.

[1] Parker and Haswell, Text-book of Zool., vol. 1, p. 491, 1897.

Functions of appendages.—The functions of the cephalic and thoracic limbs were probably similar to the functions of those of *Marrella splendens.*

Mode of occurrence.—This delicate and beautiful little crustacean occurs abundantly in association with *Marrella splendens* and *Waptia fieldensis,* and is quickly recognized, even when distorted and crushed, by its carapace and strongly marked hepatic caeca. The carapace is almost always outlined on the shale, as are frequently the body and telson; the large strong endopodites are usually more or less clearly marked, although their jointed structure has generally been lost in the flattening in the shale; the exopodites were so delicate that they are rarely preserved, and the same is true of the labrum and eyes.

Comparison with crustaceans.—*Burgessia* has certain characters in common with *Marrella* and *Naraoia* and belongs in a group with them which will be discussed later (p. 37).

Diagrammatic restorations of ventral surface.—I have endeavored to present, in text figures 3, 4, and 5, interpretations of the structure of my *Burgessia bella.*

Plesiotypes.—U. S. N. M., Nos. 83947a-o.

WAPTIA Walcott 1912

WAPTIA FIELDENSIS Walcott

Plate 18, figs. 2-5; plate 19; plate 20; plate 21, fig. 2

Waptia fieldensis Walcott, 1912, Smithsonian Misc. Coll., vol. 57, no. 6, 1912, p. 181, pl. 27, figs. 4, 5.

The general characters of this species were described in 1912, since when a large number of specimens have been collected from the Burgess shale, a few affording data from which a fairly accurate diagrammatic restoration of the animal may be drawn (text fig. 6).

Exoskeleton.—The exoskeleton of the carapace, trunk, and caudal furca was very thin and readily distorted. The trunk consists of 5 to 7 short cephalic segments; 8 narrow thoracic segments, each bearing a pair of uniramous appendages; 6 long abdominal segments and 2 broad lobelike terminal caudal furca or rami; the latter have three transverse lines indicating four fused segments. The posterior margin of the abdominal segments bears four or more strong spines with a fringe of small, short, sharp spines between them. The last or anal segment has a minute anal opening on a slightly rounded elevation near its posterior ventral margin. The abdominal segments have often been narrowed and lengthened, or broadened and shortened by distortion in the shale.

Carapace.—The carapace when viewed from its dorsal side is elongate, narrowed anteriorly, expanded posteriorly, and has the outline of two broad lobes by the incurving of the rounded posterior margin

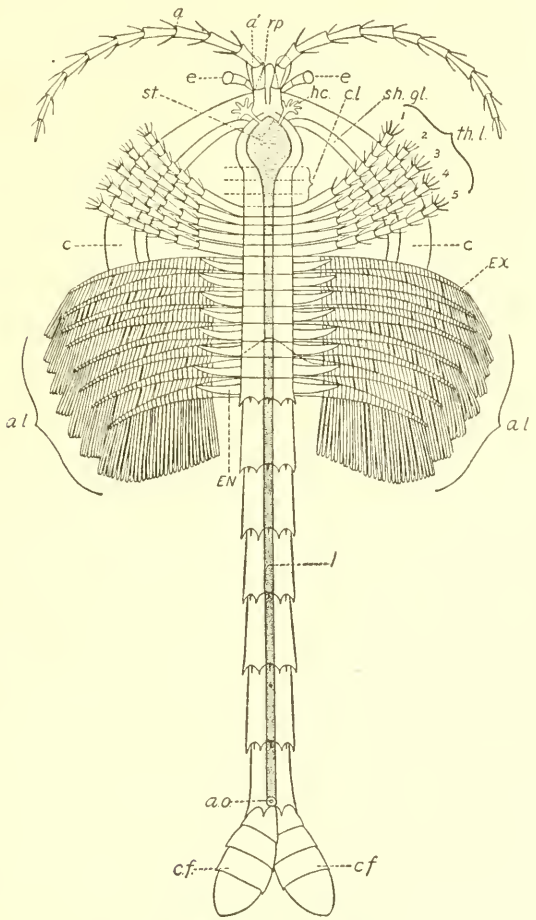

FIG. 6.—*Waptia fieldensis* Walcott.

a, antennae; *a'*, antennules; *a. l.*, abdominal limbs; *a. o.*, anal opening; *c*, carapace; *c. f.*, caudal furca; *c. l.*, cephalic limbs; *e*, eye; *en*, endopodite (??); *ex*, exopodite; *h. c.*, hepatic caeca; *i*, intestine; *r. p.*, rostral plate; *sh. gl.*, shell gland; *st*, stomach; *th. l.*, thoracic leg.

(About × 3.5.) Diagrammatic outline of ventral view of appendages and digestive organs. Most of the data on which this figure is based are shown by specimens illustrated on plates 19 and 20.

towards the median line; when folded over on its longitudinal axis each side is a long semi-oval with the narrow end in front; there is no evidence of the presence of a longitudinal median line or hinge in the many specimens collected from the Burgess shale.

Rostral plate.—A small triangular rostral plate with narrow, sharp, longitudinal median ridge has been seen in four specimens (see fig. 3, pl. 19; fig. 2, pl. 20); it is located in the median line between the antennae.

Dimensions.—The average length of an entire adult specimen is from 40 to 50 mm., the carapace being about 16 mm. in length with a width when flattened of 15 mm. The general proportions of the various parts are shown by figure 4, plate 27, of the 1912 paper.

Eyes.—The eyes are relatively large and placed at the end of a stalk or peduncle that projects from beneath and on each side of the rostral plate as seen from above. The peduncles are slender at their proximal end and expanded in a broad oval outline on the distal third of their length, the expanded section carrying the elongate oval visual surface; the peduncle appears to have had at least one joint at about the inner third of its length and to have been attached to a prostomium at its proximal end.

Cephalic appendages.—These consist of a pair of long jointed antennae that project forward beside and beneath the median rostral plate, and a pair of short lobelike antennules appear to be represented close to the eye and above the antennae (see fig. 3, pl. 19; fig. 2, pl. 20) in several specimens. Traces of three pairs of cephalic limbs have been observed but their structure and form are unknown.

Thoracic limbs.—A number of specimens have five strong thoracic limbs that extend from their union with the body trunk forward and outward beyond the edge of the carapace (see fig. 2, pl. 18); the distal joint is short and has three strong and two small curved spines projecting from its outer end and fine spines along its margin; the three next joints are rather short and spiniferous, but the detailed character of the remaining joints is unknown. The limb observed is assumed to be the endopodite of a biramous limb, but the exopodite was not developed or it was so small and delicate as not to be preserved in the fossil state.

Abdominal limbs.—Each of the abdominal limbs is represented by long, multi-jointed exopodites bearing long, slender filaments (see fig. 3, pl. 20). The proximal joint was probably short and without fringing filaments, but none of the specimens proves this to have been the case; the exopodites are rather large at the proximal end, tapering gradually to a slender, flexible terminal section; the filaments of the terminal section are sometimes gathered in tufts or bundles as shown by figure 3, plate 20. The filaments are usually flattened and matted together, but a few specimens show them to have been slender, cylindrical tubes similar to the filaments on the exopodite of *Marrella*

splendens (see restorations). The presence of a rudimentary endopodite is suggested on some specimens by an elongate, triangular, light-colored space on the proximal portion of the exopodites as shown by figure 3, plate 20; these light areas may be the outline of a space inside the broad arm of the exopodite, but they usually cross the axis of the arm diagonally; if they do represent the endopodite they were exceedingly delicate and attached by a broad base beside the exopodite in such a manner as to be held almost rigidly in place, and they are always in the fossil state pressed against the proximal section of the exopodite, and they have a silvery sheen so characteristic of the contents of the inside of the limbs of all crustaceans of the Burgess shale preserving the limbs. I do not think that they represent the endopodites, but they are the only suggestion of the latter thus far observed in connection with the abdominal limbs of *Waptia*.

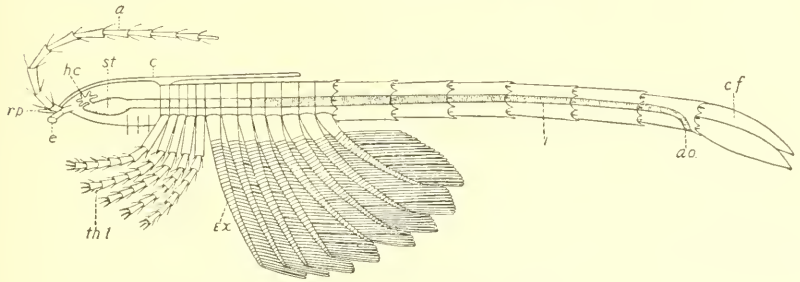

FIG. 7.—*Waptia fieldensis* Walcott.

a, antennae; *a. o.*, anal opening; *c*, carapace; *c. f.*, caudal furca; *e*, eye; *ex*, exopodite; *h. c.*, hepatic caeca; *i*, intestine; *r. p.*, rostral plate; *st*, stomach; *th. l.*, thoracic leg.

(× 3.) Diagrammatic side view of a section of the animal, illustrating the appendages, digestive tract, etc.

Functions of appendages.—The functions of the antennules and antennae were presumably sensory as in recent Malacostracans, as they do not appear to have been modified for any other purpose, and the proximal joint, as far as known, did not function as a manducatory organ.

The mandibles, maxillulae, and maxillae are unknown; the five pairs of thoracic limbs may have been used for crawling on the bottom, but with short joints and spinous distal joint they could not have been very effective; the exopodites of the eight pairs of abdominal limbs served as natatory organs and also as branchiae, the long delicate filaments presenting an extended surface area to the water.

Digestive organs.—What is known of the digestive system of *Waptia* indicates that it was somewhat similar to that of the living

Apus. The elongate globular stomach (*st*), with the small digestive or hepatic glands (*d. gl.*), long simple intestine (*i*) terminating on the last segment at the anus (*an*) all suggest corresponding organs in *Apus,* and it is highly probable that the mouth was ventral and communicated with the stomach by a gullet extending upward and forward. The shell gland (*sh. gl.*) or renal organ is distinctly marked in several specimens and, as far as comparison is possible, is not unlike that of *Apus*.

Observations.—Waptia was a pelagic, free and active swimming animal using its abdominal limbs and the broad terminal rami for propulsion. The fact that it is found in association with algae and sponges is explained by the conclusion that the sessile forms of life were detached and drifted into the Burgess pool and deposited along with the pelagic forms that dropped to the bottom of the sea.[1]

The carapace of *Waptia* is much like that of *Hymenocaris* except that it is not separated into two equal parts by a median longitudinal hinge line, and there is no evidence of the presence of an adductor muscle scar on each side as in *Hymenocaris*.

DIAGRAMMATIC RESTORATION OF VENTRAL VIEW OF THE BODY AND APPENDAGES, WITH OUTLINE OF DIGESTIVE ORGANS

Most of the data on which the restoration is based is shown by the specimens illustrated on plates 18, 19 and 20. The form and position of the cephalic appendages are unknown with the exception of the antennae and possibly antennules; the proximal joints of the thoracic and abdominal limbs are outlined on the specimens though their form is not preserved, but otherwise the limbs are fairly well known. The body cavity is outlined by figure 3, plate 18, but it is not included in this diagrammatic figure. The shell glands (*sh. gl.*), stomach, intestine, and hepatic caeca are outlined, as they represent what is known of the digestive organs.

Plesiotypes.—U. S. N. M., Nos. 83948a-e.

WAPTIA CIRCULARIS, new species

Plate 21, fig. 3

A single specimen with a short, rounded carapace was labeled *W. circularis* by Doctor Walcott. As far as the rather poor preservation permits a determination it would seem that otherwise it is similar to *W. fieldensis*.

Holotype.—U. S. N. M., No. 83449.

[1] Smithsonian Misc. Coll., vol. 67, no. 5, pp. 219, 220, 1919. Idem, no. 6, p. 265, under *Habitat*.

SKANIA, new genus

Description.—Dorsal shield thin, broadly rounded in front and tapering from the postero-lateral angles of the cephalic carapace to the posterior end of the shield.

Cephalic carapace transverse with the postero-lateral angles extended into spines; posterior margin arched forward; frontal margin reflected to form a doublure to which a small elongate labrum is attached. Eyes unknown but indicated by a bright spot on the carapace a short distance outward from the side of the labrum. No traces of facial sutures.

Posterior dorsal shield, elongate and formed of 14 or 15 fused segments with a more or less distinctly marked border. There is a short transverse segment or telson (pygidium) outlined, but whether it is free from the next anterior segment is unknown.

Surface of test apparently smooth.

Dimensions.—This genus is based on a small animal, *S. fragilis*, 5 to 17 mm. in length.

Appendages.—There are indications of antennae, three pairs of cephalic limbs, and a pair of limbs for each segment of the posterior dorsal shield.

Digestive organs.—An intestine extends from the posterior segment forward to the central part of the cephalic carapace where it widens out to form an elongate oval stomach. There are traces of hepatic caeca adjoining the stomach.

Genotype.—*Skania fragilis* Walcott.

Stratigraphic range.—The stratigraphic range is limited to a band of dark siliceous shale about 4 feet in thickness forming a part of the Burgess shale member of the Stephen formation.

Observations.—The generic name is derived from Skana, the name of a glacier in the Mount Robson District, Alberta, Canada.

The specimens representing the species of this genus are small and so thoroughly flattened in the shale that little more than a black film remains. This makes it very difficult to obtain details and also leaves some doubt as to whether the posterior dorsal shield is formed of fused or free segments.[1]

SKANIA FRAGILIS, new species

Plate 21, fig. 1

Description.—General outline irregularly heart-shaped but subject to wide variation owing to distortion by compression.

[1] At the head of these notes, Doctor Walcott later wrote, "A trilobite, C. D. W."

Dorsal shield.—Owing to its extreme tenuity there is usually little more than a dark film on the shale that has definite outlines, and shining through it are traces of the digestive organs and the ventral limbs. The transverse cephalic carapace recalls that of *Marrella* without the great median spines; it is often incurved at the center of its anterior margin and laterally projects into long backward-curving, spine-like extensions that are so tenuous as to suggest that the cephalic carapace was formed of a delicate membrane.

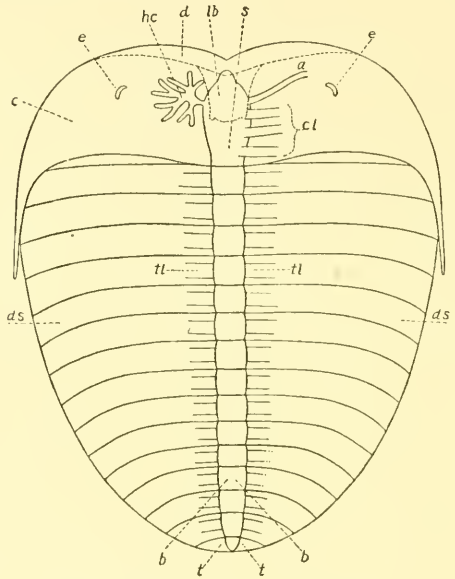

FIG. 8.—*Skania fragilis* Walcott.

(×7.) Diagrammatic outline of ventral side showing the various parts as interpreted from several specimens. No details of the segments of the posterior dorsal shield are preserved, but the segments are clearly outlined. The intestine is quite definite, also the fact that it contracted at each segment and expanded into a stomach beneath the cephalic carapace. Only the proximal portion of the limbs is outlined, although fragments of the distal portion are preserved on one specimen.

The thoracic portion of the dorsal shield is clearly segmented in two specimens, and traces of segmentation occur in others, but usually there is only a black smear on the shale with the outline of the intestine showing through it. There appear to be 14 or 15 fused segments and possibly a minute terminal segment or telson. None of the 29 specimens in the collection show the outlines of the median lobe, although one has a slight elevation along the line of the intestine.

Labrum.—Traces of a narrow doublure and small labrum have been seen on two specimens; the labrum appears to have been elongate with an outline similar to that of the labrum of *Burgessia.*

Dimensions.—The largest specimen has a length of 17 mm., but the average length is from 5 to 8 mm.

Appendages.—One specimen has several thoracic endopodites out of place on one side, and other specimens show the proximal joint obscurely but sufficiently well to recognize them; another specimen has what may have been slender antennae projecting from beneath the flattened labrum and posterior to it three pairs of slender appendages in which all traces of joints have disappeared; there are also on this specimen several threadlike, silvery lines extending from the central axis out to a margin which indicates that the limbs were long and slender; none of the specimens clearly show the exopodites or any details of the limbs. Specimens of *Marrella* and *Burgessia* often have threadlike, silvery lines representing the limbs, these lines being the pyritized contents of the joints, the test having disappeared in the process of mineralization of the original specimen.

Digestive organs.—The stomach is represented by an enlargement of the anterior portion of the intestine within the cephalic carapace, and the intestine extends back to the last segment; traces of hepatic caeca also occur beneath the cephalic carapace adjacent to the stomach.

Observations.—This very delicate form was placed, when sorting the collections, among specimens of the young of *Marrella splendens,* but it became evident upon close examination that they were quite distinct. They have a dorsal shield resembling that of *Naraoia.* I have examined all the specimens in hopes of finding free segments, but without results. There is no well-defined border about the posterior dorsal shield as in *Naraoia,* but there is a definite margin that is unbroken by the extension of the fused segments beyond it.

The almost complete flattening of all the specimens prevents any comparison with the median lobe of the trilobites, and there is no indication of facial sutures although there are slight traces of eyes on the cephalic shield at about the same place as in *Nathorstia.*[1]

Holotype.—U. S. N. M., No. 83950.

MOLLISONIA Walcott 1912

MOLLISONIA ? RARA Walcott

Plate 21, fig. 4

Mollisonia ? rara Walcott, 1912, Smithsonian Misc. Coll., vol. 57, no. 6, p. 198, pl. 24, figs. 6, 7.

Original description.—"Of this species there are several fragmentary specimens. The species differs from *M. gracilis,* with which it is

[1] Smithsonian Misc. Coll., vol. 57, no. 6, pl. 28, fig. 2, 1912.

associated, in the character of the thoracic segments and pygidium; also, so far as we can determine from this superficial study, there are seven segments and the pygidium shows distinct segmentation with a denticulated border."

A complete individual was found after the two fragments were described in 1912. The angularity of the shield at the bottom of the specimen as mounted on the plate is characteristic as its essential angles and curves are repeated in all the specimens referred to the species.

Plesiotype.—U. S. N. M., No. 83951.

MARRELLA SPLENDENS Walcott

Plate 22, figs. 1-9

Marrella splendens Walcott, 1912, Smithsonian Misc. Coll., vol. 57, no. 6, p. 193, pl. 25, figs. 1-6, pl. 26, figs. 1-6.

In the preliminary note of 1912 the general form and appearance of the carapace and appendages of *Marrella splendens* were described and illustrated. Since then a large number of specimens have been collected, some of which have added to our information both of the carapace and ventral side.

Exoskeleton.—The exoskeleton with the exception of the carapace is very delicate and formed of a series of 31 segments or somites, to 24 of which a pair of biramous appendages are attached; also a terminal segment of the body forming a minute plate-like telson and five segments of the head indicated by the presence of four pairs of free appendages and one segment incorporated in the body of the carapace; this is indicated by the anterior lateral free spines of the carapace with a pair of sessile eyes. As far as may be determined from the compressed fossil specimens the section of the body segments was broadly oval with a dorsal stergite and a ventral sternite section, the appendages being attached on the lower side on the ventral sternite below the margins of the dorsal stergite.

This does not mean that the eyes necessarily represent the anterior segment but that they represent one segment whatever may have been its original position.

Carapace.—Carapace strong, subquadrangular, and with two large dorsal postero-lateral, spinelike lobes (fig. 9) comparable with the postero-lateral lobes of the carapace of the Apodidae. At each antero-lateral angle a strong, backward-curving spine is attached by a close suture. These spines complement the great dorsal thoracic spines and may be compared with the movable or free cheeks of the trilobite. A narrow median carina or ridge extends the entire length of the lateral spines and the postero-lateral lobes.

Labrum.—The labrum is attached to the strong frontal rim (doublure) of the ventral side of the carapace (fig. 9), and extends back to within a short distance below the posterior median margin of the carapace; its posterior lateral angles are extended into short, spine-like projections and the posterior margin appears to have been provided with two short points. The labrum appears to have covered the

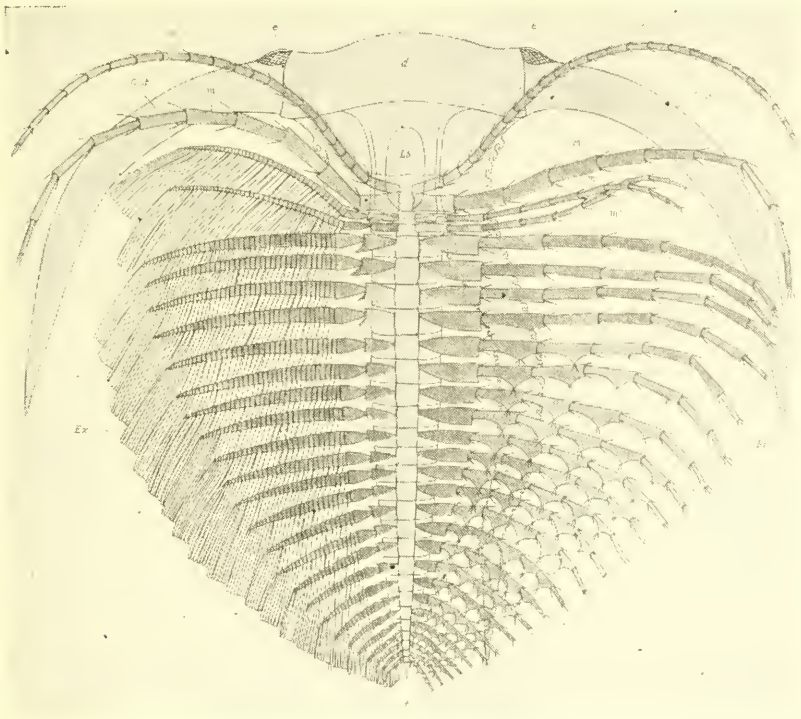

FIG. 9.—*Marrella splendens* Walcott.

Restoration as described in text: *a*, antennae; *c. sp.*, carapace spine; *d*, doublure or reflex of anterior margin of carapace; *e*, eye; *en*, endopodite; *ex*, exopodite; *m*, mandible; *m'*, maxillula; *m"*, maxilla; *t*, telson.

anterior portion of the mouth; this is indicated by the proximal end of the protopodite or basal joint of the large mandible and that of the antennae passing beneath it in many specimens (see pl. 22).

Eyes.—The eyes (fig. 9) have not been seen from the dorsal side of any of the several hundred specimens preserving the carapace, and rarely from the ventral side; this leads to the conclusions (a) that they were located on the lower anterior margin in such a position as to be concealed when the carapace was flattened by compression;

(b) that they were of a very delicate structure and readily destroyed; (c) that when preserved they were likely to be distorted and displaced by compression in the shale and could only be seen from the ventral side of the flattened carapace when they projected beyond the margin and were outlined on the shale. At first I thought that the eyes were situated on the carapace just within the line of its union with the large antero-lateral spines. Later I re-examined all the specimens showing the eyes, and found two that indicated that the visual surface of the eye was on one side of the suture separating the spines from the carapace, and the cap or palpebral lobe on the other, and one that quite clearly indicated that it was attached to the proximal end of the great spines, the latter being equivalent to the free cheeks of the trilobite. The interpretation of this is that the visual surface of the eye was attached to the great spine outside of the suture that outlined the spine from the carapace, and that the cap or palpebral lobe of the elevated visual surface of the eye was attached to the carapace as in the trilobites with elevated eyes and free cheeks.

It is difficult to determine the extent of the elevation of the eye above the carapace, but from its inconspicuous position in the fossil state I strongly suspect that it was only slightly raised and that its field of vision was largely forward and downward; this would be in accord with the needs of a small, active, free-swimming animal that spent little time on the bottom.

Among the trilobites the eye of *Deiphon forbesi* Barrande[1] is at the proximal end of a large genal spine forming the free cheek, and the great eye of *Bohemilla stupenda* Barrande[2] occupies nearly the entire width of the proximal end of the free cheek which is extended into a long strong spine.

Digestive organs.—The intestinal canal extends from the posterior margin of the labrum back to the small, platelike termination of the body; it is contracted a little opposite the line of union of each of the segments (see figs. 6, 7, and 9, pl. 22); anteriorly the intestine widens out between the labrum and carapace to form what may have been the stomach; the narrow canals of the dorsal lobes passed into the space between the carapace and labrum and probably entered the enlarged intestinal canal as did the canals of the antero-lateral spines which appear to pass without interruptions through the close sutures that unite them with the carapace; the canals of the postero-dorsal lobes may represent the shell-glands or excretory organs of the recent Apodidae.

[1] Syst. Silur. de Boheme, vol. 1, pl. 2B, fig. 4, 1852; suppl., pl. 2, fig. 19, 1872.
[2] Idem, vol. 1, Suppl., pl. 14, fig. 30.

Cephalic appendages.—These consist of antennae, mandibles, simple slender maxillulae, and slender maxillae. The proximal joints of the cephalic appendages are so badly crushed and matted together beneath the labrum or just back of it that it has been very difficult to determine exactly their form and relations to each other, but it is highly probable that they were arranged as in the restoration (text fig. 9).

Antennae.—The antennae are long, slender, and many-jointed, with fine spines at the distal end of each joint. As far as may be determined, the proximal joint was attached to the ventral surface beneath the postero-lateral angle of the labrum just in advance of the mandible. There is no evidence that it served as a jaw or manducatory organ except that in specimens preserving them their inner (proximal) end is in front of and adjoining the large proximal joint of the mandibles (see figs. 3, 6, and 7, pl. 22).

Mandibles.—The mandibles are formed of a strong proximal joint with four short, strong joints followed by five slender, elongate joints (see fig. 9), the latter being almost covered with very fine setae that give a plumose appearance to the appendage as it extends out beyond the great backward curving spines of the carapace. I examined hundreds of specimens before finding a proximal joint with its inner end sufficiently well preserved to suggest the character of its masticatory surface; two specimens indicate that it is as shown in figure 7, plate 22, and in the restoration. There is no evidence as to whether the proximal joint is composed of one long joint or two closely united short joints. The usual location of the mandibles in well preserved specimens is shown by figures 1 and 2, plate 22.

Maxillulae.—These are long, slender, and with about 10 slender joints. They look like thoracic legs (endopodite) but their position and slender joints serve to distinguish them. Portions of them may be seen in figures 1 and 2, plate 22.

Maxillae.—As far as known the maxillae are formed of joints a little longer than those of the maxillula and about the same diameter; both appear to have been slender, rather closely jointed, simple appendages as far as the endopodite was concerned; there is strong evidence that an exopodite was present, similar to those of the exopodites of the trunk appendages, but they have not been seen directly attached to the protopodite; where the parting of the shale is on the plane of the exopodites they are usually present next to the mandible and directly over the position of the maxillulae and maxillae, which suggests strongly that they were present.

The maxillulae and maxillae were so slender that they are usually absent as the result of having been torn off or crushed between the

strong mandibles and the thoracic limbs. In figure 1, plate 22, their exopodites are shown on the left side, and on the right side the endopodites of the maxilla with the exopodite of the maxillula, the endopodite of the latter having apparently been pushed under and a little forward of the mandible. Sometimes the endopodite is present but the joints are indistinguishable or only a few can be seen.

Thoracic limbs.—The biramous thoracic limbs appear to be uniform in character from the cephalon to the minute plate-like telson at the posterior end of the body. Each limb is formed of a protopodite, a jointed endopodite, and a jointed fringed exopodite.

Protopodite.[1]—The large protopodite is attached by its inner end to the lower side of the body segment about half way between the

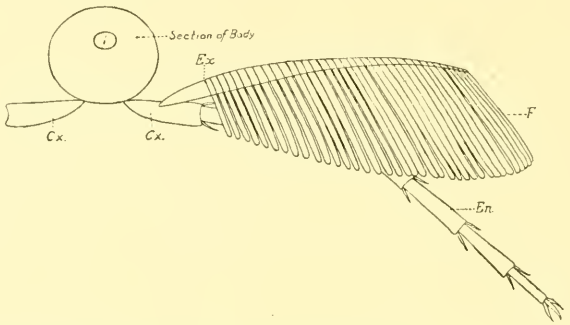

FIG. 10.—Diagrammatic outline of the posterior side of one of the anterior thoracic limbs: *pr*, protopodite; *en*, endopodite; *ex*, exopodite; *f*, filaments of exopodite; *i*, intestine.

This figure indicates the point of attachment of the limb to the body, also approximate position of the intestine.

ventral median line and the rounded outer side of the body apparently in the same manner as the trunk limbs of *Apus*, except that in the latter there is no evidence that the protopodite served as a gnathobase. The protopodite is elongate, apparently cylindrical at its inner end, and flattened somewhat at the distal end; it is strong, and supports an endopodite and an exopodite. It is usually flattened so as to appear of about the same width throughout its length; a few specimens indicate that it narrowed at its proximal end, essentially as shown in the restoration.

Endopodites.—The endopodite or leg is formed of six joints. The first five joints of the anterior limbs are rather flat and broad at the

[1] I find that at many places Doctor Walcott changed "protopodite" to "coxopodite." Whether this term was supposed to have been changed here also I was unable to ascertain.—C. E. RESSER.

sides; narrow and slender on the dorsal and ventral view; short, very fine spines occur at their distal end and along the side of the joints. The slender distal joint is more nearly cylindrical and has a short, strong, slightly curved spine with one or two fine spines beside it extending out from the end of the joint. The anterior legs appear to have been delicate and slender, but usually they have retained their natural position remarkably well. Usually the first joint of the endopodite of the fourth pair of limbs is slightly expanded, and the first and second joints of the fifth to seventh pairs of limbs, and the first five joints of the eighth to twentieth pairs of limbs. The expanded joints vary in degree of expansion from slight enlargement on the fourth limb to where the transverse diameter is considerably greater than the length of the joint. The latter recall the transverse flattened joints of the endopodite of the trilobite *Triarthrus becki*.[1]

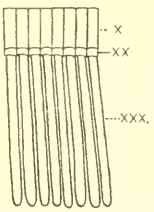

FIG. 11.—Diagrammatic enlargement of a section of the exopodite showing the body and the attached cylindrical filaments.

On some specimens showing the expanded joints the extended portion is very narrow from base to point, and gives the effect of a strong spine projecting from midway of the joint; in other specimens the base is as long as the joint and the apex is obtuse, which is the prevailing form. When in a natural condition the expansion of the joint was undoubtedly on the lower or the ventral side, and the fact that in the fossil state specimens occur with all the expansions pointing forward means only an accident of preservation; some occur with scarcely a trace of the enlarged joint, owing to the fact that the ventral side of the endopodite is buried in the shale, leaving the narrow dorsal side in view; in the restoration (fig. 9) I have outlined the flat, vertical posterior side of the endopodite.

Exopodite.—The exopodite is attached to the protopodite about midway of the length of the latter. It is formed of a long, strong proximal joint to which is attached a long, slender, multi-articulate appendage, each segment of which supports a long, slender, flat

[1] Smithsonian Misc. Coll., vol. 57, p. 137, pl. 30, fig. 20, 1912.

(formerly round) filament, which is beautifully preserved in some specimens (fig. 8, pl. 22). The fringe of filaments often overlap those of the adjoining exopodite so as to form an imbricating series of fringes the entire length of the body.

An exopodite 3 mm. in length has attached to it 42 filaments that average about 12 to 14 to the millimeter in the proximal portion, and 14 to 16 towards the distal end; they increase gradually in length from the proximal end until on the distal section they may be as long as the entire exopodite. A rusty specimen laid aside as of little value proved on cleaning to have the filaments preserved as long, slender cylinders or tubes (see fig. 8, pl. 22).

Most of the fossil specimens have the fringes extending forward and outward, but when the animal was living they undoubtedly extended outward and backward so as not to impede its forward movement.

As mentioned under *Cephalic appendages,* there is good reason to think that the two posterior oral appendages (maxillulae and maxillae) have in addition to the simple jointed endopodite an exopodite similar in structure to that of the thoracic limbs.

Epipodite.—A single specimen shows what I thought in 1912 to be a large epipodite or branchiae,[1] but which I have now decided to be several of the fringed exopodites pressed down together and more or less macerated in the contents of the body which were squeezed out on that side. It was only after finding a number of examples showing the fringed exopodites arranged in this manner but not pressed into each other that I gave up the view that a large epipodite was present.

Several specimens have been found since 1912 that indicate the presence of a small oval flattened lobe attached to the dorsal side of the protopodite, or it may be to the proximal joint of the exopodite, but it may be that this appearance is caused by the manner in which the protopodite and the segments of the body are matted down together; some of the thin oval bodies, however, are so clearly defined that they suggest the presence of a small epipodite, but I do not consider the evidence sufficient to warrant representing them on the restoration of the thoracic limb.

Functions of appendages.—The proximal joints of the antennae may have assisted in mastication and may have had a sensory function. The proximal joints of the mandibles undoubtedly served in mastication, but whether those of the slender leglike maxillulae and maxillae aided is undetermined, as nothing has been seen of either

[1] Smithsonian Misc. Coll., vol. 67, pls. 29, 32, 1918.

gnathobasic spines or lobes. It is probable, however, from their position and form they were of service in directing food to the mouth.

The long, flat outer joints of the mandibles may have been used in swimming as an aid to the thoracic limbs.

The endopodite of the biramous trunk appendages probably served both as a natatory and ambulatory leg, although from their delicate distal joints they evidently were little used in walking. The fringed exopodites may have assisted in swimming and they undoubtedly served as gills. The absence of a channel formed of gnathobases on the protopodites of the trunk limbs such as occurs in the Apodidae and Trilobita, and also of any known organ for seizing food, leads to the conclusion that the exopodite may have served to direct a current of water bearing food towards the mouth. The long, strong filaments attached to the segments of the exopodite are comparable with the filaments of the exopodite of the trilobite *Neolenus*,[1] and the remarks on the latter should be read in this connection.

Diagrammatic restoration of the ventral appendages.—This is shown in text figure 9 and presents my interpretation of the arrangement of the appendages. The long body, with its numerous segments, is attached to the carapace in its cephalic region only. The antennae (*a*), mandibles (*m*), maxillulae (*m'*), and maxillae (*m''*) are drawn in from the evidence given by many specimens, no one of which has all the limbs in place; several of the best specimens are illustrated on plate 22. The eyes (*e*) are somewhat theoretically placed, but their general position is known despite the displacement most of them have been subjected to. On the right side the entire series of protopodites and endopodites forming the thoracic limb are represented; the form of the inner end of the protopodite is based on indications afforded by several specimens, although usually the protopodite is crushed flat and appears to be of the same size throughout its length. On the left side the protopodite is cut away so as to show the approximate point of attachment of the proximal end of the exopodite. The latter are drawn from such specimens as are represented on figures 1-9, plate 22, and many others not illustrated. The relative position and form of the exopodite, endopodite and protopodite is shown by text figure 10.

Mode of occurrence.—*Marrella splendens* occurs abundantly in the compact, hard shale but there are few really fine specimens. This free-swimming, delicate little crustacean dropped down on the surface of the bottom and was speedily buried by fine mud settling over it; the mass of gradually hardening mud pressed the rounded body into a

[1] Smithsonian Misc. Coll., vol. 67, no. 7, p. 370, 1920.

thin film and matted those parts resting on each other together unless there was a thin film of mud between them. When there was such a film of mud, it later hardened into shale and formed a plane of weakness along which the shale parted when, from the action of weathering or of force applied with hammer or chisel, the shale was split open. Sometimes the parting is between the matrix and the ventral or dorsal surface of the specimen, or it may be between the series of fringed exopodites and the endopodites; a number of specimens in the collection show a part of the endopodites with the exopodites above or below them, and again the parting may have been above or below the exopodites on one side of the body and the reverse on the other side (see pl. 22). The structure of the body and the thoracic appendages is very clearly exhibited, but the cephalic appendages, labrum and carapace, are usually so matted together that it is difficult to distinguish the details of structure.

OBSERVATIONS

Marrella and the trilobite.—*Marrella* has several characters in common with the trilobite and others that are dissimilar.

SIMILAR CHARACTERS

1. A cephalic shield supporting a labrum.
2. Sessile eyes on the proximal end of a great spine equivalent to the free cheek of the trilobite.
3. A labrum (hypostoma) with the proximal joints of the cephalic limbs gathered at its posterior end in a manner comparable with that of the trilobite.
4. A pair of biramous limbs for each trunk segment formed of a protopodite, jointed endopodite (leg), and a jointed exopodite, but without any known epipodite.
5. Expansion of the joints of the endopodites on some of the thoracic limbs.

DISSIMILAR CHARACTERS

1. Absence of a thoracic dorsal shield.
2. Almost total absence of an abdominal section or pygidium.
3. Position of proximal joint of antennae.
4. A large third cephalic appendage (mandible).
5. The manner of attachment of the coxopodite of each trunk limb directly by its proximal end to the side of the ventral surface of the body.

6. The coxopodite did not serve as a gnathobase.

1 and 2 are considered to be more primitive characters.

3, 4, 5, and 6 less primitive.

My present conclusion is that *Marrella* is a less primitive form than the Apodidae, and while a more primitive form than the trilobite it is nearer the latter than the Apodidae, and should be grouped near it but not with the Trilobita. At the time of my preliminary examination of the crustaceans then known to me from the Burgess shale I placed *Marrella* and *Nathorstia* as progenitors of the trilobite,[1] but with our present information *Marrella* will be placed with *Burgessia, Nathorstia* being left under Trilobita.

COMPARISON WITH CRUSTACEANS

Marrella and the Branchiopoda.—*Marrella*, with its sessile eyes, carapace-like cephalic shield, labrum attached to the doublure, numerous trunk limbs, and the large mandible, suggests the Apodidae, but when we consider the well-developed antennae, large removable spine attached to the cephalic shield, biramous trunk limbs on each body segment consisting of a fully developed endopodite and exopodite, and the absence of caudal rami, the conclusion is that *Marrella* represents a more advanced stage in the evolution of the Crustacea than *Apus* and its allies. The biramous limb of *Marrella*, like that of the trilobite, undoubtedly passed through the foliaceous or multiramous limb stage in its evolution, probably in pre-Cambrian time.

Marrella differs from the Branchiopoda in:

a. Absence of lobed multiramous foliaceous trunk limbs with gnathobases and in the presence of biramous trunk limbs with protopodite, jointed endopodite (leg), and jointed exopodite.

b. Absence of furcal rami.

c. Presence of a pair of biramous limbs on each trunk segment back to the telson.

Marrella includes the following characters of the Branchiopoda:

a. A true carapace arising from a fold of the integument.

b. A labrum attached to the reflected margin or "doublure" of the carapace.

c. A large mandible serving as a jaw in the process of mastication.

Plesiotypes.—U. S. N. M., Nos. 83486a-i.

[1] Smithsonian Misc. Coll., vol. 57, p. 161, 1912.

HELMETIA Walcott 1918

HELMETIA EXPANSA Walcott

Plate 27

Helmetia expansa Walcott, 1918, Smithsonian Misc. Coll., vol. 68, no. 12, p. 7, fig. 8.

This is another of the species first published in the Smithsonian explorations pamphlet for 1917, and for that reason is here reprinted.

Holotype.—U. S. N. M., No. 83952.

EXPLANATION OF PLATES

Plate 1

PAGE

Margaretia dorus, new species 2

Fig. 1. Impression of outer surface.

2. A wider and less well defined specimen. Possibly a mutilated fragment.

3. Impression of surface, on which the elevations apparently were more conical and more numerous, which may indicate another species.

4. Unretouched photograph by reflected light of the typical form. This is again the impression of the outer surface. Compare the elongate elevations with the more conical ones in fig. 3.

5. Unretouched photograph of the holotype.

6. (× 2.) Another, less perfect specimen on which Doctor Walcott apparently laid stress.

Plate 2

PAGE

Miskoia placida, new species 4

Fig. 1. The holotype showing the annulations, the teeth around the mouth, and the manner in which the digestive tract seems to run along one side of the body, as it is compressed in the shale.

Redoubtia polypodia Walcott 3

Fig. 2. A specimen, possibly of a different species, since it has smaller appendages. Parts of a *Hymenocaris?* lie above it.

3. (× 1.5.) Holotype, as illustrated previously.

Plate 3

PAGE

Wiwaxia corrugata Walcott 6

Fig. 1. Photograph of a very fine individual retouched to bring out the striae on the scales.

Portalia mira Walcott 3

Figs. 2, 3. Counterparts of the holotype. A specimen of *Miskoia* lies nearby.

PLATE 4

PAGE

Canadia spinosa Walcott 4

FIG. 1. (× 1.5.) Specimen having an unusually straight position, with all the spines turned backward and thus crowded together.

2, 3. Natural size and enlarged (× 3) views of a fine complete individual. The enlarged picture has been retouched.

PLATE 5

PAGE

Canadia spinosa Walcott 4

FIGS. 1, 2. Natural size and enlarged (× 4) photographs. The larger one has been retouched.

PLATE 6

PAGE

Canadia spinosa Walcott 4

FIG. 1. (× 2.) Photograph of a well preserved specimen.

2. (× 2.) Unretouched illustration of another specimen whose specific identity Doctor Walcott doubted somewhat.

Canadia sparsa Walcott 5

FIG. 3. (× 2.) Unretouched photograph of this peculiar worm.

Canadia irregularis Walcott 5

FIG. 4. Small, somewhat broken specimen. (See pl. 9, fig. 3, for enlargement.)

5. (× 2.) An unretouched photograph of the lectotype.

6. (× 2.) Coiled specimen doubtfully referable to the species.

PLATE 7

PAGE

Canadia setigera Walcott 5

FIG. 1. (× 2.) Unretouched photograph of a rather complete curled specimen.

4. (× 2.) Unretouched photograph showing the attachment of the setae.

Canadia dubia Walcott 6

FIG. 2. (× 3.) A good illustration of this small form.

Canadia irregularis Walcott 5

FIG. 3. (× 3.) Enlargement of specimen illustrated as fig. 4 on preceding plate.

Plate 8

PAGE

Canadia dubia Walcott 6

Fig. 1. A fairly large specimen.

2. (× 2.) A specimen showing the intestinal tract.

Canadia setigera Walcott 5

Fig. 3. (× 3.) Retouched figure of a specimen showing the bundles of spines particularly well.

Pikaia gracilens Walcott 7

Fig. 4. (× 2.) A wide specimen. The illustration is slightly retouched.

5. (× 2.) Another rather well preserved example.

Plate 9

PAGE

Ottoia minor Walcott 6

Fig. 1. (× 2.) A short form that may have its shape because the mouth parts are retracted.

2. (× 2.) Small specimen, showing intestinal tract, doubtfully referred to the species.

3. (× 2.) Apparently the anterior end of a poorly preserved individual.

4. (× 2.) Another form like fig. 2.

5. (× 2.) A specimen with a peculiar restriction that may be accidental.

6, 7. Retouched photographs of a particularly fine individual. The whole specimen is enlarged somewhat (× 1.5) and the anterior end considerably (× 4).

Canadia dubia Walcott 6

Fig. 8. (× 2.) Unretouched photograph of a small individual.

Canadia simplex, new species 6

Fig. 9. (× 3.) Retouched photograph of the holotype.

Canadia grandis, new species 5

Fig. 10. (× 2.) Retouched figure of the holotype.

Plate 10

PAGE

Selkirkia major (Walcott) 7

Fig. 1. (circa × 3.5.) A large individual, possibly preserving the original proportions of the shell.

2. (circa × 3.5.) Another specimen whose shell is more or less crushed, but with even better preservation of the soft parts.

PLATE 11

PAGE

Aysheaia pedunculata Walcott 8

FIG. 1. (× 2.) An unusually perfect specimen.

2. Large coiled specimen that Doctor Walcott regarded as possibly representing a different animal, but which may appear odd only because of its unusual attitude.

PLATE 12

PAGE

Leanchoilia superlata Walcott 8

FIG. 1. (× 2.) Retouched figure of a fragmentary specimen.

2. Natural size unretouched photograph of a well preserved individual.

3. Enlarged, retouched figure of the counterpart of the preceding figure.

PLATE 13

PAGE

Leanchoilia superlata Walcott 8

FIG. 1. (× 3?). An appendage apparently belonging to this species.

2. An individual flattened out in the horizontal plane, thus giving it an unusual aspect.

Leanchoilia major, new species 10

FIG. 3. Illustration of the holotype.

Naraoia compacta Walcott 10

FIG. 4. (× 3.) An unretouched photograph of a good specimen. The appendages are only faintly shown extending beyond the carapace at the rear of the specimen. (See pl. 15, fig. 3.)

PLATE 14

PAGE

Naraoia compacta Walcott 10

FIG. 1. (× 2.) Dorsal view of a compressed and somewhat distorted specimen, on which the outline of the body trunk is well shown and, on the left side, the ends of 16 exopodites preserving their fine filaments.

2. (× 2.) Dorsal view of a specimen with the carapace shortened nearly one-half by compression. The central portion showing the hepatic glands or caeca is unusually well preserved. The posterior dorsal shield has the outlines of the fused segments and the outer border clearly indicated, and on the left side, where a piece is broken out, two of the exopodites are seen, and at the posterior margin, traces of endopodites.

3. (× 3.) Enlarged view of a specimen with peculiar features along the axis.

Leanchoilia superlata Walcott 8

FIG. 4. (× 2.) Details of a separate appendage.

5. (× 2.) Another appendage of a different type.

PLATE 15

PAGE

Naraoia spinifer, new species 15

FIG. 1. (×2.) Posterior dorsal shield with traces of segmented body and thoracic limbs; a dorsal view of another specimen shows clearly defined exopodites with the slender, distal ends of endopodites projecting from beneath them.

Naraoia compacta Walcott 10

FIG. 2. (×2.) Smaller, retouched picture of the specimen shown in fig. 4, pl. 13.

3. (×1.5.) Incomplete individual clearly showing the axis.

Burgessia bella Walcott 15

FIG. 4. (×3.) Specimen showing the outlines of 10 thoracic legs formed of the six joints of the endopodite and the large protopodite, also the annulated intestine and fragments of the crushed carapace.

5. (×4.) A dorsal view of a specimen in which the stomach and portion of the intestine as well as the large hepatic tubes are distended so as to be moderately convex. The specimen also shows the position of the antennae and portions of the hepatic caeca.

6. (×4.) A macerated specimen indicating the position of the eyes, the antennae, a portion of the labrum, the mandibles, the maxillulae, and the maxillae; also the proximal portion of seven pairs of the thoracic limbs, with a fair indication of the point of attachment of the limbs to the body.

7. (×3.) Another very fine individual.

PLATE 16

PAGE

Burgessia bella Walcott 15

FIG. 1. (×2.) Fragmentary specimen indicating structure of limbs. (Possibly oriented incorrectly.)

2. (×4.) A specimen preserving 10 pairs of thoracic limbs, showing their approximate place of attachment to the body, and also their expanded joints and general form.

The carapace has been crowded back and crushed, but the antennae project from its anterior side in an almost natural position.

3. (×2.) A badly decayed specimen that shows the manner of attachment of the limbs.

4. (×4.) Dorsal view of a specimen with the digestive organs beautifully preserved. These include the intestine posterior to the large hepatic tubes, the stomach anterior to the latter, and also the anterior and posterior branches of the main hepatic tubes and the numerous finer hepatic caeca, which occur on both the outer and inner sides of the main branches.

This specimen gives most of the data for the restoration of the digestive organs as shown by text fig. 5.

5. (×4.) Specimen showing the expanded joints of the endopodites of the cephalic limbs.

6. (×3.) Partly side view of a crushed and distorted specimen illustrated for the purpose of showing the exopodites that occur near the body, the proximal part of the endopodites with the protopodites having been flaked off from above the exopodites in the specimen; in their natural position the exopodites were probably above and between the endopodites. The outer ends of the long, strong endopodites are well shown in this specimen, although the joints have been obscured. The slender jointed leglike structure associated with the exopodites may be the distal part of the endopodites of the right side.

PLATE 17

PAGE

Burgessia bella Walcott 15

FIG. 1. (×3.) Another specimen preserving mainly the "skeleton."

2. (×2.) A small individual crushed obliquely.

3. (×3.) Ventral view of a specimen preserving the reflected anterior margin and labrum, also the antennae, outlines of the inner portions of the cephalic limbs, and more or less distinctly outlined thoracic endopodites with transversely expanded joints. The anal plate is clearly indicated, also the anterior end of the telson.

4. (×4.) Side view of a crushed specimen preserving on the left lower side the outlines of 10 thoracic legs, on the right side the outlines of four entire lobelike exopodites and the distal end of four posterior to them. The exopodites still show slight traces of fine filaments (?) along the posterior and outer margins.

PLATE 18

PAGE

Burgessia bella Walcott 15

FIG. 1. (×2.) An incomplete specimen showing the manner in which the limbs project beyond the carapace.

Waptia fieldensis Walcott 20

FIG. 2. (×4.) Side view of a flattened specimen preserving six or more cephalic limbs, the limbs from both sides being more or less crushed down together.

3. (×2.) Specimen showing on the right side a flattened uninjured antennae in its natural form, and on the left side only the outline of the interior of the joints. The latter mode of occurrence is quite common for the antennae and other appendages. This specimen also has the stalked eye preserved on the right side.

4. (×2.) A few thoracic exopodites in which the flattened filaments are unusually well preserved.
5. (×4.) Side view of a flattened specimen showing the outlines of body through the carapace, the stalked eye, antennae, four cephalic limbs, and several thoracic limbs.

This specimen is particularly instructive, as it shows the outline of the thoracic limbs from the body to their distal end.

PLATE 19

PAGE

Waptia fieldensis Walcott 20

FIG. 1. (×2.) Anterior portion of an individual showing the limbs.
2. (×2.) Unretouched photograph of a distorted specimen showing the eye particularly well.
3. (×2.) Dorsal view of the carapace of a specimen showing the outline of the body, also the small rostrum between the the antennae and the eyes.
4. (×3.) Specimen with details of eyes and antennae.

PLATE 20

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FIG. 1. (×2.) Posterior portion of specimen preserving the three segments, the anal opening, and the lobed, segmented caudal furca.
2. (×3.) Anterior portion of a carapace, median rostral plate, antennae, stalked eyes, and a palp on the left side.
3. (×2.) Side view of a flattened specimen in which a number of the exopodites retain the fringing filaments, some of the latter being gathered in a cluster at the distal ends. This specimen also shows the outlines of elongate triangular, light-colored, shiny places that may indicate the interior of the exopodite or possibly a rudimentary endopodite.

PLATE 21

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Skania fragilis Walcott 25

FIG. 1. (×4.) Specimen showing the flattened intestine and outline of thoracic segments.

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FIG. 2. (×2.) Dorsal view of a flattened specimen in which the carapace has been removed from over the cephalic area and portion of the thoracic region. The proximal portion of eight thoracic limbs is clearly shown, also of three pairs of cephalic limbs.

PLATE 22

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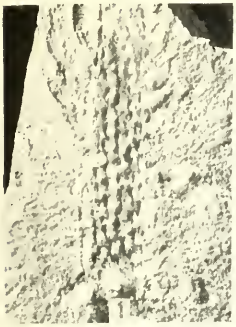
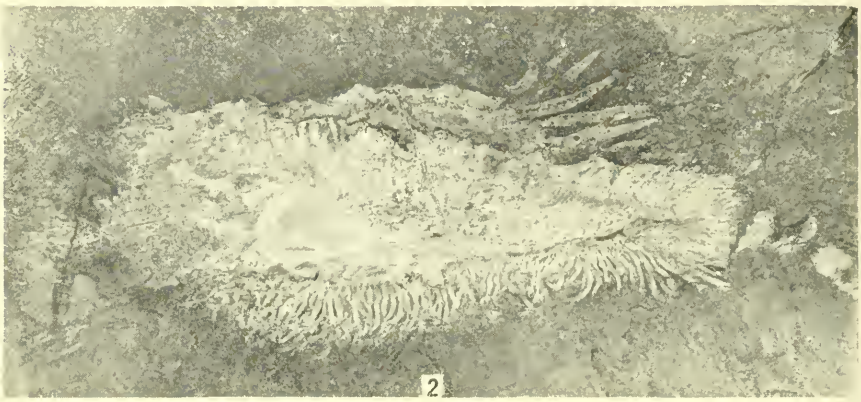
8. (×6.) Enlargement of the filaments of one of the thoracic exopodites in which the filaments retain their original round, slender tubular form. This is the only specimen among several hundred that I have examined which has escaped flattening by compression. This is due to the pyritization of the filaments of this particular specimen.
9. (×4.) Ventral view of a specimen illustrated to show what appears to be a small oval flattened lobe attached to the dorsal side of a protopodite or it may be to the proximal joint of the exopodite; a number of the thoracic exopodites with the filaments projecting forward occur on both sides, also fragments of the large postero-lateral spines of the carapace which lie above the exopodite of the thoracic limbs.

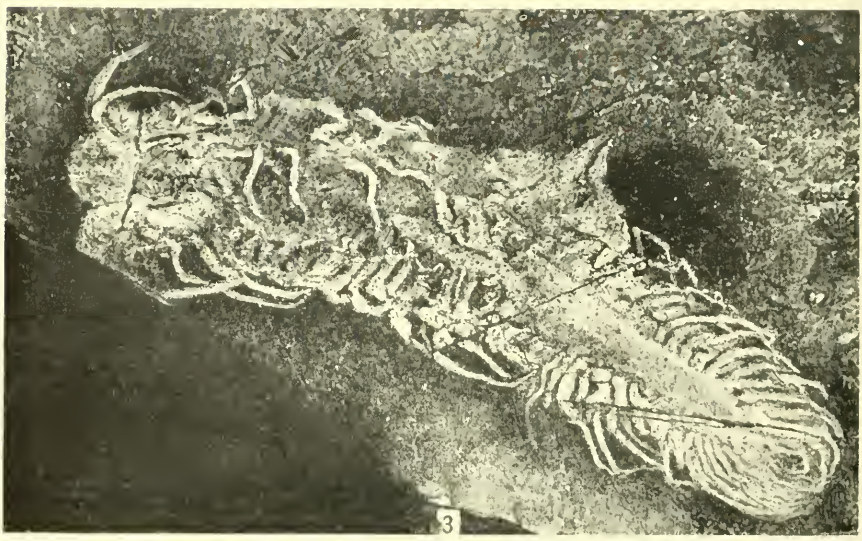
Plate 23



BURGESS SHALE FOSSILS

FOR EXPLANATION SEE PAGE 38.





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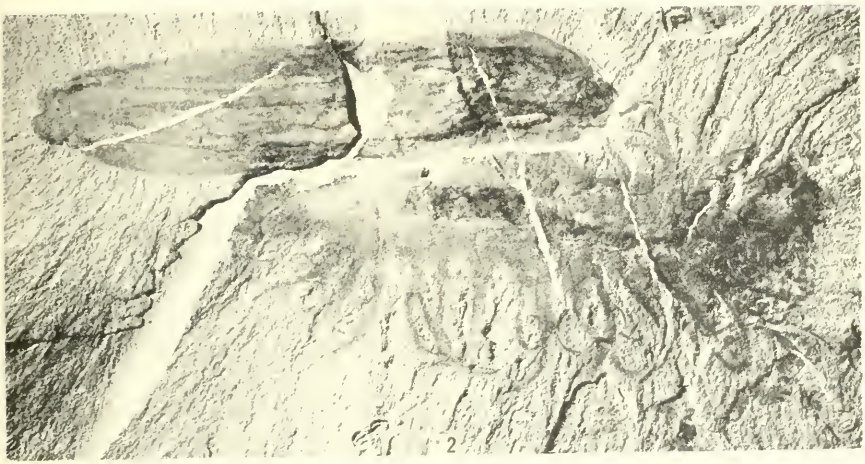

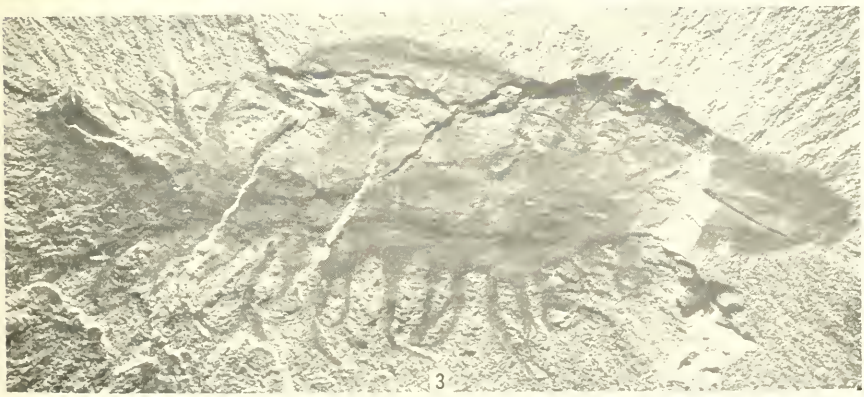

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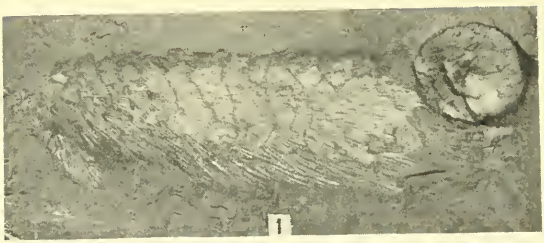

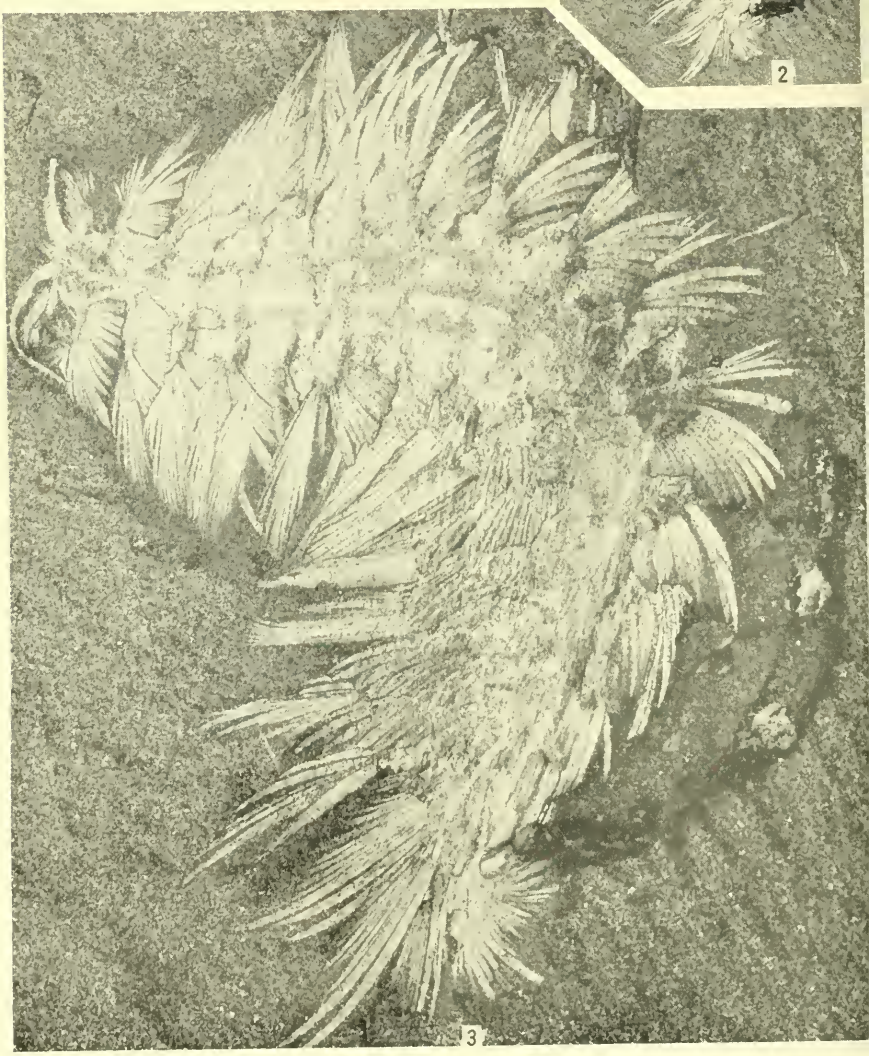

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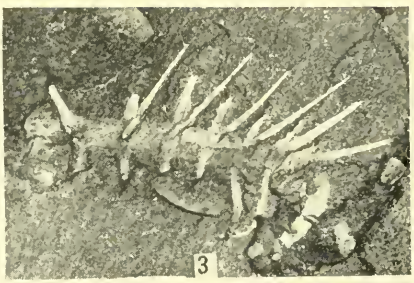

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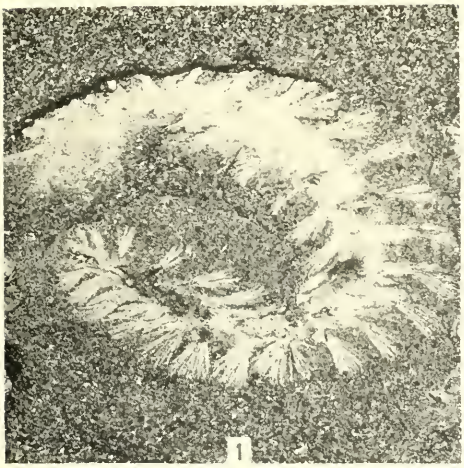

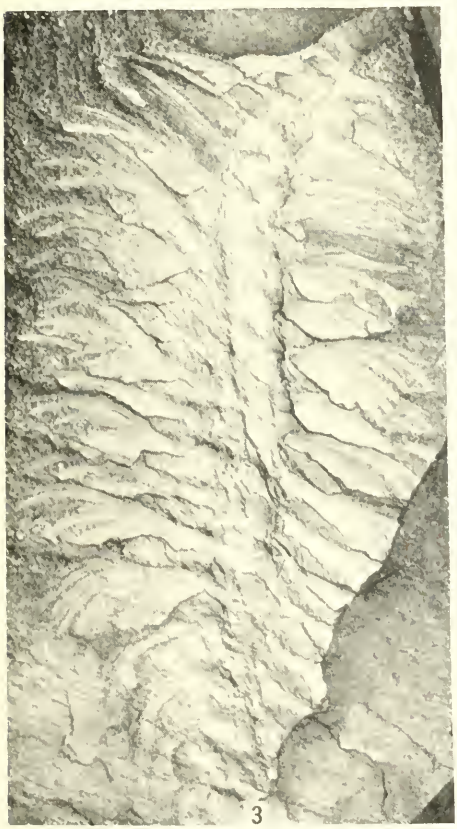

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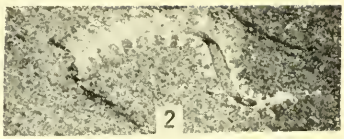

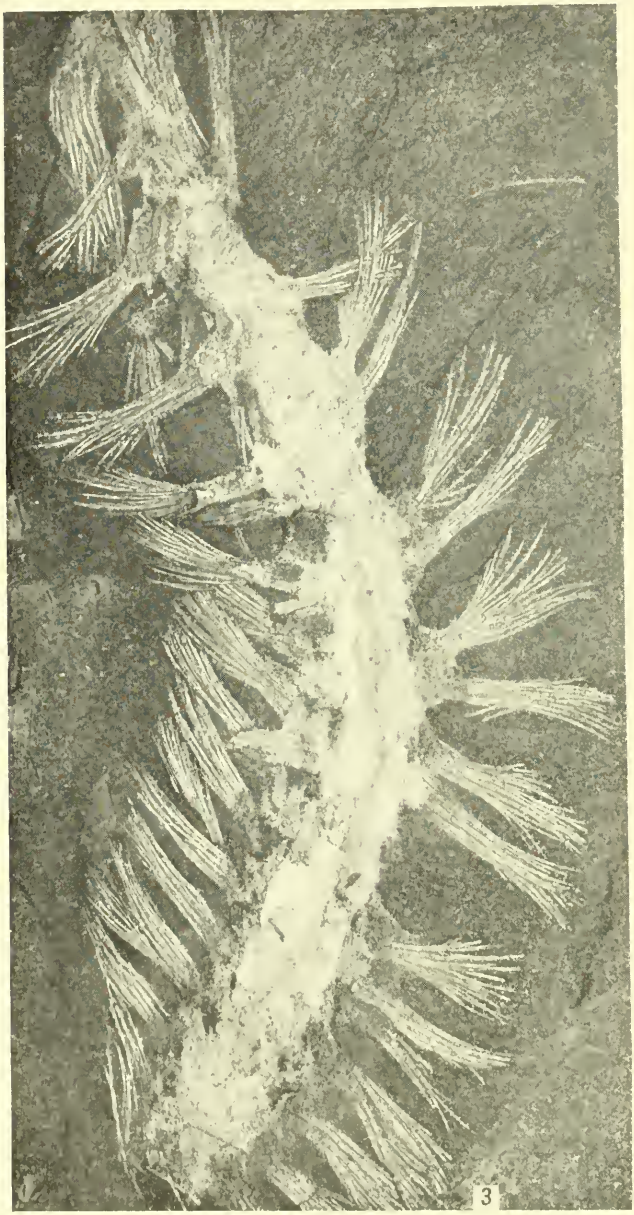

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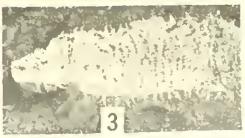
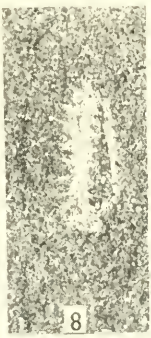
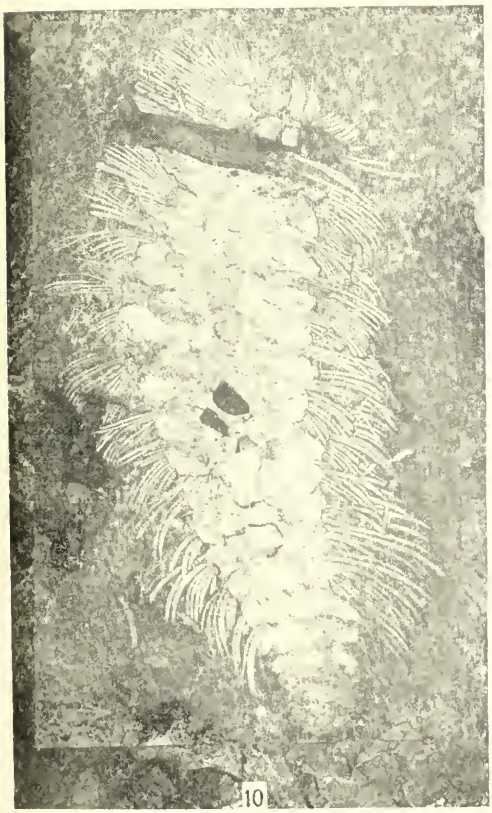
FOR EXPLANATION SEE PAGE 40.







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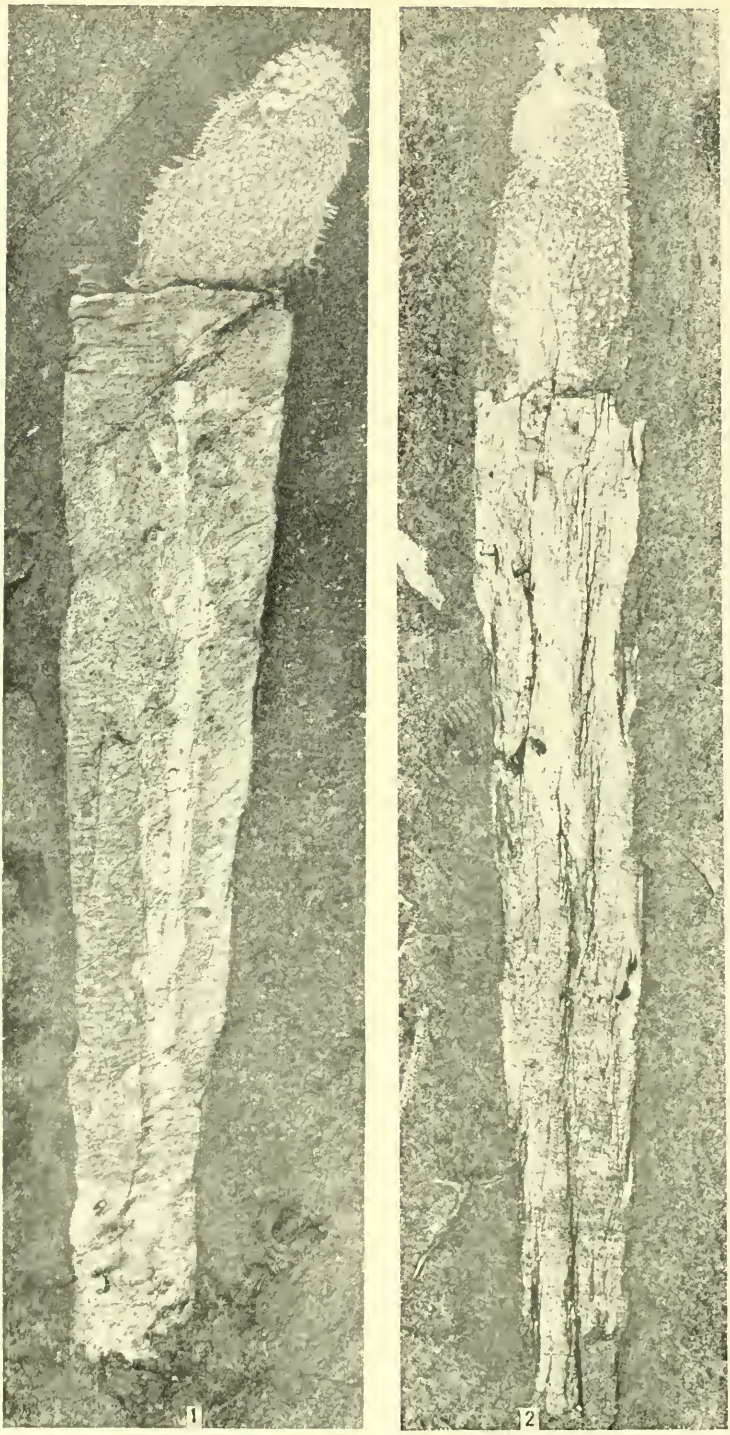

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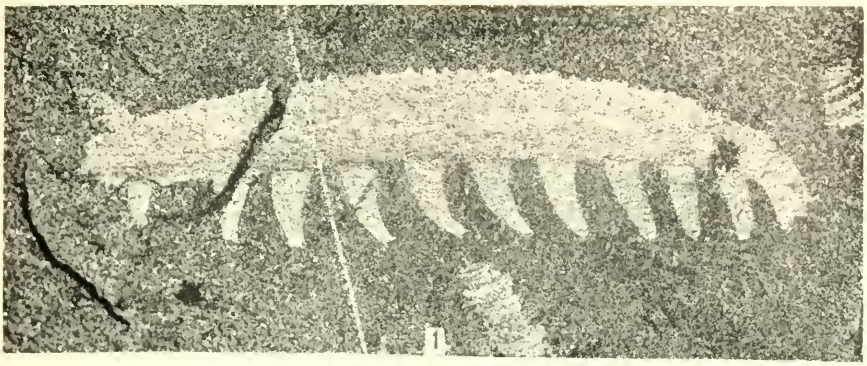

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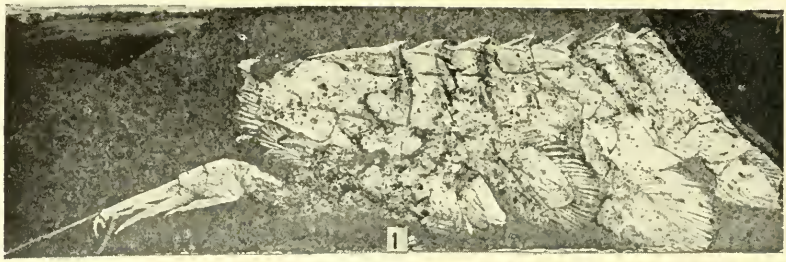

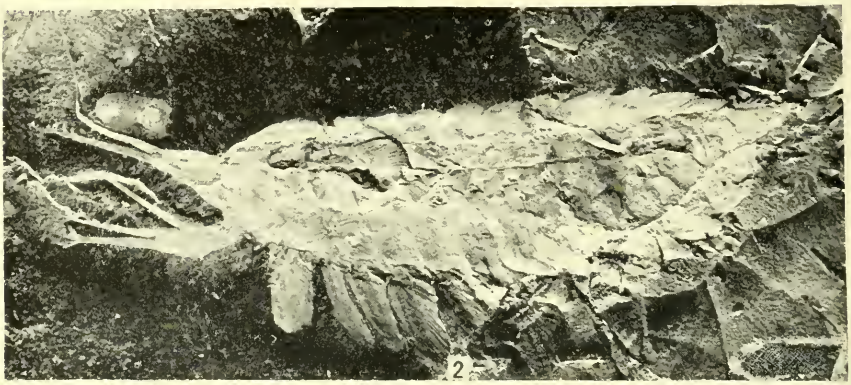

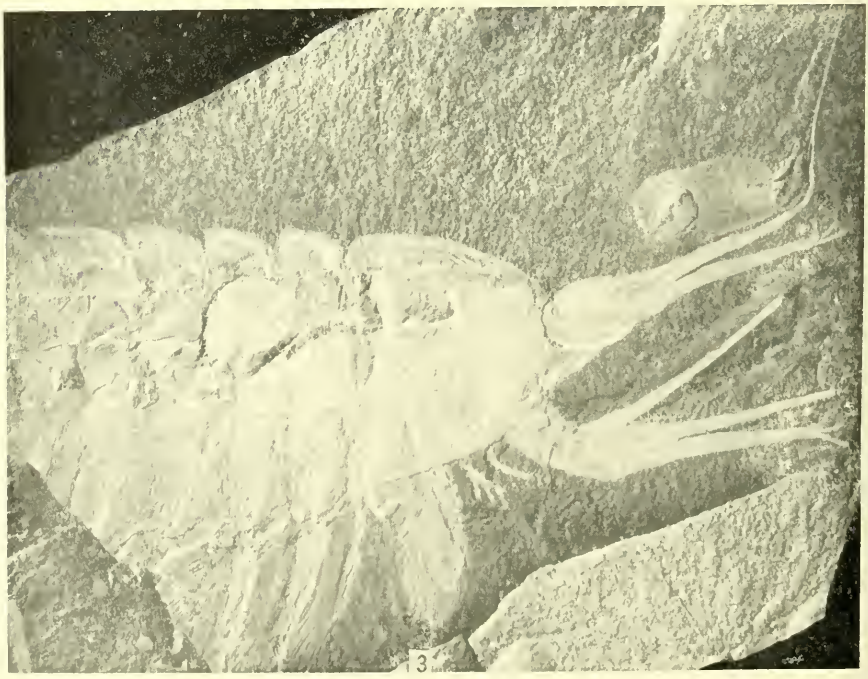

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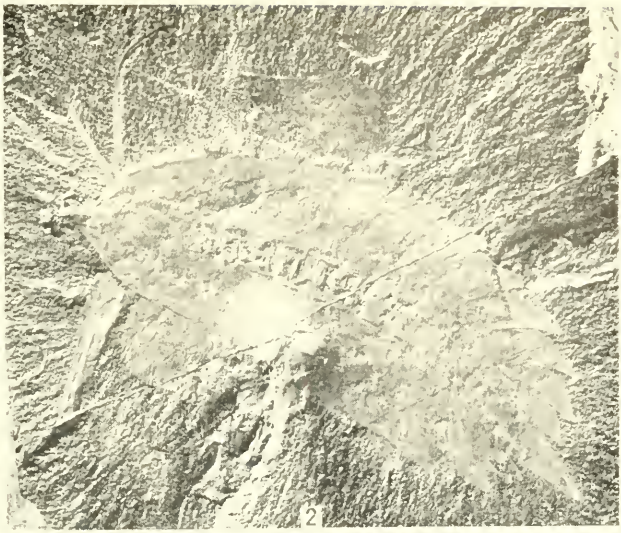

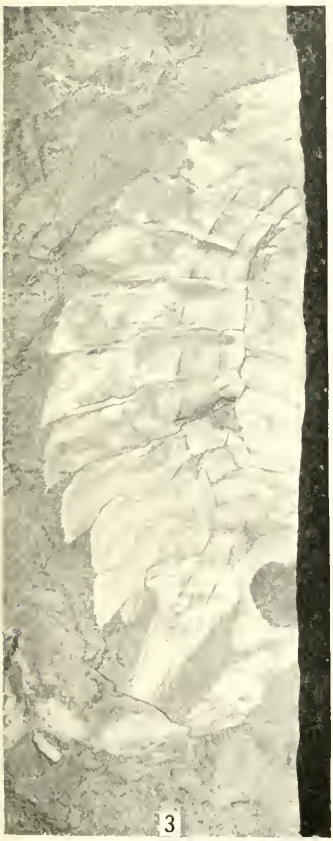

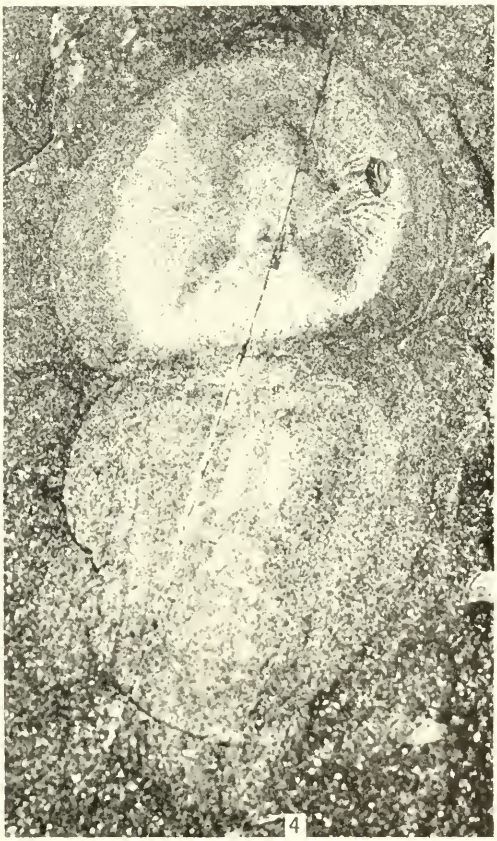

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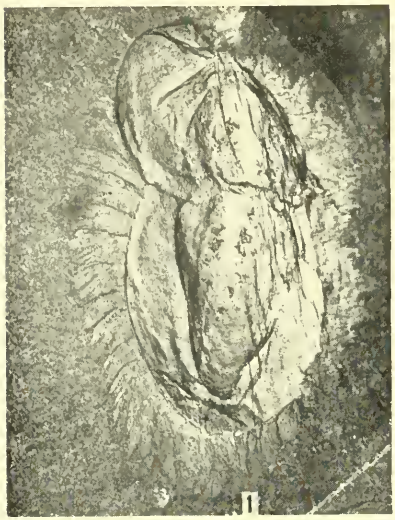

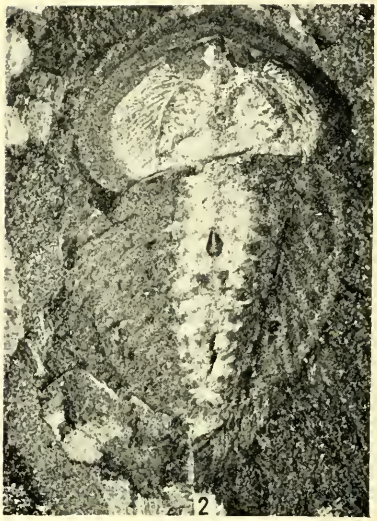

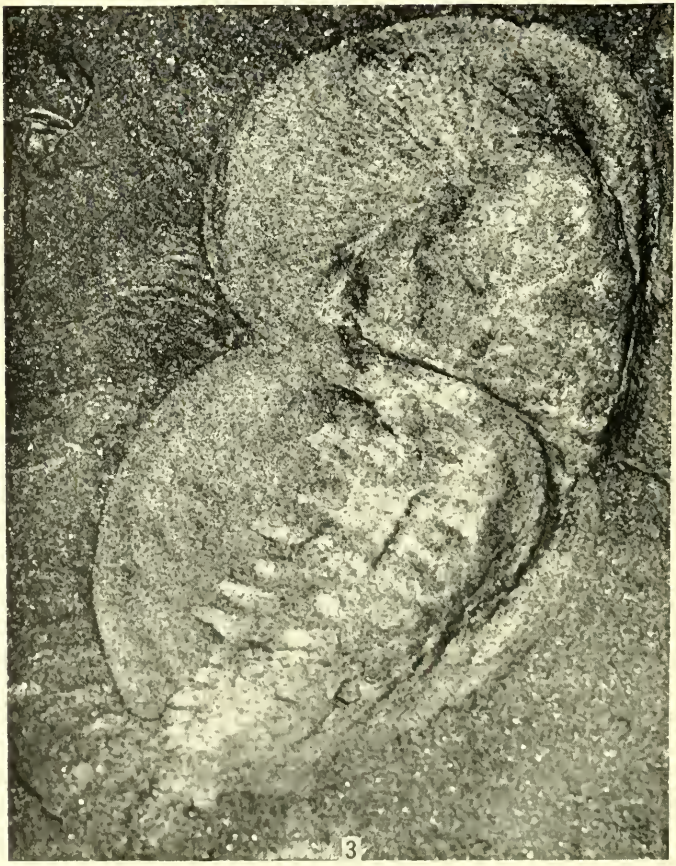

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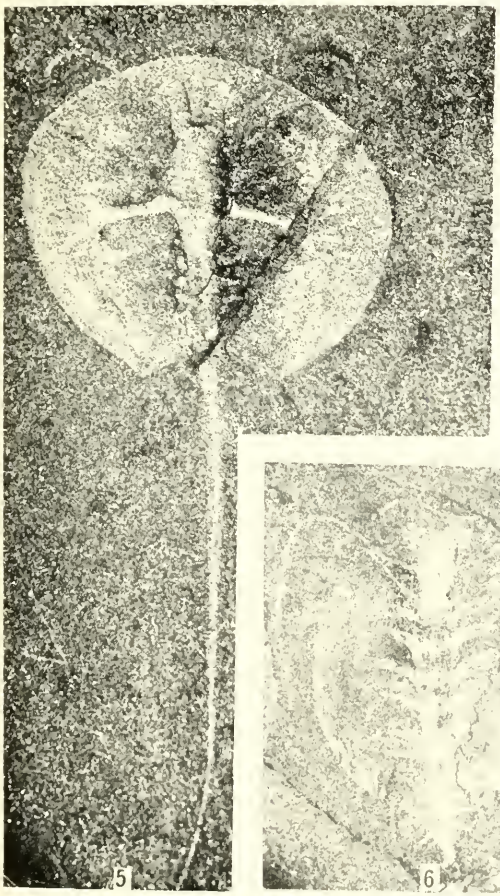

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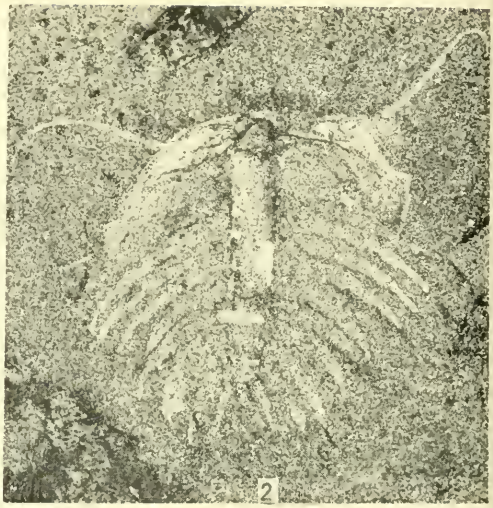

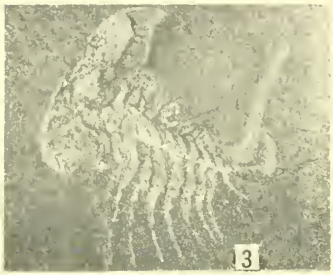

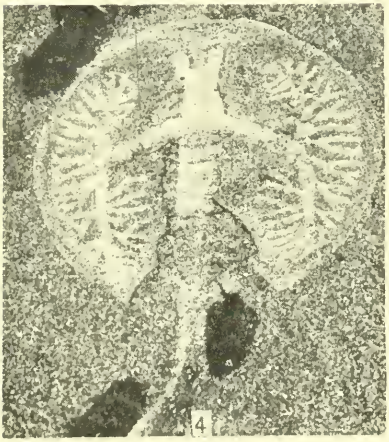

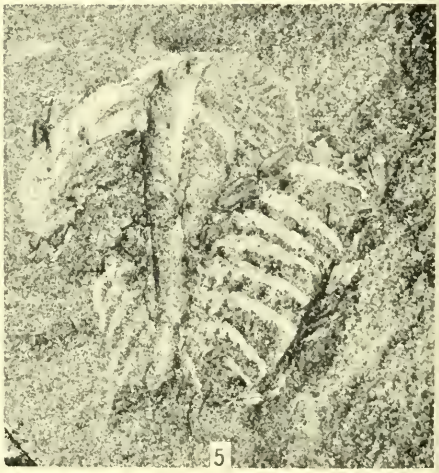

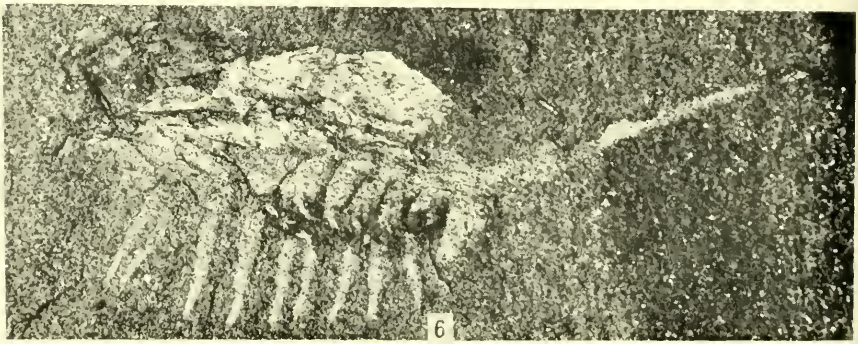

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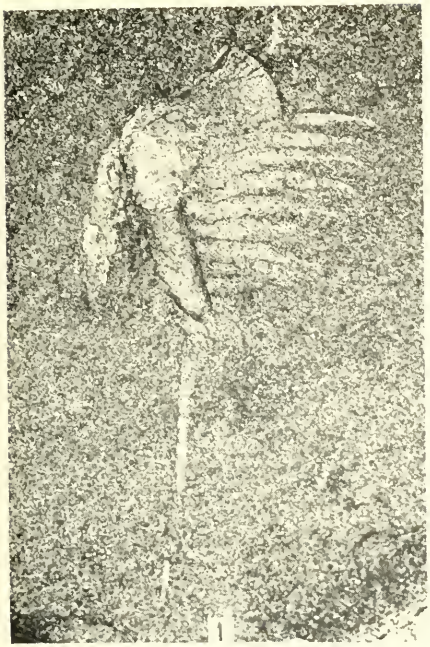

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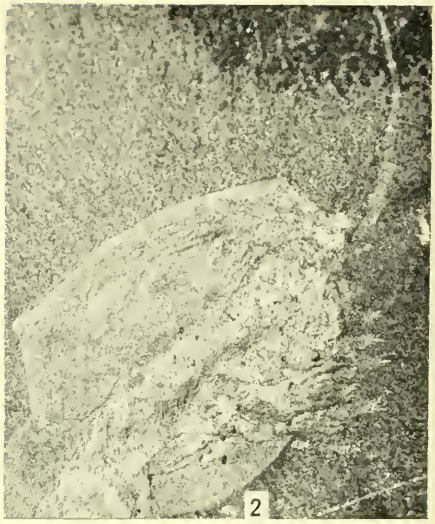

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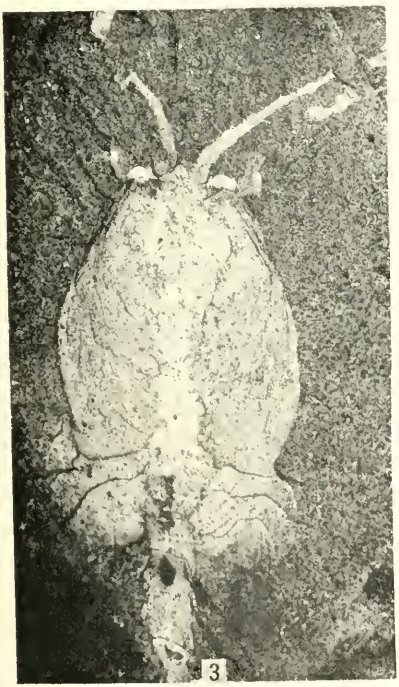

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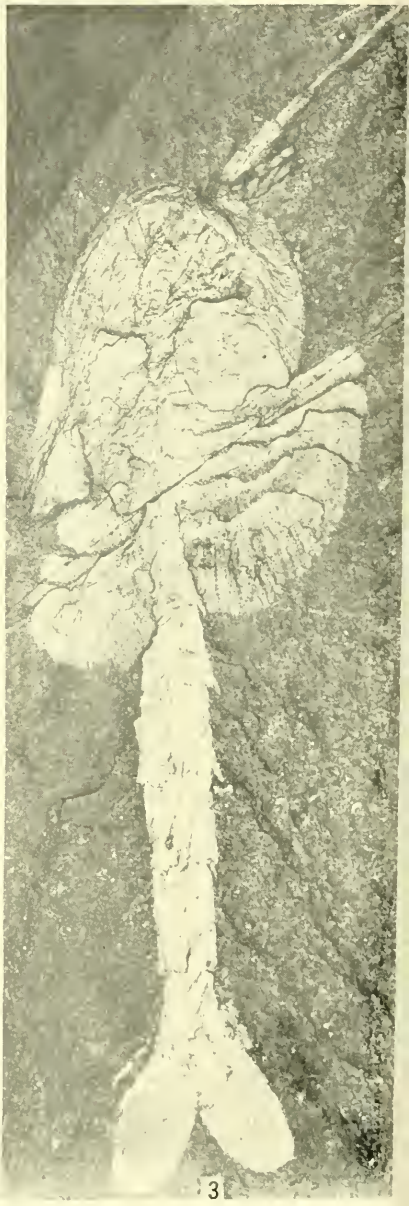

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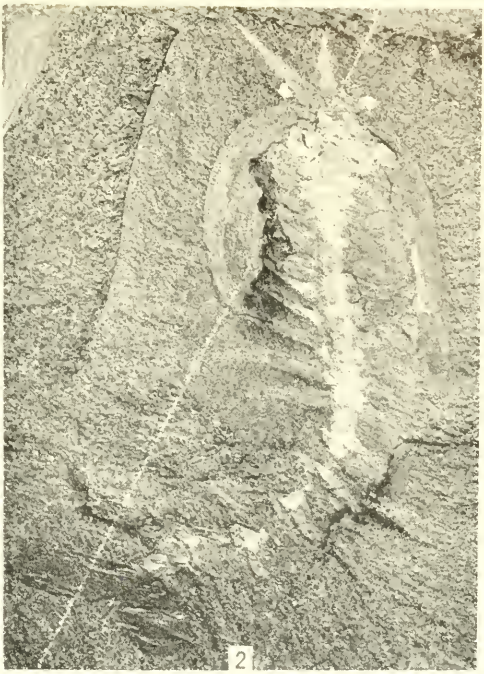

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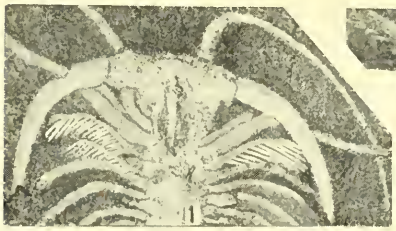

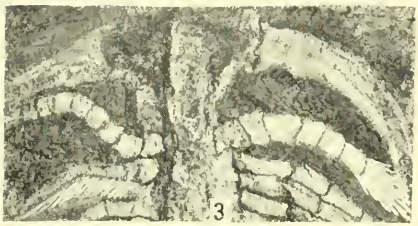

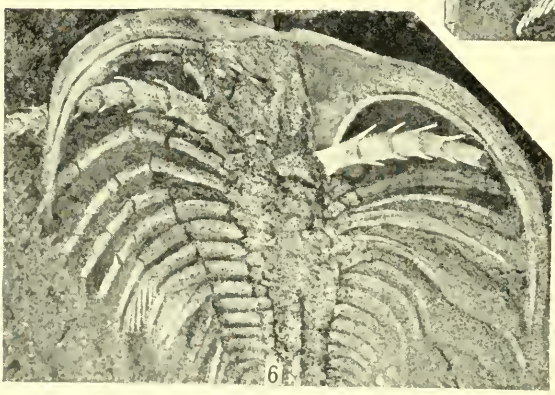

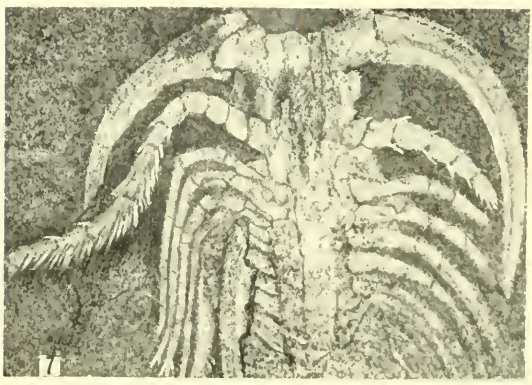

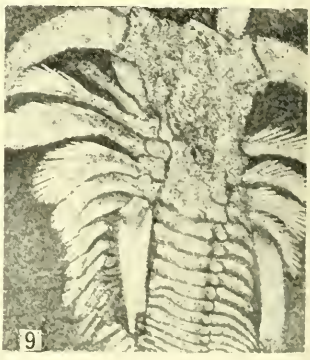

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